

**UNEASY GENIUS:
THE LIFE AND WORK OF
PIERRE DUHEM**

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STANLEY L. JAKI

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PIERRE DUHEM

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In his study (c. 1905)

Burke

By the same author:

Les tendances nouvelles de l'ecclésiologie
The Relevance of Physics
Brain, Mind and Computers
(Lecomte du Noüy Prize, 1970)
The Paradox of Olbers' Paradox
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Planets and Planetarians: A History of Theories of the Origin
of Planetary Systems
The Road of Science and the Ways to God
(Gifford Lectures, University of Edinburgh, 1975 and 1976)
The Origin of Science and the Science of its Origin
Fremantle Lectures, Oxford, 1977)
And on This Rock: The Witness of One Land
and Two Covenants
Cosmos and Creator
Angels, Apes, and Men
Chesterton, a Seer of Science
The Keys of the Kingdom: A Tool's Witness to Truth
Lord Gifford and His Lectures: A Centenary Retrospect
Chance or Reality and Other Essays

Translations with introduction and notes:
The Ash Wednesday Supper (Giordano Bruno)
Cosmological Letters on the Arrangement
of the World Edifice (J.-H. Lambert)
Universal Natural History and Theory of the Heavens (I. Kant)

INTRODUCTION

A hundred years have now gone by since in the midsummer of 1882 Pierre Duhem, a graduate of Collège Stanislas, completed with brilliant success his entrance exams to the Ecole Normale Supérieure and embarked on his career as a theoretical physicist. His father, a textile salesman, hoped that Pierre would pursue a career in business, one of the few professional fields where perhaps he would not have succeeded. Not that young Duhem lacked sense for the practical. He could have easily made a name for himself as an artist had he developed professionally his skill to draw portraits and landscapes. His ability to make a point and his readiness to join in a debate, could have earned him fame as a lawyer. A potential actor was in sight when he entertained friends with mimicry. That as a student of physics he entered and stayed first in his class at the Ecole Normale, did not thwart his talents for the life sciences. No less a biologist than Pasteur tried to obtain Duhem for assistant. His command of Greek and Latin would have secured him a career as a classicist. He was a Frenchman, not to be met too often, whose rightful admiration for and mastery of his native tongue, did not prove a barrier to the major modern languages. As one who taught himself the complex art of medieval paleography, he could easily have mastered the many auxiliary sciences needed by a consummate historian.

In fact, history was the only field which was a rival of physics as young Duhem pondered his future career. He chose to become a physicist though not to the extent of letting his bent for history be atrophied. His lectures on theoretical physics showed from the very start a keen appreciation of the history of its basic concepts and assumptions. It should not therefore seem surprising that after fifteen years of pondering on the truth of mechanics in historical perspective as well, he seized, in 1904, on an innocuous looking detail that had already been noted by several historians of science but who left it at that. Always intent on full clarity and rigor, the scientist-philosopher in Duhem followed up that detail in a manner which was nothing short of heroic. The result was a massive finding which, if given the appreciation due to factual evidence, would have resulted in a vast expansion of

the horizons of the historiography of science caught in the myth that science descended as a *Deus ex machina* from heaven on the inclined plane of Galileo. Three quarters of a century later references to Duhem all too often suggest that his fate is to remain damned with faint praise. The proofs of this are many and one of them is of monumental proportion. It relates to the emergence, during the decades following World War II, of the historiography of science as a clearly identifiable professional enterprise. Although in the process sedulous attention has been given to many minor topics and to many a figure of secondary and of even less importance, Duhem, the historian of science, has attracted the systematic attention of no one in that profession whose voice has, in recent years, gained much influence.

Duhem the philosopher of science fared better, although all too often he is brought to the scene only on Mach's coattails, a pattern particularly in evidence around 1966 when the fiftieth anniversary of Mach's death prompted a flood of symposia, conferences, monographs, and articles. Hardly anybody recalled then that the same number of years had passed since Duhem's death. The admirers of Mach should not be blamed for not being eager to say much about Duhem. They seem to suspect that, contrary to appearances and stereotyped phrases much in vogue, Duhem does not belong to the Machist camp, and much less to its logical positivist rearguard. The neglect of Duhem by those historians and philosophers of science who claim to belong simply to realms in which the professed highest standard is respect for facts and for facts alone regardless of their provenances, is another matter. As to those academics in France, to whom Duhem was really close and who knew the value of his thought, they bear a special responsibility for the fact that apparently no effort was made to recover his letters to physicists, historians, philosophers, theologians, colleagues, relatives, and friends while many of these were still alive. The task would have been all the easier because Duhem not only kept a booklet of the addresses of all his professional correspondents but also kept many of their letters to him. Never a friend of novelties, such as the typewriter, which became a widely used instrument even in official circles only a few years before World War I, Duhem made a copy of his letters only in a very few cases. In working through the over three thousand letters written to him, a collection recently acquired by the Académie des Sciences, one cannot help being seized by a sense of keen frustration: It is doubtful that two generations after his death the recovery of many of his letters and even of some academic documents relating to him would still be possible.

Any author of a book like this may find in that practical impossibility a blessing in disguise. The very thought of summarizing the well over twenty thousand printed pages which Duhem produced should seem discouraging even apart from the thought of telling at the same time the story of Duhem's life and career, together with sufficient details about the French academic, cultural, scientific, and political life during the six crucial decades which Duhem's life spanned, to say nothing of the relevant material accrued since his death. Duhem himself felt dismayed when in early 1913 the Académie des Sciences asked him to sum up his work in a few pages. So much in the way of advance apology for what could not be included in a

monograph with stringent limits. At any rate, the published material is in itself rich enough in details relating to Duhem's life and work to have justified long ago a detailed portrayal, and all the more so because Duhem was a candid soul, too candid for his own personal advancement in which he was not overly interested.

The published record contains many fascinating details which would strike even most of those, who are somewhat familiar with Duhem, as so many data still buried in manuscript sources. A chief among such published records is a work entitled, *Un savant français: Pierre Duhem*, a biography written in 1936 by his daughter, H  l  ne, who was aided by her aunt, Marie Duhem. While neither had academic training, their combined effort is certainly suggestive of inborn talent. (H  l  ne displayed something of the intellectual brilliance of her father when in her early twenties she taught herself Greek so that she might assist her father in the task of proofreading the concluding volumes of the *Syst  me du monde*). Daughter and aunt were helped by four of Duhem's friends who recounted in long letters to H  l  ne their association with him as students and colleagues. This was more than enough to make a short biography of about forty thousand words a moving narrative, with precious glimpses into the inner sanctum of its hero. In that respect it will not be superseded by any biography however detailed, meticulously researched, and attentive to unpublished material. All data, documents, and details included in it are fully incorporated in this monograph. The same holds true of a much shorter biographical notice, written by Edouard Jordan, professor of medieval history at the Sorbonne and a friend of Duhem since childhood, who had to write a reminiscence about a 'camarade' and not a scholarly document. Published as it was in an organ of very small circulation, it could make no proper impact whatever its enduring freshness.

The opposite might have been the case in France with Duhem's biography written by his daughter had it not been for the timing of its publication. In the second half of the 1930s Duhem could be no prophet in his own country, even if this had been at all possible. Duhem was better remembered in the Anglo-Saxon world, especially in the United States, but the less than a dozen copies of that biography available there were too few to serve as an effective source of information, even if they had not been resting on the shelves for most of the time. Although unfamiliarity with that biography did not often result in such misconceptions about Duhem that he was a priest, or that he played the flute in a trio, in which Hadamard at the piano accompanied Einstein playing the violin whenever the latter was visiting in Paris, he all too often survived oblivion only as a royalist ultraconservative, and religious extremist. A careful look at his life and personality belies all such and other equally misleading labels tacked onto him. The same look reveals a great variety of ways in which his Catholic faith made itself manifest in his life; its portrayal would be a mere superficiality without a careful recall of them. As to his academic career, which shows him banished from Paris, the center of French academic life, it ran its course against that unflatteringly human background whose strong presence in scientific history was until recently the object of deliberate oversight.

In writing the story of a life like Duhem's, as uneventful as are most lives devoted to unremitting scholarly work, references to his main publications and the chief ideas expressed in them are inevitable. Such references have, however, been restricted to a minimum so as to spare of undue repetitions the concluding three chapters which deal with Duhem's work in physics, and its philosophy and history. While an apology for such separate chapters should seem unnecessary, a word may not be out of place about their chief thrust which is the seeing of Duhem's work through the perspective he himself specified as commonsense realism. Since it has become a hallowed stereotype to see him as a champion of positivism, those concluding chapters are no less a challenge to the 'received view' about him than are the biographical chapters. Duhem's lifelong reflections on the aim and method of physics and on the psychological conditioning of its cultivation should have been given more than scant justice in these very decades which saw so many philosophers of science attracted to those topics. Often they merely echoed, knowingly or not, themes which Duhem had already developed with striking originality, enduring validity, and with that conciseness which is a hallmark of genius. He stumbled on those themes under the impact of his reflections of what he was doing as a physicist.

Vast and incisive as was his productivity in physics, it did not receive commensurate attention in his life or afterwards. Not that the best cultivators of thermodynamics, physical chemistry, and fluid mechanics have completely forgotten their debt to him. They are not, however, the ones to express such a debt in extensive studies which would comprise the background, the formation, the accomplishment, and the impact of Duhem the physicist. The eventual writing of such a study will hopefully be helped by the chapter dealing with him under that aspect. Duhem always looked upon himself as a theoretical physicist and wanted to be recognised as such. The long delay of recognition was a factor which turned his work in physics into a poignant drama, for he lived at a time when, more than ever before in the history of physics, new facts entered the scene at a dramatically rapid rate. Another factor was the failure of Duhem the physicist to live up to the dictates of his method even remotely as well as did Duhem the philosopher and the historian of physics. A surprising outcome whose instructiveness should seem particularly relevant at a time which is the centenary of Duhem's taking up theoretical physics not merely as a profession but as a calling.

1. YOUNG PIERRE

Parents, home and early years

In reconstructing the years of Duhem's childhood and youth, his biography by his daughter is particularly indispensable. Yet details in it concerning that period of Duhem's life show all too well that in respect to background history its data call for cautious use. A case in point is the account of a visit by young Pierre, not yet ten, to a historical place on a historic day:

On the 25th of March [1871] there were only barricades, guns, and armed crowds in the city [Paris] . . . Women themselves, so many tipsy incendiaries, were shooting at the few pedestrians venturing to the streets; they were escorted by columns of Freemasons spruced up in their gaudy apparels. This was the moment when the column of Place Vendôme fell, setting in commotion the whole city. Pierre had his wish as he was led [by his father] in the evening of this new catastrophe to the débris of Place Vendôme; he brought back a small piece of the column to add to his collection of projectiles, piled up in the courtyard of his house: precious souvenirs, kept for long with others of more intimate kind.¹

In late March 1871 Paris was not yet in the throes of street fighting. As to March 25, a Saturday, it merely witnessed the posting all over the City a list of 'advices' to the citizens about how to cast their votes in the next day's election aimed at legitimizing a Central Committee which had acted in an unofficial capacity during the siege of Paris that was lifted only on March 18. There were of course enough citizens who needed no advice whatever on how to elect on March 26 a slate of candidates which had sufficient majority to declare within a few days the famed Commune. Long before that, indeed shortly after a capitulation at Sedan in the first days of September, a committee of artists, with Courbet in the lead, proposed the demolition of the column. A masonry structure covered with a bronze spiral (provided by the twelve hundred guns captured at Austerlitz and cast into bas-relief scenes displaying Napoleon's military exploits), the column was a symbol of imperial grandeur. From the time of its erection in 1804, it was a hated eyesore for all radical reformers.

1. Hélène Pierre-Duhem, *Un savant français Pierre Duhem*, préface de Maurice d'Ocagne (Paris: Plon, 1936), 240pp; for quotation see pp. 17-18. For the abbreviations used throughout the notes, see 'List of Duhem's Publications' pp. 437-38.

Its actual toppling, ordered formally on April 12 to take place on May 5th, the anniversary of Napoleon's death, did not occur until the 16th. The procedure, no small engineering feat, was watched by large crowds treated to the music of military bands and to refreshments served in roadside buffets. These latter details are rather embellished in accounts usually silent on the irony that Napoleon's bronze statue, gracing the top of the column, remained in one piece after its precipitous fall.²

Although the downfall of the column was physically softened by vast amounts of sawdust, sand, and horse-manure, the spectacle must have struck hard in the minds of most of those not sympathetic with the Commune. The Duhem family was undoubtedly one of the many millions all across France for whom May 16 was a national day of prayer decreed by the government in Versailles, no doubt with an eye on what was to take place at Place Vendôme. Young Pierre assimilated the day and its spectacle of ruin in a perspective that had been firmly set by the atmosphere of his home and family background. Both were dominated by an unswerving attachment to Church and Country in a markedly conservative sense. Among Pierre's maternal ancestors were the Hubault-Delorme, residents of Paris already in the early seventeenth century. A portrait of one of them, painted by Jean-Baptiste Van Loo (1684-1745), was a chief ornament of Pierre's home. There he also learned of the Arnaults among his maternal ancestors. One of them was a secretary to Louis XIV, another a treasurer to the Duke of Orléans. It must have been recalled even more frequently in his presence that his maternal great-grandparents assisted at the coronation of Napoleon in Notre Dame and that they had received from Pope Pius VII a fragment of the Holy Cross and an exquisite rosary, both religiously kept as family treasures.

Through his ancestry Pierre was not only a child of Paris but also shared something of the far north and the far south of France. His maternal grandfather, François Fabre, who came as a youth to Paris, was a native of Cabrespine (Aude), a village enclosed in a narrow and rocky valley of the Montagne Noire about 25 miles north-east of the famed medieval city of Carcassonne. A Fabre from Cabrespine is mentioned in a document from 1529 as a witness to an act of donation. In more recent times the Fabres, who had their coat of arms displayed in the armory of the Hozier of Languedoc, operated a drape factory. The family was present also in other parts of France, such as Angers where a great-uncle of Pierre, Timothée Fabre, was professor of rhetoric at the Royal College.

Pierre's ties with the north of France were even more direct through his father, Pierre-Joseph, born in Roubaix in 1825, whose maternal ancestors were established there as early as 1683. The early spelling of the family name as Du-Hem or Duhesme is suggestive of the incipient transformation of a Flemish stock into the French mainstream. A Joseph-Pierre Duhem, born in 1758 in Lille (where the Duhems are still numerous) and trained there as a physician, played a prominently radical role during the French Revolution and flourished as an army surgeon during Napoleon. The widespread occurrence of the name Duhem in France today (a telephone direc-

2. See, for instance, F. Jellinek, *The Paris Commune of 1871* (London: Gollancz, 1971), p. 285.

tory of any major city in France is a ready proof) suggests that many Duhems had preceded Pierre's father in the southward move when as a young man in his twenties he took up residence in Paris. He brought with him the industriousness and enterprising spirit of the people of Roubaix, and would have made a fortune as a textile salesman had he not been unselfish in the extreme. He learned to be such from youth when following his father's death he had to discontinue his studies at the Jesuit College in Bruges and become, as the oldest of eight children, a substitute breadwinner. For the rest of his life he tried to still his thirst for learning as best he could. Young Pierre often saw his father go out for a walk with a Latin author's book in hand.

Pierre-Joseph Duhem and Marie-Alexandrine Fabre had been married for three years when their first child, Pierre, was born Sunday, June 9, 1861. His birth was reported at the Mairie of the 2nd arrondissement near the Church Notre-Dame-des-Victoires and, owing to some confusion, the date of the birth was registered as June 10.³ Perhaps the happy father was too ecstatic or the birth itself may have taken place too late in the night of June 9. For three straight days Papa Duhem watched his newborn son without taking an hour's rest. At his order the maid was not allowed to close the doors lest the baby's sleep be disturbed. Years later, a friend of Pierre, who often visited him, described Duhem's lodgings in Nr 42 of Rue des Jeûneurs as a 'small and modest apartment'.⁴ Unlike today, when many of the apartments in the street serve as offices and wholesale stores of textile producers, a hundred years ago the street was still lived in though not luxuriously.⁵ The rays of the sun could reach the pavement of the courtyard of the house, in which the Duhems had their apartment, only in the noon hours. The apartment still may have been without running water, a commodity absent in one-third of the houses of Paris as late as the 1930's. In the 1860's many streets in Paris were resounding with the cry —à l'eau! à l'eau! oh! — as horse-drawn carriages brought along fresh water.⁶ There were also carriages which offered the luxury of sitting tubs, carried by strong lads to the apartments of prospective customers. Special to the neighborhood were the ever-curious crowds throng the Rue du Croissant, parallel to the Rue des Jeûneurs, where some of the most sensationalist newspapers were printed at that time. Within a short walk from the Duhems' apartment were some new and dazzling department stores on Rue Montmartre. Also around the corner was the ever busy financial center of the City, la Place de la Bourse. The slopes of Montmartre were a mile or so to the north.

3. This conflict of dates, noted in *Un savant français* (p. 5), prompted C. E. Cardwell's remark in his doctoral dissertation, *Representation and Uncertainty: An Essay on Pierre Duhem's Philosophy of Science* (Ann Arbor, MI: University Microfilms, 1972, p. 1) that no sooner had Duhem been born than he 'found himself in disagreement with French officialdom.'

4. *Un savant français*, p. 39. The friend in question was J. Récamier.

5. Concerning details, historical and social, of the surroundings of Rue des Jeûneurs, remarkably informative is the work, *Histoire de la Paroisse de Notre-Dame de Bonne-Nouvelle*, by L.M. Casabianca (Paris: Librairie Vve Ch. Poussielgue, 1908).

6. See S.C. Burchell, *Imperial Masquerade: The Paris of Napoleon III* (New York: Atheneum, 1971), p. 94, where it is also pointed out that the five million gallons of spring water, which began to pour daily into Paris on October 1, 1865, fell 'far short of what was needed.'

The Paris of the 1860s was of course a spectacle to watch wherever one went. Baron Haussmann's enormous undertaking, which caused the razing to the ground of some twenty thousand houses, did away also with the last remnants of decrepit enclaves, some going back to the Middle Ages. One of them was the Cour des Miracles, immortalized in Victor Hugo's *Notre Dame de Paris*, which being not too far from where the Duhems lived, could still be a subject to excite the imagination of old and young in the neighborhood. With the forty thousand new houses there came the wide boulevards and avenues characteristic of modern Paris. The feverish building activity was accompanied by the rise of the population to almost two million by 1870, a doubling within two decades. Such tourist landmarks of the City as the department stores called Bon Marché, Louvre, Belle Jardinière, Printemps, Samaritaine, were constructed during the same period. They were as much places of attraction as the Bois de Boulogne and the Bois de Vincennes which were turned into places for pleasant promenades.

The explosive growth caused the drift of the poorer population towards what later became known as the 'banlieux rouges' and did not make life necessarily easier for those able to remain in the City itself. The Rue des Jeûneurs had long since lost its strictly residential character when in 1868 prior censorship was abolished and almost overnight some 150 new newspapers started their noisy operations, many of them in the immediate neighborhood. Young Pierre most likely found out that the street's name Jeûneurs [those who fast] was a deformation of the original Jeux-Neufs, that is, 'New Games.' The name stood for the original form of the street, in which small parks and playing grounds lay between the houses.

When on Thursday, June 13, the child was taken to be baptized in the parish church, Notre-Dame-de-Bonne-Nouvelle, about six hundred yards northeast near the Porte Saint-Denis, he was watched over by a group of relatives some of whom signed the baptismal record.⁷ It shows the happy father's signature on which the child later patterned his own. The child's uncle, Jean-Baptiste Maurice Henri Fabre, chevalier of the Legion of Honor and a resident of Châlons-sur-Marne, was the godfather, whereas the role of godmother was taken by the child's grandmother, Mme. Fabre, née Nathalie Eléonore Hubault of 8, Rue de Vendôme. The record shows also the signatures of Pauline Fabre, of a Fabre ainé, and of a Delafaye, in addition to that of the Abbé de Moustet who baptized the child as Pierre-Maurice-Marie.

Two and a half years later the family grew larger with the birth of twin sisters, Marie-Julie and Antoinette-Victorine, on December 5, 1862, named in part after their mother's younger sister, Marie-Antoinette Fabre. To the twins young Pierre proved to be a delightful companion. It is not difficult to imagine their frolics during their first major excursion which took them to Cabrespine in 1865. This was Mme Duhem's third visit there. First she went there in 1846 at the age of twelve when the better part of the trip had to be taken by stage coach. Her main memory of the

7. The entry, No 284 for that year, registers the day of birth as June 10, in obvious compliance with the civil birth certificate which the family had to present. Papa Duhem, who signed his name as P. Duhem, is identified there as 'négociant' (see on him also note 81 to Ch. 3).

trip was her encounter with her grandmother, a lady born in the *ancien régime*. Her second visit there capped a tour in 1860 to Switzerland in the company of her husband. Now there she was for the third time without suspecting that in twenty more years she would inherit the ancestral home and would hear an old peasant woman, who had known her grandmother, tell her: 'You must come and live with us, because real ladies are hard to come by any more.'⁸

In 1865 the grand old lady was no longer alive. The Duhems were received by Mme Duhem's uncle, Timothée Fabre, who had just retired from his chair in Angers, and by her sister, Marie-Antoinette. Pierre was to keep fond memories of his great-uncle, a charming conversationalist, to whose influence he attributed years later his own love for the humanities.⁹ Great-uncle and aunt were, of course, treated to a favorite game of the three children: the twins pulling Pierre's still blond hair with no complaint on his part. On seeing this Mme Duhem used to remark: 'Pierre, you are really too good.' Not that he had no will of his own. Indeed, the older he became, the more his determination asserted itself. He was also given to outbursts of temper when his deep sense of justice was hurt. From an early age he also showed signs of genuine individuality. While his little classmates gave to the question, 'What do you want to become?', charming but typically childish answers such as 'Pope,' 'coach-driver,' and the like, Pierre replied: 'A lawyer so that I may talk a lot.'¹⁰

He was remarkably articulate by the time he began his studies in a private school run by the two Arnoul sisters. It is to them that many years later Duhem gave the credit for his interest in mathematics. They trained their little charges in the customary subjects appropriate for the first five elementary grades, 11 to 6, according to the designation customary until recently in France. They also took Pierre and his five schoolmates every Monday to catechism in the Eglise St. Roch on Rue St. Honoré, halfway between Place Vendôme and the Palais Royal. There he quickly made an impression as one who never failed to come up with the correct answer. In turn, the church had not a few monuments which could but impress a precocious and deeply committed boy like Pierre. Such prominent figures of French letters and science as Corneille and Maupertuis had their richly decorated tombs there. Pierre could hardly miss the plaque commemorating the massacre of four priests of St. Roch during the Revolution. He may also have heard that Manzoni, the creator of modern Italian prose, recovered his childhood faith at St. Roch.

In the 1860s the family spent part of the summers in Ville d'Avray, a place nestling between two forestlike parks midway on the Paris-Versailles road. Ville d'Avray,

8. *Un savant français*, p.102.

9. A detail mentioned by Emile Picard, Perpetual Secretary of the Académie des Sciences, in his éloge, 'La vie et l'oeuvre de Pierre Duhem,' p. 2. For particulars on that éloge, see Ch. 7 and note 53 there.

10. *Un savant français*, p. 12. As an older schoolboy, Duhem may very well have thought of this while reading in Molière's *Amphitruon* the dialogue between Mercury and Sosie: 'What is your destiny, tell me -- It is to be man and to speak' (Act I, Scene 2).

already immortalized by Corot, was a painter's paradise and a convenient summer escape for modestly middle class Parisians. In chasing butterflies Pierre, who collected rocks and shells as well, may have stopped now and then to watch painters at work. Had he shown them his own sketches, it would have been their turn to be surprised. He was a boy with two passions: to draw and to study. As his sister Marie recalled, young Pierre was allowed to turn to collecting various specimens only after spending some time with his Latin grammar, a time, as will be seen, he had indeed well spent. As to drawing, he carried for the rest of his life sketchbooks whenever on vacation.

Eyewitness to a fateful year

In early September 1870 young Pierre watched long columns of French regiments march through Ville d'Avray into the capital still surrounded by huge walls and fortifications, in the hope of holding out there against the approaching German armies, who had just captured Sedan and taken prisoner the Emperor with much of his army. Before long young Pierre too was rushing with his parents back to Paris but not to stay there. With his mother and two sisters he sought safety with his uncle, Gaston de la Faye, state attorney in Chateaudun,¹¹ a quaint old town perching on an elevated bank of the Loir, about thirty miles southwest of Chartres. Mama Duhem did not guess that she was rushing into a place which was soon to prove itself true in a dramatic way to its motto 'extincta revivisco'. The tenseful reversals of drama struck the note every day of the week which ended in Chateaudun's perishing in a hail of bullets and flames.

As is the case with most dramas, the start had a touch of encouragement. The arrival, on October 11, of regular troops, about four hundred strong, brought some cheer, which quickly faded into apprehension when word came the next day about the fall of Orléans to the German troops and about their advancing toward Chateaudun.¹² Presentiment of the worst could only increase when the town found, in the morning of October 13, that the regular French troops had slipped away in the cover of wee hours. Still the town passed a resolution to make a stand with the help of over a thousand volunteers, guerillas, and franc-tireurs. On October 15 the city fathers even succeeded in obtaining from the Prefect of the Department (Eure et Loir) an order which redirected the regulars to Chateaudun. All that see-saw of good prospect and gripping apprehension could hardly pass unnoticed by a precocious boy like Pierre. Soon he became eyewitness to what war really meant. First came a ray of hope. Advance troops of the main German force of some 18,000, led by General von Wittig, were repulsed from around the neighboring villages of Verize and Givry.

11. The Duhem correspondence in the Archives de l'Académie des Sciences contains several letters to Duhem from his second cousin, Gaston de la Faye, son of the state attorney in question. Obviously, there were warm relations between the two families.

12. Subsequent details about the siege of Chateaudun are taken from G. Isambert's work, *Combat et incendie de Chateaudun (18 Octobre 1870). Avec notes et pièces justificatives* (Paris: Librairie Internationale A. Lacroix, Verboeckhoven et Cie, 1871); for the two quotations, see pp. 16 and 53.

Sheer terror showed itself in full a day later when both villages were burnt to the ground. In the case of Givry the tragedy was all the more poignant because the village had rebuilt itself from a general conflagration only four months earlier. Young Pierre then possibly assisted with all able bodied youth in the hasty erecting of barricades on which the *Times* (London) later reported that 'they were the most solidly constructed barricades during this war of sieges.' They were walls of wood and stone, five feet high and six feet deep, buttressed by sandbags from the outside. Two of the barricades were raised in the central square; the six others blocked the streets leading to it mostly from the east. While the mood could improve by the arrival, in the morning of October 16, of a hundred or so franc-tireurs from Nantes, the next day saw the withdrawal of all regular troops. The town once more asked and obtained a rescinding order, but when the emissaries reached around ten in the evening the retreating regulars at about 10 km to the south, they could not prevail on them, orders or not.

With that dispiriting news opened the terrible day of October 18. The late morning witnessed the last wagon of ammunition entering the town. By noon, the encirclement was complete, but the townsfolk refused to believe that the worst really was at hand. At any rate, the noon-day meal was hardly a thing to be passed up by genuine Frenchmen even in moments of adversity. It was not a meal to be completed. Bullets and cannonballs soon began to fly from every direction. The twelve hundred or so defendants put up a heroic resistance for over ten hours to the attack mounted by twelve thousand Germans. The barricades were broken only toward seven in the evening and resistance in the main square did not die out until eleven. By midnight high-ranking German officers could safely sit down in the best restaurant of the town for dinner, which they ended by setting fire first to the table clothes and then to the draperies. The restaurant was one of Chateaudun's 235 houses to perish in flame during that night. As the town was able to collect only a fraction of the ransom requested by the Germans, whose casualties were very high (2300 wounded and dead), a hundred hostages, some of them boys, were taken and sent to Pomerania. There was in addition a general looting which did not lack some farcical elements. A German army surgeon, who picked the best instruments of the town physician while destroying the rest, offered the following apology: 'We, we are Bavarians, not Prussians.' The Germans left Chateaudun in the morning of October 20, only to return there on November 24 for over three weeks. Sometime before that a Paris enthused by Chateaudun's heroic stand, ordered the name of one of its great streets, Rue Cardinal Fesch, to be changed to Rue de Chateaudun. Only a ten-minute walk to the north from Pierre's home in the Rue des Jeûneurs, the Rue de Chateaudun was to remain during Pierre's student days in Paris a ready occasion to remind either himself or his friends of a historic week of which he was one of the very few Parisian eyewitnesses.

Indeed, many years later, when the Cathedral of Rheims was ruined by German artillery fire, Pierre Duhem kept recalling a scene of Chateaudun under siege. From the old town clustered around the Castle one could clearly see St. Jean's church in the northern suburb across the low right bank of the Loir, with the flag of the Red

Cross flying on its spire, to be used by German gunners for a favorite target. Artillery fire had not spared the old town and in fact grew so tense by October 18 that many, among them Mama Duhem with her three children, took shelter in the cellar of the hospital. By late afternoon part of Chateaudun was on fire and bullets came through even the windows of the hospital's cellar. One such stray bullet lodged in the wall right by Pierre after grazing his ear. He pried it from the wall and put it in his pocket.¹³ Soon afterwards Mama Duhem and her children, together with some refugees, began to move toward the exit, afraid of being buried alive under the building the roof of which was on fire. Once at the exit, they were staggered by the sight of houses catching fire or crumbling as German cannonballs flew in with no letup. Mama Duhem was courageous enough to grab her three children and start running toward her cousin's house several blocks away. The route led through an intersection where bullets were sizzling from every direction and where battle-worn franc-tireurs could see no place for women and children. As Mama Duhem was stopped with the yell, 'Where do you go?', only young Pierre had the mental presence to reply: 'To the attorney's house.' There they went but only to pack some essentials and to be on the run again. For the night they found shelter in a farmhouse several miles outside Chateaudun. They were on the move again next morning. Luckily, because Chateaudun soon fell and a number of noncombatants, including women, were massacred. The Duhems' goal was Bordeaux where there were some relatives and where the government was in quasi-exile. They had to travel in hay wagons before they reached the railroad line to Bordeaux where they arrived on the 21st. For a young city boy like Pierre, wartime too had its compensations. He was—and especially in the company of his mother, sisters, and relatives—too young to feel exiled in Bordeaux. He could not suspect that his last twenty-two years would be spent, in a subtle sort of exile, in that city. He was of course old enough to understand something of the gravity of Marshal Bazaine's surrender in Metz in late October, and of the terms of peace dictated by the victors four months later. The ardent patriotism of Duhem the man was a characteristic forged in part through his having lived as a child through a trying phase of the history of his country. The worst days of that phase were still to come.

By the middle of February talks of armistice, signed on the 26th, had made so much progress as to make increasingly possible the return of civilians into the city. Mama Duhem and her three children arrived back home on February 20th, only a week before the Prussian troops had to move outside the walls. Their final parading up and down the main avenues may very well have been watched by Pierre who

13. 'Such was his first encounter with German culture,' is the note added to the incident by Duhem's daughter (*Un savant français*, p. 14; see *ibid.*, p. 15 for young Pierre's words to follow), who most likely recalls here a remark her father may have made in reflecting on World War I. The hospital or Hôtel Dieu forms one side of the Square de la Madeleine and is still in use in much the same form in which it was completed in 1763. A visit there dissolves any doubt about the possibility that a bullet could indeed have entered into the cellar, the front of which had windows whereas its back led to a door on the ground level. Details about the siege are readily available in the Musée Municipale.

heard from his father not only bitter patriotic comments but also plenty about the hardships of the siege. The short trunks, which alone remained of most trees of Paris, were a vivid reminder of the winter freeze. The scarcity of horses, of which 72,000 were slaughtered during the siege, bespoke of the hunger endured. The craving for food did not spare Castor and Pollux, the two elephants of the zoo, whose flesh was grabbed up by the rich at 40 francs per pound. The poor had to avail themselves of the offerings of butchers of cats and dogs, if they could afford the price at all. The rich kept having their opulent dinners, as was the case with a group of a dozen to which Berthelot and Renan belonged. This particular dozen had their insensitivity to the general hunger commemorated with a golden medallion, deposited at their favorite restaurant, *Chez Brébant*, whose one side carried their names and the other boasted of that very insensitivity of theirs.¹⁴ Meanwhile the rate of infant mortality became so high as to call for a special common grave in the Père Lachaise cemetery to accommodate their countless small coffins.

Relief from hunger, disease, and bombardments was only temporary. A month after the Prussians moved out of the City, only to camp outside its northeast walls, the Commune was installed in the Hôtel de Ville. Before long a large number of priests were arrested, among them 'citizen Darboy, who calls himself the Archbishop of Paris.' Clearly, much more was meant by this move than the protection of important Communards, such as Blanqui, already in the hands of the Versailles government. Rigault, a chief Communard, was more to the point as he decried priests as 'the most powerful agents of propaganda.'¹⁵ Not all priests on the list were caught immediately. They were not even pursued after the first heat of reforming zeal was over and attention was paid to maintaining the semblance of due process. Such a lucky priest was the Abbé Millaud, pastor of St. Roch, whose escape was somewhat hilarious. Pierre learnt the story quickly as he resumed his going there for catechism every Monday morning with his handful of classmates under the Arnoul sisters' guidance. His own parish priest, the Abbé Victor-Emile Bécourt was not so fortunate. He became one of the many victims of despairing Communards who began to see the handwriting on the wall after their great attack of April 3 on government troops failed. The Abbé Bécourt was arrested on April 11 and, after passing through the Conciergerie and the Mazas, he was thrown into the Roquette bursting with hostages. All the parishioners at Notre-Dame de Bonne-Nouvelle could do for him was to pray in church and at home. Meanwhile, the Communards distributed oil for the eventual burning of all public buildings, churches, and museums.

14. 'During the siege of Paris a few people accustomed to foregathering at Monsieur Brébant's once a fortnight never on one single occasion perceived that they were dining in a city of two million besieged souls.' Quoted from A. Horne, *The Fall of Paris: The Siege and the Commune 1870-71* (London: Macmillan, 1965), p. 184. For a day-to-day account of the events under the Commune, see J. d'Arsac, *La guerre civile de la Commune de Paris en 1871, suite au Mémorial du siège de Paris* (4th ed.; Paris, F. Curot, 1871).

15. The exaltation by Rigault, chief of police, of guillotine and concubinage was largely responsible for the image in which the Commune went down in history outside Marxist realms. In his lavishly illustrated *The Terrible Year: The Paris Commune 1871* (New York: Viking Press, 1971) Horne quotes Rigault: 'I want sexual promiscuity. Concubinage is social dogma' (p. 134).

Then came the month of May with clear signs that a final confrontation with the government in Versailles was in the making. On May 6th, a Saturday, Pierre read with other Parisians a proclamation which the union of women workers posted everywhere in the city in reply to an appeal by the government in Versailles to women in Paris:

It is not peace but war to the bitter end which the women workers of Paris have chosen. Today, a reconciliation would be a treason . . . This would be to renounce all the aspirations of working women who hail the absolute social renewal, the annihilation of all existing social and juridical framework, the suppression of all privileges, of all exploitation, the substitution of the role of work to that of capital, in a word, the liberation of the worker by himself . . . Six months of suffering and of treason during the siege, six weeks of gigantic struggle against the coalition of exploiters, the flood of blood spent in the cause of freedom are our titles of glory and vengeance . . . The women of Paris will prove to France and to the world that they too will be, at the moment of supreme danger, on the barricades, on the ramparts of Paris, if the reaction tries to force her gates – to give, as do their brothers, their blood and life for the defense and triumph of the Commune, that is, of the people.¹⁶

Three days later, shortly after noon, the leaders of the Commune had to post the following bulletin:

The tricolor flies over the fort of Issy, abandoned yesterday by its garrison.¹⁷

Later that day, May 9, another bulletin carried, falsely, a denial of the news fateful to the communard cause. Although no further advances were made by the Versaillais, tension could but grow throughout the City. Adding to that was the frustration with the difficulties encountered by engineers who were given the task of toppling the column of Place Vendôme. Cries of sabotage were heard when at 3 o'clock Tuesday, April 16, the bundles of ropes could not budge the column which fell only three hours later to resounding cheers. That the jubilation did not mean security could be seen from the bulletin which warned on Friday, May 19, that any title of renting an apartment in Paris would be declared invalid and burnt, unless its occupant would return there within forty-eight hours.

Two days later, in late afternoon, Sunday, May 21, the fateful hour struck. The government troops entered around five o'clock through the Porte de St. Cloud. Word of this spread throughout Paris with lightning speed. The next day, May 22, Pierre was in all likelihood not allowed to go to catechism to St. Roch. He would of course just venture outside the house to see the bulletin posted on the walls:

Take up arms, citizens, take up arms! . . . If you want that the generous blood, which flowed like water since six weeks, be not fruitless . . . if you want to spare your children of your pain and misery, you will rise as a man, and in the face of your formidable resistance, the enemy, which boasts of subjecting you to his yoke, will find himself under it . . . Citizens, your elected officials will fight and die with you if necessary; in

16. Translated from the text in A. Adamov, *La commune de Paris. 18 mars – 28 mai 1871: Anthologie* (Paris: Editions Sociales, 1959), pp. 40-41.

17. *Ibid.*, p. 43.

the name of this glorious France, the mother of all popular revolutions, permanent foyer of the ideas of justice and solidarity which must and will be the laws of the world, march against the enemy, and your revolutionary energy will show him that Paris can be sold, but she cannot be taken or be defeated.¹⁸

Later that day, the following bulletin was posted:

Let all good citizens rise! To the barricades! The enemy is within our walls! No hesitation! Forward, on behalf of the Republic, for the Commune and Liberty!¹⁹

Indeed the enemy was by then in possession of a third of the city. The government troops could have taken all the strategic points of Paris during the night of May 21-22 had they not been overcautious. Now they had to face a week-long grim resistance during which the communards forced at bayonet point all passersby to build barricades. Unfortunately for the Duhems the vicinity of the Rue des Jeûneurs was not abandoned by the communards until about noon, Wednesday, the 24th, when, following the advance of the government troops in the north (Montmartre) and in the south (Observatoire), they had to withdraw hastily from the area of the Place Vendôme to Les Halles, well behind the Duhems' residence. The previous evening the Duhems could see the Opera burning. The Duhems lived close enough to the Bourse to learn first-hand about its four hundred employees who on Wednesday morning fought off the communard unit dispatched to burn it to the ground.

Once the line of fighting passed their quartier, the Duhems could venture to the streets to see what really had taken place. Pierre was taken by his father a few blocks to the south, to the church of Notre-Dame-des-Victoires. A place of intense worship and devotion which drew, as it still does today, the faithful from all over Paris, Notre-Dame-des-Victoires had seen the Duhems before. Whenever in later life Pierre had to go to Paris, he never failed to take time out for a visit there.²⁰ As many other churches in Paris, Notre-Dames-des-Victoires too was in shambles. A memorable aspect of this desecration was the uniform of an army kitchenmaid pulled over a much-venerated statue of the Virgin. Pierre's sister also recalled that father and son went to see the burnt-out Tuileries and Hôtel de Ville. On seeing the Sainte Chapelle intact in the midst of charred ruins they could only think of a miracle. It is not difficult to guess the thoughts of father and son, both fond of books, as they went by the Bibliothèque Nationale, also slated to perish by arson.

Pierre certainly saw the devastation inside his own parish church where altars, chairs, paintings, fixtures, benches were all slashed to pieces. There he was also told of the sad end of the Abbé Bécourt. He died, like many other priests, on May 27th, the last day of the Commune. Set free to go, he immediately fell into the hands of roving communards who made him and three companions, two of them priests.

18. *Ibid.*, pp. 48-49.

19. *Ibid.*, p. 50.

20. *Un savant français*, p. 155.

stand against the wall of the Petite Roquette. There they were shot in cold blood.²¹ Other victims were shot as so many running rabbits. Young Pierre heard many such incidents told and retold with sorrow and indignation, among them the execution of Mgr. Darboy, Archbishop of Paris.²² In the modest though typically bourgeois and traditionalist home such as the Duhems' much less was known about what happened to many a captured communard. Details of reprisals against them were for the time being spread mostly by word of mouth and mostly among their relatives, friends, and sympathizers. Those details, when taken proper account of, were grim enough even from the distance of two generations to prompt one, as they did in the case of Bernanos, a Catholic and a royalist, to speak of the 'vile repression of the Commune.'²³ Of course the Commune itself could be seen as a proof that the ills of society call not so much for a political dream as for genuine compassion. Young Pierre, who imbued Catholicism and royalism in the family home, together with a dislike for impetuous social change, also acquired there a vivid understanding of the plight of the deprived, an understanding of which years later he was to give much tangible evidence. His deep sense of justice made him in his later years speak with admiration of that communard leader, who refused to move into a better apartment and whose wife continued washing the family linen in the communal facilities.²⁴

Pierre was ten when the Commune blew over. He belonged to a home that was intensely relieved by the return of stability and more or less normal development. Slow normal growth served years later as a chief explanatory device for Duhem the historian of science. Of scientific revolutions, in which everything is turned upside down or starts wholly anew, he saw no evidence. Such was either a pretence rooted subconsciously in his having been once threatened by a revolution or was a view with greater depths than can be gathered by the tools of psychology, sociology, and economics, to say nothing of a heedless infatuation with the paradigm of revolutions. Those relying heavily on those tools will find no detail nearly as striking as the Paris Commune in the rest of Pierre's life. Not that subsequent decades of French history lacked in political and social tension. The next ten years of Pierre's life were certainly rich in background events, though, as will be seen, Pierre's love of learning was

21. *Histoire de la Paroisse Notre-Dame de Bonne-Nouvelle*, p. 180. The Abbé Bécourt expected his execution. He left behind in his cell a note the contents of which became widely known among the parishioners, including young Pierre, long before they were printed. 'Would that those who are enemies today find agreement tomorrow and that Paris become a city of brethren who love God. I make ready as if ascending to the altar of God. Let it be told to my parishioners and the children that I die because I wanted to remain faithful to my duty and to save souls by not fleeing Paris. Will God accept me?' (ibid., p. 182).

22. Marx in London was anything but indignant: 'The priests were sent back to the recesses of private life, there to feed upon the alms of the faithful in imitation of their predecessors, the Apostles' (Horne, *The Fall of Paris*, p. 337). On being told about the Archbishop's execution, Delescluse, a truly unselfish communard leader, muttered in despair: 'What a war! What a war!' (Horne, *The Terrible Year*, p. 161).

23. D.W. Brogan, *The Development of Modern France (1870-1939)* (new rev. ed.; London: Hamish Hamilton, 1967), p. 73.

24. Duhem had in mind Eudes, minister of finances, who prior to his execution instructed his wife to transmit state papers in his possession to the government in Versailles.

too strong to let such events distract him from stretching farther, at an astonishing pace, the horizons of his own mental world. As a young boy, he must have been much impressed by the unusually heavy snowfall, a rarity in Paris, during the winter of 1871-72.²⁵ This was also the last schoolyear he spent under the tutelage of the Arnoul sisters.

Collège Stanislas

The wish of Pierre's father was to send him to a state lycée, a wish that may have been motivated by the better prospects of their graduates to be admitted to the *grandes écoles* —the Sorbonne, Polytechnique, and Ecole Normale, to name only the most important. Papa Duhem may also have thought of the financial burden of a private Catholic school. It was one of these, Collège Stanislas, that was chosen at the insistence of Mama Duhem, particularly sensitive to anticlerical and secularist influences. Although those Republicans who championed a radical laicization of France had not yet seized the control of the Third Republic, 'free thinking' made itself increasingly felt in state schools and public forums when, in the wake of the Second Empire, legal supports of ecclesiastical influence began to erode. Mama Duhem's initial reservations about the Collège Stanislas may have been occasioned by its rapid extension. Founded in 1804, the Collège was given royal approval in 1822 when Louis XVIII permitted the Collège to use the name of his maternal ancestor, King Stanislas of Poland who finished his life in Nancy. When in 1855 the direction of the Collège was taken over by the Marianists, a young congregation of priests founded in Bordeaux in 1817, the Collège had only 95 students. The Marianists, who made Stanislas their headquarters in Paris, increased the student body by a factor of five within ten years. When Pierre entered in the fall of 1872 he was one of 762, a further growth which did not slacken for another ten years. Simultaneously, the Collège added one new wing to another, becoming in the end a massive complex occupying one half of a huge block at the intersection of the Rue de Rennes and the Rue Notre-Dame-des-Champs, not far from the Gare Montparnasse.

Chiefly responsible for that rapid extension was the Abbé de Lagarde,²⁶ a native of Paray-le-Monial, who, while preparing in the Lycée of Besançon for the Ecole Polytechnique, decided on an ecclesiastical vocation. His association with Stanislas started with his theological studies at St. Sulpice in Paris when he also served as pre-

25. The heavily printed quarto pages of *Histoire de France contemporaine de 1871 à 1913* (Paris: Librairie Larousse, 1916) are a storehouse of data and illustrations for a period of France's history which largely coincides with Duhem's lifetime; see Planche IV, facing p. 37.

26. Both on the Abbé de Lagarde and the Collège Stanislas a major source of information is the two-volume work by J. Simler, *Vie de l'Abbé de Lagarde, Directeur du Collège Stanislas* (Paris: Librairie Victor Lecoffre, 1887). The history of the Collège prior to the Franco-Prussian war is amply given in *Le Collège Stanislas: Notice historique (1804-1870)* (Paris: Imprimerie de l'Oeuvre de St. Paul, 1881). Very useful for the period (1872-1882) which Pierre spent at Stanislas are the collection of essays, one of them by Duhem, 1905 (22), *Le Centenaire du Collège Stanislas (1804-1905)* (Paris: Imprimerie de J. Dumoulin, 1905); *Le Collège Stanislas* by H. Bordeaux (Paris: Gallimard, 1936); and the booklet, 'Le Collège Stanislas 1804-1979: Notice historique' (Paris: Collège Stanislas, 1979).

fect of discipline for the boys. He had already been assistant director of Stanislas when it fell upon him during the siege of Paris to turn part of the Collège into a military hospital which cared with its hundred beds for over half a thousand injured, both military and civilian. The devotion and heroism which the Abbé de Lagarde showed while Prussian cannonballs were hitting the Collège had its impact among the sick as well as the healthy. Among the latter was Captain Trestour, who recovered his faith while serving as a commanding officer at Stanislas.

The combination in the Abbé de Lagarde of piety, learning, and dedication set the tone of life at Stanislas as he served as its director from 1867 until a few months before his death on September 1, 1884. As one who had once set his sight on the Ecole Polytechnique and who had earned his *licence* in mathematics, the Abbé de Lagarde had no hesitation in steering his best students to the *grandes écoles*. The Church was yet to start founding her own free universities—Instituts Catholiques—and it had been all too clear to far-sighted Catholics that only a fraction of Catholic students could ever be accommodated by such institutions. The policy of the Abbé de Lagarde was obviously responsible for Duhem's conviction voiced especially in his later years that bright Catholic youth must not be discouraged from entering state universities nor from seeking teaching posts there subsequently, a conviction hardly expressive of an 'ultra-conservative and religious extremist.'

The policy set by the Abbé de Lagarde would have been self-defeating had it not rested on an intensive practice of the faith and on its thorough study. Such a policy, which did not remain a dead letter at Stanislas, may well balance the impression given by François Mauriac's complaint relating to the next generation that Catholic schools formed 'not Catholic intelligences, but Catholic sensibilities.'²⁷ In both respects Mama Duhem must have felt fully reassured following her visit sometime in the spring of 1872 with the Abbé de Lagarde. She of course may have already heard details about his steadfastness during the siege and the Commune. When on Wednesday May 24, 1870, Stanislas was in the center of the street fighting, the imposing presence of its director sufficed to dissuade a communard, charged with setting the college on fire, from executing his order.²⁸ The visit must have left in Mama Duhem a vivid image of a relatively young priest of increasing importance in his own congregation. Six years earlier he was the aide of his superior general on a three-month-visit in Rome, the aim of which was to obtain for the Marianists the pontifical approbation, given during that visit on May 12, 1865. Only thirty-two, the Abbé de Lagarde had two audiences with Pope Pius IX for whom he had the deepest loyalty. He greeted the Apostolic Constitution, *Dei Filius*, as a 'safe guide for philosophy' and viewed the declaration of papal infallibility as a 'source of rejoicing in an age in which all authority is being debased.'²⁹

27. Stanislas itself was in decline around the turn of the century, the period to which Mauriac's further strictures refer: 'I am certain that not one boy in my class would have known even broadly the sort of objections that a Catholic had to answer during the first years of the century.' *God and Mammon* (London: Sheed & Ward, 1936), p. 19.

28. See Bordeaux, *Le Collège Stanislas*, p. 100.

29. *Vie de l'Abbé de Lagarde*, 1: 418-19.

Clearly, Mama Duhem, who wanted Pierre to make his first communion prior to his entrance in Stanislas so as to be all the better shielded against any possible harmful influence, did not need to worry. At any rate, Pierre, not yet eleven, was not eligible for first communion in May 1872, the customary month for such an event in parish churches at that time. The postponement was an unintended bonus for Mama Duhem as well. Pierre found at Stanislas for his spiritual director none other than Msgr. Ségur, a bishop renowned for his saintly life, who was also to become Mme Duhem's spiritual advisor. It was long remembered in the family how Pierre returned home one evening in October 1872 and announced triumphantly: 'I picked the bishop!'³⁰ He meant his choice of Msgr. Ségur, from a long list of ecclesiastics available as confessors for the students who started the schoolyear with a four-day retreat. Pierre may have also spoken about the notice made in words and in writing in the school that confessing was entirely the free decision of everyone.

By then Pierre had a baby brother, Jean, born on the 30th of September, who had Pierre for godfather, and Marie, older of the twins, for godmother.³¹ Papa Duhem was now joined by three children in watching the baby ecstatically. Their happiness was not to last long. In an unusually humid and cold November, diphtheria took hold of Paris. Little Jean died on the 15th after three days of sickness. Pierre and Marie were rushed to Grandma Fabre, lest they catch the disease from Antoinette who struggled valiantly. Before her throat was cut open by the surgeon in a last attempt to save her life, she received first communion. On November 24, she joined Jean in heaven. It was the eve of the feast of Saint Catherine, virgin and martyr, —a detail pointedly noted by Marie Duhem for whom that day took on a poignant significance when she became a nun. Her way of recalling that day should convey something of the deeply Catholic atmosphere which pervaded every aspect of life in that modest apartment at 42 Rue des Jeûneurs.³² In the same breath Marie Duhem added words which tell not only of the symbiosis in which she and Antoinette spent their first nine years, but cast a priceless light on Pierre: 'And what about his [surviving] sister? He would be for her a twin. He prevented that soul, who did not know how to live alone, from flying to Heaven. Through tactful attention, intimacy, support, and encouragement, he made her smile. Almost as much as to his mother, he confided to her his thoughts.'³³

There was plenty to confide about the school Pierre now attended. The place exuded history. Over the opening of the main entrance to the courtyard students could see day after day a sculptured frieze, the only remnant of the infamous Brasserie Santerre, where during the Terror masses of priests were summarily sentenced and carried across the street to the Carmelite cloister, their place of execution.

30. *Un savant français*, p. 20.

31. The child's full name was Jean-Charles-Marie. See entry No. 422 for that year in the baptismal records of the parish of Bonne Nouvelle. In signing the record, Pierre did not start with a capital letter his middle name Maurice.

32. Its modest financial circumstances are indicated by the rather low rank of funeral service accorded to both children.

33. *Un savant français*, p. 22.

The facade of the Carmelite church was to be decorated with the words, CI-GIT LE CI-DEVANT CLERGE FRANÇAIS (here lies the late French clergy), but before they could be chiseled into the marble slab chosen for the purpose, the henchmen of the Terror secured the word 'late' in front of their own names. Quite different history was attached to the Villa Belgiojoso, the only edifice which remains unchanged of the Collège as Pierre saw it. An elegant two-storey 'hôtel', now housing the administration, it hosted, prior to its purchase by the Collège in 1862, many a famous personage, among them Liszt and the Comtesse d'Agoult. The history of the Collège as such was formally in evidence in the 'Salon Rouge,' still extant above the old main entrance, which served as the office of the director. Its name was due to the red silk decorating its walls on which hang the oil portraits of the school's directors. The only director whose memory was to be recorded by a marble bust was the Abbé de Lagarde. Pierre, as will be seen, made a signal contribution to that history. Today the Collège is dominated by modern and even ultra-modern buildings, one of which stands on the spot of that impressive chapel in whose apse Pierre sat during services with other upper-classmen preparing for the *grandes écoles*.

Life at Stanislas

The history of the Collège was somewhat prosaically given in the *Annuaire*s of over 300 pages printed in small format which prominently carried the motto, 'Français sans peur, Chrétiens sans reproche,' which the Abbé de Lagarde chose for the school. Needless to say, each issue³⁴ contained in full the aims and rules of education. It is tempting to picture Marie listening in awe to Pierre's reading to her from the *Annuaire* that behavior at Stanislas was set by 'Ordre et Discipline.' Born actor as Pierre was, he could easily make those words sound even more fearsome than they could be for a girl not yet ten. Discipline as objective of the rules of conduct was based on Saint Paul's words, that all authority is from God. The spirit of the rules was summed up as 'Order, work, docility, decency, piety.' The love of order was in turn described as 'the characteristic of the children of God.' Clearly, the place was not for boys, talented though bent on morose enjoyment, as was Jacques Anatole Thiébauld, future apostle of 'volupté,' better remembered as Anatole France. He attended Stanislas in the late 1850s, just after the Marianist Fathers had taken over the school, and for all his adult life he resented the time he had spent there.³⁵

It was not Anatole France who published the prize-winning essay he had delivered at fifteen before the Académie d'émulation of Stanislas, an essay praising in brilliant prose, evocative of the future virtuoso of polished phrases, the pastoral wis-

34. On entering Stanislas in the fall of 1872, Pierre received a copy of the *Annuaire 1872-1873: Documents relatifs à l'année scolaire 1871-72* (Paris: Typographie Lahière, 1872). The section, 'Règlements du Collège' (pp. 145-69), was reprinted in essentially the same wording in the *Annuaire*s of the next ten years which Pierre spent in the Collège.

35. Although Anatole France's reminiscences give an obviously one-sided account of Collège Stanislas, they have been uncritically taken over in many a work with a veneer of scholarship, such as *To the Finland Station: A Study in the Writing and Acting of History* by E. Wilson (1940; Garden City, N.Y.: Doubleday, 1953), pp. 56-57.

dom of the Renaissance Pope, Leo X.³⁶ The son of a modest bookseller, young Thiébault was certainly not denied prizes at Stanislas which he later charged with rank favoritism toward the sons of aristocrats. Nor was Duhem, the son of a modest salesman, passed over when prizes were distributed. Prizes were available to any boy applying himself to his studies and respectful of discipline, hardly a matter of heroism. Years spent at Stanislas could be recalled by a healthy boy with sincere admiration. Witness a letter which Duhem wrote on October 28, 1913, to eleven-year-old Norbert Dufourcq, son of Albert Dufourcq, a colleague of Duhem in Bordeaux who had just moved to Paris and had enrolled his son at Stanislas. Young Norbert was instructed to write to 'Uncle Pierre' whose fond relations with the Dufourcq family will come up later.

My dear camarade, wrote Duhem back, you really have an opportunity. The regime at Stanislas has softened since the month of October 1872 when I entered there as a half-boarder, in the fifth class, section green. At that time half-boarders as well as full-boarders wore the uniform. On Feasts and Sundays, in warm or cold weather, one had to keep the long blouse fully buttoned and the belt tight around it. We had only one free day each month, the first Wednesday of the month. On Sunday we [here Duhem speaks for full-boarders] could go out only after the vespers at 4 o'clock. On ordinary Wednesdays the half-boarders, who could pay 400 points of exemption, all that could be earned for good behavior and work in a week, could leave at 11 and a half. The others went, three by three, walking with the full-boarders [their blouses] always buttoned up and their belts tight. On the Day of All Saints, we exited at 6 in the evening and next morning at 8 o'clock we were back at the Collège for Mass for the dead. I have led this life until my entrance at the Ecole Normale, that is, until I was 21. If one day you have the urge to complain, you will think of me and right away you will find that you are lucky. Since you are given more vacation than we were given, use your study-time better than we did. When you grow up you will never regret it.³⁷

Discipline at Stanislas accommodated a wide variety of boyish pranks in and out of classrooms. In a priceless account of his last four years there, Duhem, already forty-four, recalled with relish the snowball-battles as well as the student strategies aimed at distracting the prefect of discipline who tried to track down the fragrance of a cigarette, 'this modern version of the forbidden fruit.'³⁸ In the case of one teacher (Moutier), who preferred noise to quiet, students did not mind observing deadly silence in order to unnerve him on occasion. The same account reveals also the keen awareness which upperclassmen had developed of the school's contribution to them. They knew they were effectively guided toward one or the other of the coveted *grandes écoles*, an impression strengthened by chance visits at Stanislas of older camarades already in the uniforms of St. Cyr, the Ecole Polytechnique, or the Ecole Normale. They were immediately surrounded and treated to the latest conflicts between the 'reds' and 'yellows' and 'greens.' Then it was the turn of these to listen with awe to the exploits of their visitors, especially if on the sleeves of their

36. For the text, see H. Bordeaux, *Le Collège Stanislas*, pp. 124-26.

37. Letter in possession of Monsieur Norbert Dufourcq who generously provided me with much valuable information.

38. 'Souvenirs de l'Ecole Préparatoire (1878-1882),' 1905 (22), p. 102.

uniforms there shone a silver stripe or two. 'I still remember the respect with which we, humble pupils of elementary calculus classes, gazed at the double stripe of a major shining above the white gloves of one of our older camarades. Of him who bore them, we spoke with admiration. We kept telling one another that he would become a great mathematician. The joy of his old camarades had something in it of a feigned surprise on the day when the doors of the Académie des Sciences turned wide open before Georges Humbert.'³⁹ Last but not least, the years spent together at Stanislas were an assurance of friendship for the rest of life even when decades were to pass until meeting again. Duhem very likely spoke of a fresh experience of his when he wrote in the same account: 'There formed ties of solid friendship capable of resisting long years of separation. How promptly is that friendship revitalized, warm and joyful, when at the corner of a street in an unknown town, where one was exiled by the chance of an appointment, one encounters under the four-gallon hat of a battalion of artillery or of the hussards, a friend whom one had not seen for twenty-five years! How the hands are extended and pressed while one recalls already old memories, the furious battles in which *taupins* and *cornichons*, massing at opposite sides of the courtyard, bravely bombarded one another with snowballs.'⁴⁰

This personal glimpse provided by Duhem may justify the tone of the ensuing reconstruction of his years spent at Stanislas. Whatever its deep religiousness, the place was not a minor seminary or a military boarding school. Attendance at Mass was compulsory only on Sundays, feasts of obligation, and Wednesdays, a weekly holiday free of classes. Any other day attendance at Mass was left 'to the individual's piety'. The syllabus is worth quoting about the integral role of athletics, compulsory twice a week, in education: 'A student does not do, in recreation, his duty, except when he plays.'⁴¹ Clearly, Stanislas was not a place where, according to Taine's bitter recall of his days at the Institution Mathé and the Collège Bourbon, 'the collegien lives, deprived of all initiative, like a horse between the shafts of a cart'⁴² —representative as this complaint could be most of the collèges and lycées of Paris in the mid-19th century.

Pierre, a demi-pensionnaire, reported to the school by half past seven every morning and set out for home at six in the evening. With the first metro line still more than two decades away, he had to manage, rain or shine, the distance of about two miles from the vicinity of the Bourse to near Montparnasse, now and then on a horse-drawn trolley bus, but mostly on foot — hardly a problem for the intrepid hiker into which he developed while at Stanislas.⁴³ On going from home to Stanislas

39. *Ibid.*, p. 104. Georges Humbert (1859-1921) became member of the Académie des Sciences in 1901.

40. *Ibid.*, p. 102. *Taupins* and *cornichons* were the respective nicknames of candidates for the Ecole Polytechnique and St. Cyr.

41. *Annuaire 1872-1873*, pp. 153 and 157.

42. Quoted by A. Hyams in the introduction to his translation of *Taine's Notes on England* (Fair Lawn, N.J.: Essential Books, 1958), p. x.

43. It is unlikely that the Duhem family took advantage of the coach service which the Collège provided for the transportation of day students.

and back he had, at least in the long days of late spring and early summer, also the advantage of seeing plenty of the new buildings and avenues. Pierre's regular route to school did not pass too far from the Place Dauphine area under demolition in 1872. In 1873 there came the restoration of the column of Place Vendôme. In 1874 and 1875 construction of the Opera and its famed avenue provided further incentive for a little detour.

In the 1870s Collège Stanislas still included the *petit collège* corresponding to elementary school in which the youngest ones, six years old, started in grade 11 and moved up to grade 6 by the time they were eleven. Pierre entered as a 'fifth grader,' which meant the lower of the two grades (5 and 4) comprising the *moyen collège*. The next stage, or the three grades of the *grand collège*, were marked 3, 2 and 1. Above these was the *école préparatoire* which could extend to three years depending on the future university studies contemplated by the individual student. Each grade was divided into sections marked with colors, a feature which readily promoted the kind of rivalry relished by boys. The color of Pierre's section was green to which he was attached for the next ten years as he was to the number 472 assigned to him when he entered. This number marked his dossier, exam papers, and, for identification purposes, his books and clothes as well.

The yearly reports (*Annuaire*) of the Collège contain not a few details about Pierre. In the *Annuaire* about 1872-73 he is listed among the 59 who took their first communion on May 21, 1873, from the hands of Msgr. Ségur. In the *Annuaire* about 1873-74 he is among the 78 who received the sacrament of confirmation. His signature was undoubtedly on that statement of loyalty which the Faculty and student body of Stanislas sent in late 1874 to Pius IX who replied with a message exhorting the youth 'to show courage in the best possible manner through the aid of religion, and triumph thereby over the evil which plagues our times.'⁴⁴ The expressions—evil of the times, aid of religion, courage—were all too familiar to Pierre. About the evil of the times he must have had very specific ideas at a time which saw French Catholics rally as a man behind the vast program of erecting the Basilique du Sacré Coeur on Montmartre, still under construction when the Tour Eiffel, its chief rival as a landmark of Paris, had been completed for the Exposition universelle of 1889. The erection of the Basilica was to symbolize *Gallia penitens*, that is, an attitude indispensable if triumph over the 'evil of the times' was to be achieved. Although the Assemblée Nationale declared the project to be of 'public utility,' a move necessary to force the sale of land needed for the construction, the purchase of land and the cost of construction were entirely financed by donations from the faithful to the total cost of 40 million francs. This vast sum came mostly from small donations that poured in over four decades, among which were those of Pierre. Students of Stanislas, which was consecrated to the Sacred Heart of Jesus and Mary in the early summer of 1873, sponsored one of the marble columns surrounding the sanctuary, a column marked with the coat of arms of the Collège.⁴⁵ Pierre

44. *Annuaire 1875-1876*, p. 11.

45. *Annuaire 1878-1879*, p. 181.

witnessed the progress of the construction of the Basilica as he partook in the annual pilgrimage which the Collège made from 1876 on to Montmartre.

The Duhems may very well have taken part in one of the great national pilgrimages which reached their high point in the spring of 1873. One of these pilgrimages saw a large part of the Assemblée in Versailles go to the Cathedral of Chartres. French Catholics, especially the hierarchy and the clergy, still were convinced that Church and monarchy were inseparable, a conviction which the Duhems certainly shared. Twelve-year-old Pierre was deeply involved emotionally in that last euphoria of French monarchists which came when the Comte de Chambord, who for the previous two years had been the head and symbol of their aspirations, came to Versailles in November 1873, trusting that the Assemblée was ready to turn to him.⁴⁶ As is well known, General MacMahon could easily hold out against the monarchist pressure brought to a high pitch by the presence of the Comte who had gravely undermined his cause with his earlier insistence on the white flag of the Bourbons as against the tricolor by then sacred to most Frenchmen. Young Pierre was one of those who, though keenly disappointed in the outcome, did not give up hope in the cause. A few years later, he surprised many among the Faculty and students of Stanislas by declaring himself a 'royaliste' on a questionnaire circulated in the Collège.⁴⁷ Clearly, Stanislas was not a stronghold of monarchism. Otherwise it would not have produced a Marc Sangnier, the future leader of Sillonists, who was as idealistically Republican as Duhem was royalist. The idealist royalism of Duhem, young and old, had deeply ethical overtones. He was steeped in the conviction that democracy was in practice a gradual erosion of any and all principles and as such the fomentor of the 'evil of the times.' Of such evil any decade could provide plenty of evidence, especially if one was keen on spotting it. While in his idealist royalism Duhem never wavered, his keen realization from youth, pointedly recalled by his sister, that evil had to be first attacked within one's very self, made him a better 'reform democrat' than many others so-called. Neither in the school nor elsewhere did he ever sermonize. 'He was certainly devout,' a former classmate of his, Joseph Récamier, a physician, recalled, 'and very respectful of matters of religion. But in no way was he a bigot or a preacher. It was only later and gradually that I became aware of the depth of his reasoned convictions, of the fullness of his faith. At the Collège he limited himself to preaching by example.'⁴⁸

As to self-mastery achieved with the aid of religion, Pierre was reminded by his mother, whom he accompanied every Sunday to communion, that God enters only the soul of one who has already conquered unruly impulses. Sister Marie also saw the teenager Pierre humbly bow his head as he was reprimanded at table now and then by his father. Toward his parents, as the same former classmate of his was to

46. *Un savant français*, p. 129.

47. *Ibid.*, p. 127, where the report is based on the reminiscences of Joseph Récamier, himself an ardent royalist.

48. *Ibid.*, p. 37. The quotation is part of a letter of Récamier written 'a few days before his death' (p. 35) to Hélène Duhem. Récamier died in 1935.

write, 'he was most respectful, the most obliging son I have ever seen.'⁴⁹ The parents, especially the mother, taught him the highest form of self-mastery: the art of forgiving the jealous, the suspicious, and the hostile. Mastery of his own self Pierre needed all the more because he was a boy disproportionately courageous to his median size and somewhat thin frame. His courage had for its main target the readiness to stand up for his convictions. 'From childhood on,' continues the recollection of Récamier, 'I have noticed in Pierre that independence of character which he kept for the rest of his life. At the Collège no consideration [of his own interest] could prevent him from saying what he thought, even though this meant contradicting camarades much stronger who, less intelligent than he, replied to his arguments or jokes with blows.'⁵⁰ For all his being aware of his intellectual prowess, he was never ostentatious about it. 'To me, who had been such a close friend of his during our youth,' added Récamier, 'and so inferior to him, he never said a word that could have hurt in this respect.'⁵¹ Among those with whom in the Collège he developed close ties was Jean de Guebreuil, a future missionary to China and a bishop, for whom he had particularly tender respect. Others were Guy de Sainte-Gertrude, Charles Bioche, Léon Vivet, Jean and Lionel de la Laurencie. Their future professions and habits were as diverse as could be, but on their rare reunions they felt as if they had parted only the evening before.

Young scholar

For all their depth and commitment, Pierre's friendships implied orderliness and freedom, characteristic also of his intellectual pursuits. His classmates never saw him pressed with his studies or caught in last-minute cramming. From his schooldays on 'he had this regularity in work which made him always ready'. Récamier also found it significant to recall a detail, a gold mine for a graphologist, that 'already at that time Pierre had that neat writing, without erasures, which he retained all his life. His geographical maps were pieces of art as were his sketches.' And, of course, any reader of his work can only agree with the observation: 'He had the habit . . . not to learn anything superficially. Duhem went to the very bottom of everything he undertook. From grade 3 [1875-76] on, he knew all molluscs of which I had a collection and which he wanted to classify and sketch.'⁵² For a while Pierre seemed to be heading more in the direction of natural history than mathematics and physics. At the end of his fourth year, in the summer of 1876, and just past his fifteenth birthday, he was especially praised for his excellence in natural science studies. In this connection his sister recalled that Pierre loved to spend Wednesdays in the Natural History Museum (greatly modernized in the 1870s) near Pont d'Austerlitz. He used to take there specimens of his own collections, ranging from minerals to lizards, and compare them with those exhibited in the Museum. His sister was somewhat too admiring in stating that Pierre 'was to remain . . . at the head of his class' since his

49. *Ibid.*, p. 39.

50. *Ibid.*, pp. 35-36.

51. *Ibid.*, p. 38.

52. *Ibid.*, p. 36.

entrance in the Collège.⁵³ The *Annales* give a somewhat different picture. At the end of his third year (summer 1875) Pierre ranked fifth in a section of 33, and fourth in a section of 34 at the end of the next school year, which saw him finish *grand collège*. At that time he could boast of 5 prizes and of 6 accessits (honorable mentions), and of having taken part in four competitive exams (concours général).⁵⁴

Prizes were not given easily, if this is to be judged by the teacher's remarks on an essay written by Pierre in his last year in the *grand collège*. The essay, a part of his assignment in the philosophy course, was on Bossuet's dictum that 'man wants to be happy, he cannot but want this, and does want all to that end.' The outline of the essay, its only part now extant,⁵⁵ shows Pierre's early bent on rigor in reasoning. The teacher, A. Noyer, deplored the presence of not entirely relevant details while praising the philosophical gist of the third section. The rest, Noyer jotted on the margin, 'is much too long, at times banal,' and not always consistent with the sequence as indicated in the outline. After stating that the essay itself dealt with the proposition that happiness is the goal of human actions, Pierre stated that the proposition can be proven both with a reference to reason and to experience. Reason showed (I) that all our decisions and motivations carry us toward some good and that (II) our freedom is limited to the pursuit of good. Experience in turn showed that (III) even when man is in pursuit of something evil, he either does not see it or he proceeds with a view to a greater good. Bossuet was therefore wrong (IV) in claiming that we are free in wanting to be happy. 'It was therefore necessary to enlighten the mind,' Pierre concluded, 'and to combat the bad inclinations.'

Pierre's chief ambition related of course to science. Long before he became the recipient, in 1881, of a special chemistry prize,⁵⁶ he knew that prizes and distinctions were so many steps toward admittance to one of the *grandes écoles*. Pierre fully understood what was implied in the statement of an inspector sent by the Sorbonne in 1878 to Stanislas:

The success of this house has surpassed all expectations . . . You have at the concours général to the *grandes écoles* of 1855 one prize [first place] and three accessits [second places]. Ten years later 3 prizes and 19 accessits. The last year [1877] the Collège Stanislas obtained 18 prizes and 53 accessits, placing itself thereby the third among all lycées and colleges of Paris. Yesterday you have been even more fortunate: 23 prizes and 51 accessits keep you at the same rank with respect to the total number of placements and raise you to the second rank with respect to prizes. Finally, during the last four years you have given one first to St. Cyr, one first to the Ecole Polytechnique, and two firsts to the Ecole Normale, one in the section of letters, another in the section of sciences.⁵⁷

53. *Ibid.*, p. 21, where the qualification is added that Pierre shared first place with his classmate, André Nouette-Delorme.

54. *Annuaire 1876-1877*, p. 38.

55. In the Archives of the Collège. Courtesy of the Abbé G. Milet, present director of Stanislas.

56. *Annuaire 1881-82*, p. 202.

57. Quoted in Simler, *Vie de l'abbé de Lagarde*, 2:83. The Collège could with full justice state about its class of special mathematics that it 'includes, in the span of one year, instruction in all that is necessary for admission to the Polytechnique . . . The Collège can cite the names of students whom it had accepted with such aims in view and who entered the Ecole Polytechnique and the Ecole Normale Supérieure in the highest ranks' (*Annuaire 1881-82*, pp. 111-12).

Another inspector, a former graduate of the Ecole Normale, declared:

Many have graduated, as I did, from that Ecole Normale which owes you some of its most brilliant students and which today pays its debts to you by giving you teachers, trained for the lycées, some of whom, in spite of their youth, have already deserved being called to chairs at the Sorbonne and the Collège de France. It is the first time, young students, that I have the honor of being in the midst of you, but your names are familiar to me for some time. The echos of the Sorbonne repeat them each year and since four years they are found at the head of the promotions [graduating classes] of the *grandes écoles*.⁵⁸

Did Pierre, on hearing this, think of becoming one day one of those firsts and of being called eventually to one of those chairs? Most likely he did. He was right and wrong at the same time, as his heart was beating faster than usual.

Pierre also took great pride in the excellence of premilitary training at Stanislas. The 1870s saw in France an outburst of patriotic efforts aimed at securing revenge for the defeat of 1870. Some of those efforts, such as the putting of schoolboys and university students through military drills, once or twice every week, were certainly good for the burning souls of patriots, young and old. Twice a week, Duhem recalled,

There came the drill, the rushes of lining up into formation, the exact motions, the jerky turns of the rifles in hands bitten by the cold, the riflebutts hitting with one crisp thump the hard ground, and, above all this noise, Adolphe's beautiful voice of command, brief and resounding. We had high esteem for that drill-sergeant of the Republican Guard, his breast sparkling with a constellation of medals. With the drill finished and the rifles in the racks, we loved to make him tell us episodes of his life as a soldier. His manly recitals brought us always the same sentiments, simple and grand: energetic endurance, respect of discipline, and veneration of the flag.⁵⁹

In view of this, it may not be a flight of fancy to see young Pierre among those who with their heads held high listened, following the performance of the student battalions of Stanislas, to an inspector from the Ministry of War:

My friends told me that at Stanislas I will find young men who are good in Church processions but not in bearing arms. I now must declare that as far as military exercises are concerned Stanislas is first . . . If war breaks out, I know where to find officers. Of this I will notify the Ministry of War.⁶⁰

Thirty some years later Pierre Duhem would gladly have served, officer or not, in World War I, had his age or health permitted.⁶¹ The inspector himself was so over-

58. Quoted in Simler, *Vie de l'abbé de Lagarde*, 2:88.

59. 'Souvenirs de l'Ecole Préparatoire,' 1905 (22), p. 104.

60. *Vie de l'abbé de Lagarde*, 2:349-50.

61. Duhem had the classification 'réformé' with respect to military service, as shown on his personal card in the Archives of the University of Bordeaux.

whelmed as to send a few days later his photo to the Abbé de Lagarde with the note: 'You have now in a way at Stanislas the head of a Republican, of a man who has spoken his mind concerning your devotion to the country.'⁶²

Personal exploits

Pierre, who was always near the top of his class, could, if he had wanted to, have taken the very top. But this would have meant sacrificing some of his free time which he loved to enjoy in a way which suggested a teenager unwilling to be glued to his desk, let alone to the gloomy mood this could generate. The vast main hall of iron and glass of the Exposition Universelle of 1878, which covered much of the Champs de Mars, must have been an enormous attraction for Pierre. In the *galérie de travail* he could have spent hours watching the latest industrial products being manufactured in full view of the visitors. The same hall housed also the Rue de France with building characteristic of all her regions, and the Rue des Nations whose chief attraction was the house of the Spanish unit, a mixture of the best details of Moorish architecture of Granada and Sevilla. Across the Seine, there rose the twin towers of the newly built Palais de Trocadéro adjoining a new park for exhibits from exotic lands, some of which were just about to become the target of France's newfangled colonialism. The greatest popular success of the Exposition was a permanent balloon of observation anchored on the roof of the Tuileries.

The exhibit was opened on June 30, 1878, the government being anxious not to create unnecessary friction by choosing Bastille Day. The move produced only a momentary lull in the opening phase of a conflict which kept France in its throes for over a generation. The centenary of Voltaire's death on May 30 provided the first broadside, followed by Gambetta's famed speech in Romans, on September 18, in which he declared clericalism as France's chief enemy. The Comte de Falloux, architect of the famed law of 1850 which secured the existence of schools operated by the Church, was more farsighted as he warned two years earlier Radicals as well as Catholics, but especially the 'ultras' among the latter. The Radicals must count with the immortality of Christianity, and the Catholics with the endurance of the Revolution.'⁶³ Pierre, as will be seen, made his contribution to the resistance to the laicisation of Catholic elementary schools, but, just as later as a professor he was not to become an activist, he was not to be one as a student. A student he was, cheerful and eager to pursue his personal projects.

As to his cheerfulness, Récamier recalled: 'Pierre in his youth was very happy. Nobody understood a joke better than he did. He had an instinctive sense for the comical which he could not resist and which he illustrated in a large number of cartoons, including caricatures of his teachers.' A happy-go-lucky boy, indeed, setting

62. *Vie de l'abbé de Lagarde*, 2:350.

63. The Count's warning was aimed at Catholics mustering strength for a 'counter-revolution.' See Alfred P.F. de Falloux du Coudroy, *Discours et mélanges politiques* (Paris: Plon, 1882), 2:388. Pierre would have readily agreed in that widely read warning, 'De la contre-Révolution,' with the Count's contention that had Catholics of the Ancien Régime stood up against social injustice, Voltaire and his cohorts would have lost their appeal to the masses, always less interested in ideas than in actions redressing deep grievances.

out with his friend Récamier after Sunday Mass for long walks, which at times took them to Versailles and back. Though not robust by any means, Pierre showed no fatigue. Nor was he ever seen with a cold in spite of the fact that even torrential rain could not stop him. 'I remember', recalled Récamier, 'a day of great storm when the Rue de Rennes turned into a stream as we left the Collège. Pierre was unwilling to wait out the storm; he exited with me trampling, with the joy of a kid, in the water which was well over his shoes.'⁶⁴

One can only wish he had been more careful, if not with rain, at least with sea water. It was in St. Gildas, a fishing village on the ocean side of the Rhuys peninsula (Bretagne), that he contracted in the summer of 1877 (he was then sixteen) a severe rheumatism which, mostly through cramps in his stomach, plagued him for the rest of his life. Already the next year he was handicapped in his studies. 'Duhem could not take part in the concours général,' stated the *Annuaire* of 1877-78, his first year in the class of rhetoric in the *école préparatoire*.⁶⁵ He first went to St. Gildas in the summer of 1874 at the advice of the family physician who recommended exposure to sea air. The 11th-century church of St. Gildas had its own attractions, such as the gate adjoining the garden through which Abélard once escaped the wrath of his monks resisting reform. Pierre appreciated much more the opportunity of strolling for hours on the beaches or staying half submerged in sea water to enlarge his collection of molluscs and other specimens. As his sister recalled, his luggage was more and more damaged with each return to Paris. Living in a Breton village meant also the collecting of personal impressions which could be no less instructional than pieces relating to natural history. The famed monolithic pillars, the menhirs of Carnac, were not too far, although then as now beyond the reach of 'scientific' explanations which had been numerous already a hundred years ago.⁶⁶ Some of them obviously challenged the imagination of Pierre, who after a visit there could not help raising the topic with his peasant hosts. For them the howling winds blowing from the oceans were the loud signs of those perished in shipwreck. The ocean had a hold not only on them but also on their surroundings. 'Shut your houses tight and don't go out,' Pierre heard them say, 'especially on November 2 [All Saint's Day] because on that night all the menhirs of Caesar's Camp go in procession to drink in the sea.' Pierre, the young scholar bent on reason and evidence, was stunned by such credulity and broke in: 'Have you seen them?' He immediately noticed that such a question was too much, amounting in their eyes to having no faith. He caught on and asked no more such questions in order to remain their friend, as reported by his sister.⁶⁷ She also recalled that those primitive Bretons and their stories interested Pierre more and more. He never forgot their stark, single-room dwellings which housed their large families as well as their cows and pigs. It was never a problem for him to communicate with the simple and the poor. As for the Breton legends about

64. *Un savant français*, p.38.

65. *Annuaire 1877-78*, pp. 38-39.

66. For a sample of those explanations, see 'Carnac' in *La Grande Encyclopédie* (Paris: H. Lamirault et Co., n.d.), 9:459.

67. *Un savant français*, pp. 32-33.

the menhirs, he must have later realized that they were at least not coated in scientific jargon, unlike the fanciful theories of which ‘menhirists’ never run short.

He saw simple folk at close range also at St. Martin-du-Tertre, a village about 30 miles north of Paris and 7 miles southwest of Chantilly, where he spent a part of his summer vacations between 1875 and 1882. The Labrouste, relatives of Pierre’s mother, had a house there, serving as a summer home also for the children of other relatives –the Blanchart, the Bonneau, the Pavet de Couteille– and last but not least, to the many grandchildren of Henri Labrouste, a retired architect from Paris and a winner of the Prix de Rome. At the age of fifteen, Pierre became the leader of the band. He not only organized trips during the day, but also some ‘horror’ games in the evening. To test the courage of the small fry, he told them to go in the dark to the end of a long courtyard surrounded by haystacks and deposit there small objects. ‘These,’ Pierre declared, ‘I am going to collect to verify that everyone made the entire distance.’ Upon collecting the objects it was his turn to congratulate his little troops.⁶⁸ He sat with them at the feet of grandpa Labrouste, a sprightly octogenarian and a master story-teller, who drew on the years he had spent in Rome in the early decades of the century. At that time the Campagna Romana was ‘still full of bison, less fearsome than the brigands holding up travellers and stage coaches.’ Marie Duhem’s picturesque phrase betrays one present in that entranced audience. She and Pierre had also vivid memories about grandpa Labrouste’s watercolors ‘with incomparable skies, bathed in luminous transparency.’ They were among the happy recipients of small holy pictures which grandpa Labrouste painted for his grandchildren, grandnephews, and grandnieces for their first communions.

St. Martin-du-Tertre was as happy a summer place as could be. Pierre’s parents ended up by renting a summer house in Presles, a neighboring village also nestling in the Carnel forest. It was there that Pierre and his sister one day easily persuaded the cook to make a casserole of mushrooms which they found amidst patently poisonous toadstools, but did not find listed in their manual of mushrooms. A risk it was but a very delicious and healthy one in the end.⁶⁹ The curiosity of the experimenter was also in evidence when Pierre asked Edouard Hardy, a family friend and a pharmacist near the Hôtel de Ville in Paris, to inoculate frogs with extracts of his poisonous mushrooms to measure the rate of their deadly effectiveness.⁷⁰ Pierre may have also been given by Mr. Hardy inside information about the new and vast Ecole de pharmacie under construction in the late 1870s and early 1880s. In those years Pierre spent part of his summer vacations in the Vosges with Jean and Lionel de la Laurencie, his schoolmates at Stanislas. Jean recalled many years later: ‘As I was becoming a friend of plants, he proposed to me to herborise. We chose the kingdom of ferns and the *spaignes* whose visitors and behavior he knew by heart. One day we saw him carrying a *Drosera* into his room, planning to watch, he said, the capture of midges by the small carnivorous leaves. Yet his favorite garden, his en-

68. *Ibid.*, pp. 28-29.

69. *Ibid.*, p. 30.

70. *Ibid.*

chanted garden, was in his home Rue des Jeûneurs in Paris, where he cultivated that plant in two or three saucers containing fruit juice. Under the microscope he followed the proliferation of mould and sketched progressively each phase with an admirable virtuosity and precision.⁷¹

Teachers remembered

By then Pierre was well in the final phase of his studies at Stanislas. Gone were the years during which he mastered the chief objective of the *grand collègue*. It consisted, according to the *Annuaire*, in the student's knowing 'how to give to his style, in translating French to Latin and Greek, and in French composition, a touch which demonstrates a solid acquaintance with the genius of the language in which he writes.'⁷² Gone were also the years when he was a student of Anatole Feuguère and Gustave Larroumet, who taught him the various literary and philosophical courses lumped under 'rhetoric', and of Louis Cons, author of widely used history textbooks. Feuguère's and Larroumet's courses profited much the future master of clear, exact and at the same time picturesque style. As to Cons, an advocate of Comtean positivism whose tenure at Stanislas was a source of bafflement for many,⁷³ a glance at his textbooks shows that Pierre's royalism was not inspired by history courses at Stanislas. Cons held high the Revolution as a tool of an ideal fully achieved. Since all privileges, Cons wrote, had now been abolished, 'there is no further reason for starting new revolutions and therefore anyone who would appeal to violence in order to change the established order and to disturb the peace of his country, would be a bad citizen.'⁷⁴ Cons telescoped the anarchical end of the Commune into its entire duration. 'After two months of civil war and anarchy, under the very eyes of the Prussian army, the Commune is vanquished and Paris is occupied after eight days of bitter fighting in the midst of murder and arson.'⁷⁵ Pierre could not learn from Cons much enthusiasm for the Middle Ages. The medieval institutions 'served their purpose but they could not cope with innovations.' This remark of Cons from his *Biographies d'hommes illustres des temps ancien et modernes*,⁷⁶ a textbook which, although written in compliance with the programme laid out by the Ministry of Public Instruction in August 1880, required no change of mind on Cons' part and can therefore be taken as representative of the thrust of his history courses attended by Pierre. The textbook, unabashedly positivist, was in its first half a survey of ancient Greek, Roman, medieval, and Renaissance history. Its second half was entirely devoted to the 17th, 18th, and 19th centuries. The history was told in the framework of the lives of statesmen, men of letters, inventors, philosophers, ex-

71. In the issue Nr. 2-3 (vol. XIX) of *Archeion* (1937), largely devoted to the memory of Duhem, p. 149.

72. *Annuaire 1874-75*, pp. 96-97.

73. See 'Cons, Louis,' in *Dictionnaire de biographie française* (Paris: Librairie Letouzay et Ané, 1933-), 9:486.

74. L. Cons, *Histoire de France depuis les origines jusqu'à nos jours . . . Cours moyen* (Paris: C. Delagrave, 1880), pp. 227-28.

75. *Ibid.*, p. 220. Cons had very harsh words for absolute monarchs.

76. Paris: Librairie Ch. Delagrave, p. 139. At the same time Cons wrote enthusiastically about Diderot and the *Encyclopédie* (pp. 141-42).

plorers, and scientists. Cuvier, Ampère, and Arago stood for contemporary history, and in a graphic way which could but stir interest and imagination. Cons even had an eye for the immunity which a great scientist could expect from a powerful ruler. Arago, and this was the last lesson of the book, kept his Republican faith, refused to swear allegiance to Napoleon III, and yet the latter made him an exception, the only of its kind, from the general rule demanding such an oath from all employés of the state. Arago was allowed to continue as director of the Observatory.⁷⁷

Cons was such an inspirational teacher that Pierre for a while considered becoming a historian. ‘Cons, so prematurely removed by death from the admiring gaze of his pupils!’ – exclaimed Duhem in his account of his years in the preparatory school of Stanislas. ‘With what a talent he knew how to retrace the phases of modern history in sober and lively portrayals, in precise, comprehensive and profound views! With what a sureness of method and with what a keen sense of criticism! How many vocations of historians had he sparked in his very short existence!’⁷⁸ Clearly, Pierre must have been strongly drawn toward that calling. But Cons and history were no match to four no less extraordinary science teachers and to Pierre’s love of science. Already a corresponding member of the Académie and renowned for his teaching, Duhem saw himself formed as a mathematical physicist and a professor through the courses of mathematics and physics given at Stanislas by those four: Maleyx, Vazeille, Moutier, and Biehler:

During four years, longer than was the case with most of my fellow students, I was their student. For four years I could deeply impregnate my mind with their teaching. Marching behind them, even in the very career which they had chosen, I had many an occasion to analyze the methods which they used and to compare them with the methods of their colleagues. Very often in that intellectual examination of conscience which the professor must do continually I could discover the very large part which each of them had in the formation of my ideas. I could repeat with the poet: It is through them that I am, if I am anything.⁷⁹

Duhem first recalled Maleyx, a ‘rude initiator,’ who gave the introductory calculus courses. A short and vigorous man with a beard and facial features which evoked the ‘portraits of the Galilean,’ Maleyx had a hat whose unique profile made his students invent the word ‘maleyxoid’ in obvious imitation of words such as paraboloid, ellipsoid, and the like. Duhem must have been thinking of himself as he wrote: ‘The energetic and strongly characteristic silhouette of Maleyx offered an irresistible temptation for caricaturists, more numerous than skilled at that merciless age. Between two equations our notebooks were graced by a profile drawn with a few strokes of the pen. Often the model seized the drawing from the hands of the artist and without any irritation put it with a smile into his pocket. At any rate, we had hardly had the time to finish the sketch. The course advanced at big steps.’ Many found the course too exacting after the relatively comfortable years of languages and philosophy. It was a very hard apprenticeship, this course so packed and

77. *Ibid.*, p. 185.

78. ‘Souvenirs de l’Ecole Préparatoire,’ 1905 (22), p. 106.

79. *Ibid.*

rich. It proved to us above all that the most fortunate skill, the most brilliant intelligence were not enough for the formation of the scientific mind. There is necessary, in addition, the continuous training, the tenacious will which nothing tires, which nothing repels.' Maleyx was also most intent on enforcing the rigorous, precise style demanded by mathematical reasoning. He mercilessly caught any fault of style, each 'an attempt at logic.' He was also a profound mathematician with original contributions to the theory of algebraic roots. On occasion he treated, without referring to himself, to some of his discoveries his students, who however were alert to his modesty. 'It was a great joy for us to greet with a warm applause the findings of our teacher.'⁸⁰

After Maleyx' course students 'who wanted to march at the head of Stanislas' were admitted to the advanced calculus course given by Vazeille. 'Since the time when, in the benches of Stanislas, I followed the discussion of the equation in S , I have heard many a lecture. Some of them I have analyzed with the meticulous curiosity of a specialist; others I have followed with the fervent attention of a disciple. None of them have evoked in me the feeling of perfection to the same degree as did Vazeille's teaching.' Duhem still could see the tall and noble figure of Vazeille and his perfectly aligned equations on the blackboard:

The word elegant was one of those which Vazeille pronounced readily. It certainly characterized best his teaching. His course was a true work of art. Each of the chapters which composed it was lovingly chiseled. The algebraic method and the geometrical method used in turn seemed to rival one another in power and skill. This emulation between the two procedures by which the human mind takes cognizance of the mathematical truths let the theories unfold in a perfectly balanced symmetry which barred all monotony. No affectation whatever in that elegance! The absolute clarity, the irreproachable ordering of the theories, which Vazeille set forth, had their *raison d'être* in the very nature of the problems treated, in the penetrating intuition by which the professor grasped that nature. No artificial simplification, none of those too easy procedures which success alone justifies, was allowed in the advanced calculus classes in Stanislas. With no letup Vazeille asserted that the general method is always the most direct, shortest and simplest, provided one knew how to make use of it. The ease with which he gave the solution of the most difficult problems more than amply proved the justness of the principle of which he made himself the champion.⁸¹

Duhem then spoke of the revolution in mathematics teaching achieved in the late 1870s by Vazeille and his friend Moutard, who taught at St. Barbe, another famed Catholic lycée. His claim that innovations of teaching had better chances in private schools than in the vast system of state education and that not a few overseers of the latter had reached that conclusion, need not detain us here. It is rather what Duhem wrote of Moutier, professor of physics and chemistry, that casts a noteworthy light on what Duhem was at Stanislas. All the 'taupins' of Paris knew, Duhem wrote, 'this big body, this powerful amplitude, this large face, this disheveled

80. *Ibid.*, pp. 109-10.

81. *Ibid.*, pp. 110-12. Vazeille's courses are most likely the ones recorded by Pierre in three algebra notebooks (now in the Archives of the Académie des Sciences) which he fondly kept. Their impeccable format attests the clarity of Vazeille's teaching no less than the student's mastery of the subject.

bear, these eyes resembling two goggles, all this mobile physiognomy which delighted in putting on the funniest and most unexpected expressions.' Moutier could not function when the boys on occasion and for sinister reasons kept absolute order in the amphitheater where the physics and chemistry courses were given. But once the amphitheater looked again like a Roman circus, Moutier, the thinker, was at his best:

Delivered before an audience at the boiling point, his course was marvelous by its neatness, precision, conciseness. Not a demonstration which had not been reduced to absolutely needed propositions. Not a law whose enunciation had not taken the form of absolute rigor. A few words of extreme soberness, sufficient to mark the hypothesis subject to caution, the experimental procedure of doubtful value. To form the critical sense of his students such was the aim which Moutier set to himself and it would have been difficult to attain it more exactly than he did.

In recalling Moutier's pioneering in France the new thermodynamics of Gibbs, Duhem referred not so much to his classroom experiences as to the frequent private tutoring he received from Moutier. But it was in classes of chemistry at Stanislas, so Duhem insisted, that 'French audiences first heard of Moutier's great discovery about the true meaning of the sign of the quantity of heat developed in chemical reactions. That discovery put an end to a more than a century long hesitation on the part of a Lavoisier, a Laplace, a Berthelot, a Favre, a Thomsen.'⁸²

Finally, it was the turn of Abbé Biehler, director of the preparatory school. Pierre must have been one of those few 'who in a corner of the big courtyard listened to the pleasant voice of the director, a calm and serene figure under an ever present velvet cap, the smiling face behind the immovable glasses.' The conversation quickly turned to some particular aspect of an algebraic theory or calculus which Biehler had explained the previous day in his course, where 'the always same voice, the always impeccable diction set forth the proofs with extreme rigor and perfect elegance. Now he extended his lecture into a formal conversation by showing us, behind the propositions already known to us, an unlimited domain of new truths which made shine before our eyes, beyond familiar lights, the infinite splendors of science.'⁸³ There were of course always those whom Duhem pointedly called 'utilitarians', who disdained this theorizing nowhere inscribed into the syllabus of any school and never claimed by any examiner. But these utilitarians were few at Stanislas at that time. 'We made it a matter of honor to pursue with passion the pure truth, for its own sake, for the love of its beauty. We spurred ourselves to disdain the dishonest calculations of those who with the program of competitive exams under their arms did business with science and wanted to impose on it a tariff. We would not accept success bought at reduced price and, as it were, at a discount!'⁸⁴

Pierre and others knew all too well that their director sacrificed a very promising

82. *Ibid.*, pp. 113-16.

83. *Ibid.*, p. 119. As they walk across the courtyard of Stanislas, students are still reminded of Biehler by his relief marble bust crowned by the words: PRO DEO ET SCIENTIA VIXIT.

84. *Ibid.*, p. 120.

career in mathematics — ‘his thesis on elliptical functions — true masterpiece of algebraic elegance, stirred the applause of the Sorbonne’— for the sake of youth to be turned into ‘Christians and Frenchmen.’ Students saw time and again a limping old man making his way, with the help of a huge cane, up to the small room of Biehler. The smile of some new boys, not knowing what was taking place, ‘turned quickly into respectful curiosity when an older boy whispered into their ears the name of that handicapped old man: Hermite!’ In addition to visiting with Biehler, his former student and friend, Hermite wanted news about his students as well. Pierre must have been one of those students who were called into Biehler’s room. The description of what followed is too vivid to be a second-hand account: ‘Overcome by the closeness of the one whom the entire scientific Europe viewed as the purest incarnation of the mathematical spirit, the student did his best to discuss the theories which were taught to him. Then, not without astonishment and confusion he heard the great mathematician make ecstatic exclamations about the beauty of proofs recited to him and even about the talent for algebra of the one who did the recitation. When the latter returned to the study hall after one such interrogation, he had the awareness of having seen at close range a genius.’⁸⁵

Duhem fondly recalled a young priest who turned up briefly at Stanislas and helped there as a répétiteur while pursuing his studies at the Sorbonne in mathematics. It was the Abbé Pautonnier who later became a trusted friend of his and the ‘savior’ of Stanislas.⁸⁶ Duhem’s last words were about a

tall priest, his body emaciated, his back bent, his looks tired and colored by a ravaging sickness, who sometimes went across the courtyard at slow pace. He was soon to die a cruel death. Everybody knew it and he knew it better than everybody. He walked along, surrounded by a profound respect, and controlling his pains he smiled at us benignly. He knew each of us thoroughly as a father knows his children. He spent on us with a surprising and supreme solicitude all that the ravaging sickness left to him in the way of strength and activity. And after the Abbé de Lagarde had spoken to us, we were left troubled to the depth of our souls because we felt that we have just talked with a saint.⁸⁷

Such reminiscences cast a priceless light on school and student. The solemn, yet sincere tone at which Duhem concluded his reminiscences of Stanislas, must not distract from the impish tone which started them. His classmate, Jean de la Laurencie, vividly remembered from a distance of over fifty years, that the one whose graphs of analytical geometry and calculus were unsurpassable for their precision, could with the same precision draw the caricature of Biehler, a perfect target in that respect: ‘a round face of incredible placidity, with spectacles, a little Greek hat, and a coat

85. *Ibid.*, p. 121. Students at Stanislas were hardly kept in the dark about Hermite’s return to the Catholic faith in 1856, partly under the impact of his conversations with Cauchy, a no less prominent French mathematician.

86. Being a member of the secular clergy, the Abbé Pautonnier was not affected by the laws of 1904 which forced the Marianists (as well as all members of religious orders) to disband and abandon their schools. On the role of the Abbé Pautonnier in the ‘saving’ of Stanislas, see Bordeaux, *Le Collège Stanislas*, pp. 134-44.

87. ‘Souvenirs de l’Ecole Préparatoire,’ 1905 (22), pp. 121-22.

from a bygone age.’⁸⁸ On visiting one day with Pierre in the Musée du Luxembourg, the same classmate saw Pierre’s face suddenly lit up with malice as they stood in front of Frémiet’s statue of a satyr handing out honey to two bears. Immediately after returning from the Musée, Pierre made a sketch: the satyr transformed into the Abbé Biehler and the two bears into two teachers, one of them Moutier.⁸⁹

Ready for the grandes écoles

The fun-loving Pierre was able to achieve what could not be done by Moutier, no master of discipline. His classes and demonstrations of physics in the amphitheater of Stanislas were taking place, as Jean de la Laurencie recalled, in a rambunctious atmosphere encouraged by Moutier himself. ‘But once Pierre was called up for recitation on the central podium, silence fell on the amphitheater: nobody wanted to lose anything of his presentation.’⁹⁰ Not only his classmates but much younger students too used to look on Pierre in awe, as ‘someone born for making discoveries.’ This phrase is a reminiscence by Edouard Jordan, professor of medieval history at the Sorbonne, who entered Stanislas four years after Pierre.⁹¹ Jordan, who years later became one of Pierre’s closest friends, also remembered how the whole student body was impressed after a student, seeking extra help from Moutier, reported him as having remarked: ‘Remember well the name of your camarade Duhem. He will be famous one day.’⁹²

Moutier, possibly the most undeservedly forgotten nineteenth-century French physicist, was always remembered by Duhem with deep gratitude.⁹³ Pierre owed to Moutier a grasp of mathematical physics which would have done credit to any second-year student of the *grandes écoles*. Moutier, a graduate of the Polytechnique, earned his living as an inspector of telegraphic facilities in addition to being a teacher at Stanislas and St. Barbe. In 1881 he became a répétiteur at the Ecole Polytechnique, but his strongest ties were with the Ecole Normale where he was given opportunities to experiment on the thermodynamics of chemical processes. Author of the best books on thermodynamics available in French at that time,⁹⁴ Moutier was in full command of the latest German and English publications on the topic. Last but

88. See *Archeion* 19 (1937): 149.

89. Actually, Frémier’s sculpture contains only one bear. Pierre obviously enlarged on the theme.

90. See *Archeion* 19 (1937): 149.

91. E. Jordan, ‘Duhem,’ p. 159. This most valuable obituary notice was part (pp. 158-73) of the section, ‘Notice sur les membres décédés’ (pp. 9-206), in *Association Amicale de Secours des Ancien Elèves de l’Ecole Normale Supérieure*, the yearbook published by the Association in Paris in 1917.

93. Duhem’s reminiscences on Moutier will be discussed later.

94. Although there is a substantial entry on Jules Moutier in Poggendorf (3d ed., 1898, pp. 941-2) with a brief updating in the 4th edition (1904, p. 1037), no French encyclopedias have an entry on him. No trace of Moutier was found in the vast files of the editorial offices of the *Dictionnaire de biographie française* when I tried to ascertain there, in late 1980, the date of Moutier’s death.

not least, he could not help speaking about thermodynamics to Pierre without, as Duhem himself hinted fifteen years later, revealing to him something of that bitter struggle which divided French chemists into two camps. The older group's first leader was Henri Sante-Claire Deville, professor at the Ecole Normale, to be succeeded by Jean-Baptiste Dumas, no less famous as a chemist. The leader of the younger group was Marcelin Berthelot, famed for his synthesis of benzene and phenol, but in Moutier's eyes a threat to the future of chemistry in France.

Pierre's decision to look in the direction of the Ecole Normale and not of the Polytechnique may find its explanation in his having sensed through Moutier's words that a crusade was to be joined in the interest of France. Whatever of Pierre's resonance to a patriotic cause and of Moutier's influence on him, his independence of mind must not be forgotten. Long before he made up his mind about choosing the Ecole Normale, he had made a stir at Stanislas by his erstwhile refusal to join its Académie d'émulation reserved for top students.⁹⁵ In not choosing the Polytechnique he also had to disregard the wish of his father, a friend of whom held out for Pierre the firm prospect of a well paying position in the textile industry.⁹⁶ Through his admittance, which nobody doubted, either to the Polytechnique or to the Ecole Normale, in both of which students were in part on state stipend, his father was of course relieved of some of the heavy financial burden entailed by higher education.

Owing to his sickness in the spring of 1881, Pierre's participation in the competitive entrance exams to the Ecole Normale had to be delayed by a full year. Having become bachelier-ès-lettres in July 1878 and bachelier-ès-sciences in July 1879, and having completed two years of preparatory courses for the *grandes écoles*, Pierre had, by July 1881, profited by all courses Stanislas could offer. On account of his temporary inability to enter the Ecole Normale, Pierre would have had to face an inactive year had it not been for the far-sightedness of the Abbé de Lagarde. He retained Pierre at Stanislas as an assistant teacher (*maître auxiliaire*) for the year 1881-82 and made the necessary steps to have the Ministry of Public Instruction officially recognize Pierre in that position. The letter of the Abbé de Lagarde, written on October 30, 1881, was addressed to the Minister of Public Instruction, Jules Ferry, also Prime Minister. Ferry, whose cabinet was to fall two weeks later, had of course much more important matters to attend than to act personally on the request of the Abbé de Lagarde, whose letter was followed up on November 14 by letters of Vazeille and Moutier. These two stated their respective confidence that 'élève Duhem' would compete in 1882 for admission to the Ecole Normale 'with the most serious chances of success' and 'with complete success.' Three days later, Liard, director of the bureau of higher education in the Ministry, called the attention of the new Minister, Paul Bert, to the fact that a favorable decision would exempt Duhem from a military service interrupting his studies. On November 29, Pierre became officially *maître auxiliaire* at Stanislas. At the same time the Ministry of Public

95. Jordan, 'Duhem,' p. 159, where the impression is given that Pierre never joined the Académie d'émulation.

96. *Un savant français*, p. 40.

Instruction opened on him an official dossier which was to grow into a thick volume, an invaluable source of information on his entire career.⁹⁷

Pierre's appointment as maître auxiliaire entailed his commitment to at least ten years of service as a teacher in State schools. Such was hardly a burden in his eyes. In the curriculum vitae, which he had to submit on February 22, 1882, to the Ministry of Public Instruction as part of his candidacy to the Ecole Normale, he pointedly noted that precisely because of his deep interest in teaching he did not consider the Ecole Polytechnique for which, as he noted with characteristic straightforwardness, 'je n'éprouvais aucun goût.' Much of the curriculum vitae was a long list of the prizes and accessits which between 1876 and 1881 he obtained at Stanislas and in the concours généraux. In the latter category he gathered 4 prizes and 5 accessits. Among the prizes was the one adjudged for chemistry in 1881 by the Association Scientifique de France. As to his achievements at Stanislas, the salient items were his having been inscribed in the Livre d'Or of the Collège and the medal which he obtained in 1878 as the one who presented the largest number of essays on various topics to the Académie d'émulation. The curriculum vitae contained also the information that in the spring of 1881 he had, at the order of several physicians, to go to the baths of Plombières in the Vosges and that his father at that time was a 'représentant intéressé de la Maison Benoist Frères et Cie de Reims,' a company operating spinning mills and weaving factories. The curriculum vitae ended with the statement: 'My desire is to devote myself in the Ecole Normale especially to the physical and chemical sciences.'⁹⁸ The preliminary official evaluation of Pierre's candidacy noted that he was a 'candidate only for the Ecole Normale, with a sense of vocation long-established and unwavering, who holds the first rank in the natural sciences, is of good character, excellent mind, and sound judgment.'

Pierre's success in gaining admittance to the Ecole Normale could not have turned out to be more impressive. The forty places (twenty in the sciences, and twenty in the humanities) available at that time for the new class each year at the Ecole attracted in early 1882 almost a thousand applicants from among the best students graduating the following June from collèges and lycées across France, though with the majority of them from Paris. On June 12 the Ministry of Public Instruction allowed 471 applicants to take the written exams of admission which were administered in their respective schools. For those competing for the places in the science section, these exams were held from Monday through Thursday, June 26-29. Six hours were

97. The 'Dossier P. Duhem' is filed in the Archives Nationales (Paris) in the packet F¹⁷ 23295. One of its first items is a letter of L. Liard, then Vice-Recteur de l'Université de France, a ministerial post, recommending to the Minister of Public Instruction the request made by the Abbé de Lagarde whose letter is followed by the letters of Vazeille and Moutier. My study of the Dossier is based on its microfilm copy sent by the Archives Nationales to Dr. Donald G. Miller who numbered the regular photocopies made from each frame. In subsequent references to that Dossier consistent use will be made of that pagination, which runs opposite to the time-sequence as document was placed upon document as the years went by.

98. Details and documents about the concours of 1882 are in packet F¹⁷ 4212 in the Archives Nationales.

for answering the questions in mathematics, philosophy and physics on Monday, Tuesday, and Wednesday, respectively, and four hours on the last day, Thursday, for Latin translation. Of the 471, less than a fourth qualified and on July 19 about half of these, or 58 to be exact, were authorized to present themselves at the Ecole Normale for a final oral and written exam in the sciences on Sunday and Monday, July 23-24. The jury of which Fustel de Coulanges, director of the Ecole, was the president, and Bertin, the physicist, its vice-president, also had Appel for mathematics and Gernez for chemistry. The results formalized by the jury on August 1 were sent to the Ministry of Public Instruction on August 2 in the form of a list which ranked the 58 candidates according to achievement. Duhem ranked first.⁹⁹ Indeed, he was expected to finish first by none other than Jean-Baptiste Dumas, the famed chemist and since 1868 *secrétaire perpétuel* of the Académie des Sciences, who had played also an important role with Haussmann in the modernization of Paris. The day before Pierre took his exams with Gernez, the latter received the following letter from Dumas:

I would be very grateful if you would kindly inform me about the result of the exams of young Pierre Duhem who will be examined by you in physics and chemistry tomorrow. He is a distinguished subject, but since he is in need of a stipend – his family not being wealthy – I would be happy to be authorized by your opinion to support him at the Minister [of Public Instruction]. It seems that, in view of the results at the concours général, he is a young man with a future.¹⁰⁰

On Tuesday, August 2, Gernez wrote to Dumas the following letter: 'I am glad to tell you that following the competitive exam of admission to the Ecole Normale Supérieure Mr. Duhem finished first in the list with a marked superiority over his competitors. This young man seems to me worthy of all expression of interest you may show him and it is my considered judgment that he will do credit to the Ecole Normale.' Dumas in turn forwarded the letter to Pierre's parents with the following words jotted on his visiting card: 'The letter of Mr. Gernez will please the family of Mr. Duhem.'¹⁰¹ The letter reached the Duhem home Wednesday morning, August 4, perhaps together with the official notification from the Ministry. Young Pierre was certainly pleased, though not to the extent of losing anything of his aplomb and sense of humor. The same morning he wrote to his friend Jean de la Laurencie

99. Mainly through his performance in the orals. Candidates ranked 21-58 were on a 'liste supplémentaire'. Pierre Duhem was one of the ten graduates of Stanislas, who in that year tried for the Ecole Normale. Of the three competing in the science section, only Pierre qualified for the finals. Of the seven competing in the section of letters, six failed to reach the finals, the seventh, Camille Simon de Quirielle, finished fifth. Pierre's achievement must have therefore been all the more appreciated at Stanislas.

100. This letter is bound into a volume of reprints of Duhem's articles, now in the possession of Dr. Donald G. Miller, who put at my disposal this and many other documents relating to Duhem's life and work. His generous co-operation is acknowledged here with my sincere appreciation.

101. The text of these two notes, reproduced in full in *Un savant français* (p. 40), is now in the Duhem correspondence at the Académie des Sciences.

a letter¹⁰² in which a reference to common sense evidence was the chief though not the only phrase with a future significance:

Wednesday morning

Dear Friend,

It is hardly believable but at long last there is no doubt about it. Since yesterday evening I am a 'cacique,' that is, I am ranked first in this tribe of redskins, savages, and man-eaters which will rush around in the three-times-holy sanctuary of the Ecole Normale after next September.

When I look for the part which is mine in this success, I am struck by its smallness. I see well what the recommendations of Mr. X and Mr. Y have done, and I see especially what has been done by the recommendations of Mr. Moutier who, as always, went out of his way on my behalf. But the exams! God save you from ever passing so dull and mediocre ones. There was one pleasant afternoon, the physics exam, where during one hour and twenty minutes Mr. Bertin tried to prove to your servant that he had never seen any mass and that he did not know what it was, and where your servant remained very much convinced that his senses never fooled him; and indeed a huge mass it was in front of him, leaning on the green desk cover.

The exam in chemistry consisted in an amiable conversation of ten minutes 'de omnibus et de quibusdam aliis' with Mr. Gernez, a man known for his small blisters.

I am very honored that you intend to communicate to me your geological discoveries; unfortunately, I am on that score a frightening nullity, but I hope that your example will force me to escape my ignorance.

The college is deserted. Only two or three 'taupins' [candidates for the Ecole Polytechnique] remained there during these last days. Among the catastrophes we have to deplore is the failing of Léon Vivet, who had passed his exams fairly well but who got very low marks. [Prof.] Marie (*monstrum horrendum, informe, ingens*) slept during Vivet's exam and is convinced that Vivet did not do well. May the devil strangle that damned Marie!

Mention me to your parents and convey them my respects. My friendship to Lionel, for you an affectionate handshake.

P. Duhem

P.S. In his last letter Edmond asks me to convey to you his friendship and his respect to your family.
Paris

Pierre's reference to the place where his letter was written was perfunctory but cryptically prophetic as well. His brilliant performance at the Ecole Normale was to keep him, for the rest of his life, away from Paris, the only place where he truly felt at home.

102. This letter was read in full by Jean de la Laurencie at the session, devoted to Duhem's memory, of the Académie Internationale d'Histoire des Sciences (Paris, January 27, 1937) and printed in *Archeion* 19 (1937): 150-51.

2. THE NORMALIEN

A far cry from 'normal' school

On entering the Ecole Normale, Pierre became a 'cacique' (captain) among 'conscrits' or first-year students in the jargon of a school which by then was proudly conscious of its special student vocabulary.¹ In 1882 there was much more to that pride and self-consciousness than the school's centenary, only a dozen years away.² Had the Ecole Normale not been something very special, a prominent historian of modern France would hardly have noted that 'one of the most gratifying signs of progress in the new [post-World-War II] France has been the 'eclipse' of the 'Normale' by the Ecole Polytechnique not only in the natural but also in the social sciences.' The remark carried a built-in credibility if it was true, to quote the same historian again, that 'naive and sentimental thinking on social questions' was 'the chief contribution of that dangerously complacent institution, the Ecole Normale.'³

Naiveté and complacency readily go hand in hand. As to complacency, it had a natural breeding place in so auspicious a beginning as the Ecole Normale could boast of. When established by a decree of the Convention on the ninth day of the month Brumaire of Year III (30 Oct. 1794) of the Revolution, the Ecole Normale was meant to be, in sober practical terms, a place of formation of directors of provincial institutions where elementary school teachers were to be trained. Dominique-Joseph Garat, chief architect of the decree, had a far more ambitious vision. According to his report to the Convention,

1. See 'Lexique de la vie normalienne', in A. Peyrefitte, *Rue d'Ulm: Chronique de la vie normalienne*, with an introduction by Georges Pompidou (new revised and enlarged edition; Paris: Flammarion, 1963), pp. 389-405.

2. It occasioned the publication of *Le Centenaire de l'Ecole Normale 1795-1895* (Paris: Hachette, 1895), a quarto volume of 696 pages, rich in documentary and illustrative material, which is complemented by *Ecole Normale Supérieure*, a commemorative work published shortly before the school's 150th anniversary (préface de A. François-Poncet, introduction de J. Hyppolite, texte et iconographie de P. Jeannin; Paris: Office Français de Diffusion Artistique et Littéraire, 1963).

3. A remark of D.W. Brogan in his *The Development of Modern France [1870-1939]* (new revised ed.; London: Hamish Hamilton, 1967), p. xv.

For the first time in the history of the globe truth, reason and philosophy will also have a seminary . . . For the first time, the most eminent men in all branches of science . . . will be the chief schoolteachers of an entire nation . . . The Normaliens will be the executors of a plan which has for its aim the regeneration of human understanding in a Republic of twenty-five million whom democracy makes all equal . . . The decision you are going to take will be [the start of] a new epoch in the history of the world.⁴

Joseph Lakanal, the first director of the school, voiced no less complacent –and naive– views:

As soon as these courses in the art of teaching . . . will be completed in Paris, the youth, turned into scientists and philosophers through these courses . . . will open everywhere *écoles normales*. This course of light, so pure and abundant, as it originates in the foremost men of the Republic in every field and spreads from reservoir to reservoir, will expand through all France without losing anything in its course. As far as the Pyrenées and the Alps, the art of teaching will be the same as in Paris, and this art will be that of Nature and of Genius.⁵

Fifteen hundred young men, none older than twenty-one and selected from all departments of France, duly assembled for 20 December 1794, the day fixed for the school's opening. They found no school, no courses, and their frustration was only enhanced by an unusually hard winter. Instruction began on January 20 in a provisional location, the amphitheater of the Muséum of Natural History. To be sure, the teachers were first rate, though not necessarily as teachers. Laplace, Lagrange, Hauy, Berthollet, and Monge were certainly leaders in their respective fields but not necessarily experts in the *art* of teaching. They could at most try their best to come down from their esoterically Olympian heights to that low level usually represented by any vast audience, however select. As one could expect, their popularisation appeared trivial to some and far above the reach of most. The light which was to illuminate the whole world was visibly blinding its prospective torchbearers. By March the enterprise was turning into ridicule and, after less than three months, the school was closed amidst such remarks that 'the shortest-lived folly is the best folly.'⁶ By the 1880s the Ecole was powerful enough to recall with a chuckle its boastful and shaky beginnings. In fact Normaliens were amply reminded of the whole history of their Alma Mater in the second year which Pierre spent there, a reason for recalling that past in some detail.⁷

Had Pierre entered the Ecole Normale fifty years earlier, he would have been reminded only of the flattering aspects of the school's origins. In the 1830s the famed

4. *Rue d'Ulm*, p. 24.

5. *Ibid.*, p. 23.

6. *Ibid.*, p. 29.

7. The reminder was an over four-hundred-page volume, *L'Ecole Normale (1810-1883)* (Paris: L. Cerf, 1884) by P. Dupuy and three other recent graduates of the Ecole. The volume, of which more than a half was a list of publications by former Normaliens, had a section (pp. 3-79) on the history of the Ecole by Dupuy. Pierre and his colleagues had to take note of the book and all the more as it was immediately reviewed in a prominent context by Fustel de Coulanges, director of the Ecole (see note 23 below).

Michelet taught history at the Ecole Normale, re-established in 1811 by Napoleon in the buildings of the Collège du Plessis. Glory was the principal hue on the palette of Michelet the historian who would hardly have found symbolic that in 1834 a little old man, marching in the rear of a row of funeral carriages, spotted a group of Normaliens, all too recognizable by their uniforms, and ran up to them with the question: 'Don't you recognize me, young gentlemen?' 'No, monsieur,' was their answer. 'I am Lakanal. I am poor . . . I follow funeral cortèges as often as I can [to make a living] . . . Yes, gentlemen, I am Lakanal, yes, Lakanal.'⁸

Lakanal was less of an unknown entity by 1882 for Normaliens who could not miss his name writ large in the foyer of the building which had been completed for the Ecole thirty years earlier on Rue d'Ulm, a street that became synonymous with the Ecole. Also, sometime before the 1880s the Ecole was turning into a beacon for the world of intellect, a process envisioned by Lakanal. A main source of the school's international repute was Pasteur, himself a Normalien in the mid-1840s. Pasteur became a professor in the Ecole in 1857 and served as the school's director for ten years (1857-1867). Long before Frenchmen and foreigners began to visit the school either to see the ramshackle laboratory, in which Pasteur produced his famous cure for rabies, or to seek the cure itself, Pasteur's work on diseases affecting vine, silkworm, and poultry, turned the Ecole and Rue d'Ulm into an international byword. Pasteur certainly was an attraction for Pierre, who never let his interest flag in natural history and biology. Jules Tannery, much younger than Pasteur and a mathematician of first rank, in addition to being a sensitive humanist, was more of an idol for Pierre. The old Pasteur, who loved to play 'aux boules' in the center courtyard in early afternoons, was also the embodiment of a past never to return to the Ecole. Pasteur ran the place with strict adherence to tradition, which included rising at five, the shutting of the school's gate at five in the afternoon, and a ban on smoking, novels, newspapers (with the exception of the official *Moniteur*), and all illustrated magazines, so many means of distraction from studies. Pasteur even resented attendance of lectures at the Sorbonne and the Collège de France by Normaliens of the third year, arguing that it was a 'waste of forty minutes,' the time needed to go there and return, including the change of clothes twice.⁹ Other old rules, still strictly enforced under Pasteur's 'dictatorship,' included the compulsory wearing of quasi-military uniforms off the premises, attendance at mass, and no meat on Fridays. Enforced Catholicism was hardly a pleasure to nominal Catholics and freethinkers of which France had an ample share for some time on all social levels. Pasteur insisted on at least a perfunctory adherence to Catholicism to the point of refusing to acknowledge that a student had chosen to become a Protestant.¹⁰

These and similar details were still fresh stories, steadily embellished, in the 1880s. In 1872, when Jules Lemaître entered the Ecole, he gathered impressions which made him describe the Ecole as a 'gay convent.' Lemaître, who as a leading French

8. *Rue d'Ulm*, p. 23. Lakanal, then 72, died eleven years later.

9. *Rue d'Ulm*, p. 45.

10. *Ecole Normale Supérieure*, p. 74.

literary figure was asked around 1895 to write on the Normalien spirit for the centenary of the Ecole, spoke of the leaves, given twice a month, to go to the theater, and the twice-a-week sorties into the City. He noted the enormous variety of social and cultural backgrounds of the students and the no less large variety of intellectual positions taken by them. To speak of a 'Normalien spirit' revealed, according to Lemaître, as much naiveté and ignorance as to speak of 'the ethic of Jesuits' or of 'the intelligence of universal suffrage.'¹¹ These barbs were mainly directed at Zola, who in 1881 made in the *Figaro* a much remembered attack on the Ecole as a breeding place of narrow-minded mediocrity and closed his portrayal of several prominent Normaliens with the refrain: 'Opportunists, all opportunists, nothing but opportunists!'¹² Yet Normaliens were hardly opportunists with respect to Zola. Long before Zola as a celebrity, Lemaître remarked, such early and racy works of his as the *Fortune des Rougons* and *La curée* were avidly read in the Ecole.¹³

Opportunism, the kind not to be noticed by Zola, was at work in the abolition by 1882 of the post, vacant for some time, of the school's chaplain.¹⁴ Fustel de Coulanges, the famed historian and director of the school when Pierre entered, faced no opposition from the Republican government as he turned the school's chapel into two long utility units for the purposes of teaching and storage.¹⁵ This did not prevent Pierre from becoming an admirer of the director whose fame as a scholar largely rested on painstaking studies which showed that ancient Gaul owed its customs and laws to the Romans and not to the influence and invasions of Germanic tribes. More than thirty years later, Pierre Duhem spoke with unmistakable familiarity of Fustel de Coulanges, the historian, as he outlined the genuine French spirit in the study of history, a spirit he opposed to the German approach and method in matters historical.¹⁶ Pierre could not help learning while in the Ecole that in order to cope with strenuous objections on the part of German historians to his interpretation of early Gaul, Fustel de Coulanges had engaged in lengthy critical reviews of all the pertaining source material. When twenty years later Pierre Duhem came to realize that centuries of records of the history of physics lay still largely uninvestigated, he turned to the exploration of that record with an attitude which owed much to Fustel de Coulanges' conviction that history itself was largely equivalent to its written documents.¹⁷

11. The article, 'L'esprit normalien,' by Jules Lemaître, who graduated from the Ecole in 1872, was published in *Le Centenaire de l'Ecole Normale* (pp. 565-71); see especially p. 571.

12. Zola's 'Notre Ecole Normale' (*Le Figaro*, 4 avril 1881) is reprinted in *Emile Zola Oeuvres complètes* (Paris: Cercle du Livre Précieux, 1966-), 14:574-79.

13. As pointedly noted by Lemaître.

14. Compulsory participation in religious services was abolished in 1866. See *Ecole Normale Supérieure*, p. 74.

15. *Ibid.*, p. 90.

16. In chapter 3, 'Les sciences historiques,' of his *La science allemande*, 1915 (2), Duhem made much of an article which Fustel de Coulanges published in the *Revue des deux mondes* in 1872 under the title, 'De la manière d'écrire l'histoire en France et en Allemagne depuis cinquante ans,' 101 (Sept. 1, 1872): 241-51.

17. Duhem most likely spoke from first-hand experience, as he recalled that 'each time a statement concerning history was made in Fustel de Coulanges' presence, the master asked in reply: 'Do you have a document?' (*La science allemande*, 1915 (2), p. 90).

In the Ecole Normale Pierre saw, of course, week after week Moutier, his former teacher at Stanislas who kept going there as guest of the chemistry laboratories, which between 1882 and 1885 were under the direction of Henri Debray and Désiré Gernez. These two were also Pierre's tutors in chemistry and may have urged him to attend at the Sorbonne the courses of their teacher, A. Würtz, a supporter of atomism.¹⁸ Pierre also followed the courses of Hermite, the grand old man of French mathematics, and of its rising sun, Poincaré. In the Ecole, Duhem had a brilliant group of tutors of mathematics: Jules Tannery, Paul Appell, and Emile Picard. The latter, Pierre's senior by only two years, could hardly suspect that only forty years later he was to deliver, as Perpetual Secretary of the Académie des Sciences, a memorable eulogy on his former student. In physics, Pierre could not have had a less congenial tutor in Emile Bertin, a master engineer of warships and similar tours de force in technology. In portraying a quarter of a century later, the atmosphere of physics teaching in the *grandes écoles* when he was a Normalien, Duhem noted with tongue in cheek that not all physics teachers were at that time as averse to theoretical physics as was Bertin.¹⁹ The real target of that remark may have been Gabriel Lippmann, professor of physics at the Sorbonne, who did not carry on in the spirit of his teacher, Kirchoff, a great champion of theoretical physics. Acquaintance with courses at the Sorbonne, while not compulsory, was certainly useful for the final exam which took place before a jury that always included one or several professors from that august place.

Great as a Normalien's devotion could be to his chosen field, the compactness, which at that time was still a characteristic of the Ecole, offered marvelous opportunities for exposure to excellent teachers of a wide variety of expertise, ranging from letters through philosophy and sociology to the exact and biological sciences. The views of such a professor of philosophy as Emile Boutroux, who startled his time by stressing the uncertainty of the laws of nature,²⁰ could not help causing debates across the lines of specializations. The teaching of another professor of philosophy, Léon Ollé-Laprune, was no less a challenge to potential advocates of scientism.²¹

18. The official courses in chemistry or in any other subject were offered at the Sorbonne, just beyond the upper end of Rue d'Ulm. Although a Normalien was not strictly obligated to attend those courses, familiarity with them was certainly useful for him as his final exams were to be taken before a jury which included professors at the Sorbonne. The courses given at the Ecole were tutorial and abolished in 1906, three years after the Ecole became fully attached to the Sorbonne on November 10, 1903.

19. 'Physique de croyant' (1905); see English translation, 1954 (3), p. 276. Bertin's place was taken by Violle and Bouty in the Fall of 1884, but by then Pierre had a mastery of mathematics and physics well above the otherwise high standards set in the Ecole. Pierre's grasp of electromagnetic theory was also, as will be seen, surpassing by that time what was taught by Mascart in the Collège de France.

20. Pierre remained immune to Boutroux's notion of contingency which formed the subject of the latter's famed doctoral dissertation (1874). Boutroux taught at the Ecole for ten years (1877-86) before taking a chair in the Sorbonne.

21. Ollé-Laprune taught at the Ecole for twenty years (1875-95). His epistemology, very much akin to the one set forth in Newman's *Grammar of Assent*, must have struck all the more a chord with Pierre, as one of his best friends at the Ecole, Delbos, edited years later a course which Ollé-Laprune gave on reason and rationalism. Shortly after his death, in 1889, Ollé-Laprune was described as 'the greatest Catholic layman who has appeared in France since Ozanam' (see *New Ireland Review*, June 1899, p. 195).

The views of a history professor like Fustel de Coulanges had a universal appeal in a French intellectual milieu desperately trying to assert itself against the rising tide of German cultural leadership. Pierre was certainly not that rare a kind of Normalien whom Fustel de Coulanges described in 1884 in his review of a history of the Ecole published in the same year,²² as one ‘who spent in the Ecole three years without acquiring a good idea of it and who learned to know only the little group to which he belonged.’²³ The Ecole was indeed an institution wholly apart from the typical continental university. One could think of a college in Oxford as Fustel de Coulanges compared the Ecole to a ‘machine of such a complex structure of which no one who had not lived there could form a proper idea.’²⁴ The Ecole was not one school but the interpenetration of six or seven schools where no one could completely withdraw into one’s own specialization. Everyone there had to make a contribution to the claim that ‘this school, so lively through the various regimes, so free in spirit, so obstinate in work, deserves at least the recognition that it labored much.’²⁵

In the intellectual development of a Normalien no less decisive than his constant touch with excellent tutors, was his continual encounter with camarades, equally eager to learn and more often than not all too convinced of the truth of their sundry views. A ‘most disputatious place’ at all times,²⁶ the Ecole Normale was certainly in an intellectual ferment in the 1880s. The ferment was expressive also of the pride of young men who felt they were soon to be called to be among the chief implementers of the progressivism and secularism of the Third Republic which had just triumphed over the monarchist challenge calling for stability and tradition. Tradition was not, however, an unqualified loser while ideals of the future were proclaimed at the Ecole. Its student body heatedly protested when, in 1881, Ollé-Laprune, a deeply spiritual Catholic, was suspended from his post for having openly criticized the government’s restrictive rulings on religious orders engaged in teaching. Sometime before Ollé-Laprune regained his chair, Jean Jaurès, the highest ranking third-year student, or ‘cacique général’ in the school’s jargon, gave the atmosphere of the Ecole a striking expression in his New Year’s greeting for 1881 which he offered to the Faculty on the part of the student body: ‘One cannot introduce here a single course not supported by curiosity. Here the mind is awakened and sparked in every sense, not only by teachers but also perhaps and particularly by the camarades.’²⁷ Among these were between 1875 and 1885—in addition to Jaurès, who was to distinguish himself as a spirited leader of a French socialism which he wanted to keep distinct from German Marxism—Henri Bergson, certainly a source of intellectual ferment at

22. See note 7 above.

23. ‘L’Ecole Normale,’ in *Séances et travaux de l’Académie des sciences morales et politiques. Compte-rendu* 21 (1884):833-48; for quotation, see p. 833.

24. *Ibid.*

25. *Ibid.*, p. 848.

26. Already in its very first year, 1795, the Ecole Normale was described as a ‘Tower of Babel’ in a pamphlet written by a student; see *Rue d’Ulm*, p. 29.

27. *Ecole Normale Supérieure*, p. 88.

the deepest level, and such other luminaries of the intellectual life of France at the turn of the century as Brillouin, Durkheim, Lachelier, Jullian, Imbart de la Tour, Baudrillard, Lévy-Bruhl, Berr, Koenigs, Fabre, Blondel, Delpuech, Delbos, Painlevé, Hadamard, Le Dantec, Bouasse, Strowski and others. Some of these names representing not only the full spectrum of intellect but also of religious and political ideology, will be met again as the story of Duhem's life unfolds.

Cacique général

While Jaurès was quickly engulfed in politics and may never have heard of Duhem, the latter heard much of Jaurès until the very day he was shot to death on July 31, 1914, in the vicinity of the house where Duhem grew up in Paris. In a very different style, Duhem was just as imposing as a *cacique* and a *cacique général* as was Jaurès. The reminiscences about Pierre, one by a classmate, another by a younger Normalien, and a third by one of his teachers, are priceless in this respect. The classmate, Louis Houlevigüe, became in 1893 professor of physics at the University of Montpellier. From a distance of fifty years Houlevigüe's admiration for his former classmate was as vibrant as ever:

Duhem was my camarade at the Ecole Normale. He was the *cacique* . . . and what a *cacique*! When we entered the Ecole as students still almost green-horns, rough sketches of the men we were to become, Duhem was already a fully developed man. His character and intellect had already taken their definite form. He knew what new truths he would bring to the world. In fact, he was already a master and we, who lived alongside with him, had not for a moment the idea or the wish to contest his intellectual superiority.²⁸

The younger Normalien in question, Jacques Hadamard, who was to excel as a mathematician and was Duhem's colleague for a few years at the University of Bordeaux, kept this memory of him:

He was a physicist and a physicist he wanted to remain. It is well known that this vocation of his did not have to wait for the Ecole Normale to assert itself. For us, his camarades in the Ecole, this precocity of his was not the only subject of astonishment. The taste for physics was rare at that time when, it must be spelled out, we felt around us something of a stagnation with respect to that science. How marvelous, in contrast, was our enthusiasm for mathematics when facing a Hermite, a Poincaré, a Darboux –to speak only of those already dead– and when we were in the serene and inspiring company of [Jules] Tannery! No one felt this enthusiasm more completely and profoundly than Duhem whose knowledge had been truly universal and who, as is well known, could just as well have become a biologist as he could be a mathematician and a physicist. With respect to natural history he had an extensive erudition and he could have, with a little more effort, easily put together his data of original research on cryptogams [plants without seed]. In the long and precious conversations, through which, since my entry in the Ecole Normale, our friendship developed, I sensed him resonate to the genius of Hermite and Poincaré whose works he followed more closely than most of us, I mean those specialising above all in mathematics, could have done. But in a general way all the great ideas of mathema-

28. 'Un savant français: Pierre Duhem,' in *Feuilleton du TEMPS* (Aug. 11, 1936), a notice, about two thousand words, prompted by the publication of Duhem's biography by his daughter.

tics, all those that were fruitful at that time, were familiar to him. From then on I owed him new insights – insights how broad and disdainful of details in favor of what was truly essential! – which saved me, without effort and almost unnoticed, long months of studies.²⁹

Pierre was remembered by his teacher of mathematics, E. Picard, with no less admiration:

The years which Duhem spent in the Rue d'Ulm were the happiest in his life. He appreciated that varied milieu in which scientists and men of letters were in constant touch. He formed there lasting friendships, especially with the ones who were close to his religious beliefs. Such was, to mention only those who are no longer alive, our confrère in the Académie des Sciences Morales, Victor Delbos, to whom we owe remarkable studies on Kant and Spinoza, and whose death, preceding but a little his own, must have saddened the last months of his life. No one was less a man of a single interest than Duhem, and already then his amount of reading was immense. This manner of studying is not always the most favorable for succeeding in the exams; these have their hazards, and Duhem was ranked seventh in his exams for the licenciate in physics and chemistry, but he was left at the head of his class, so evident was his superiority.³⁰

What neither of the first two witnesses of Pierre's excellence as a Normalien mentioned was the fact that already as a student of the Ecole, Pierre provided an impressive public evidence of his genius. Jaurès himself would have soon noticed this had he not been one of those humanists, however brilliant, who never read a scientific periodical, be it published by their own Alma Mater. The chief glory of the Ecole was the *Annales scientifiques de l'Ecole Normale Supérieure*, launched in 1864 by Pasteur who wrote as its justification: 'I thought that it would be useful and praiseworthy for this school to create a periodical in which there would be together the best productions of former students and professors'³¹ (Italics added). Soon afterwards the *Annales* achieved international repute precisely because of its roster of contributors, invariably with a standing in the academic life. Away from the Ecole and Paris, Jaurès hardly can be pictured as paging through the *Annales* while teaching philosophy at the University of Toulouse between 1883 and 1885. Upon returning to Paris in the Fall of 1885 as a 26-year-old deputy from the Tarn, Jaurès no doubt showed up in the Ecole as its latest celebrity. As a former 'cacique général' Jaurès may have inquired about his successors in that 'exalted' rank and then would have heard of Pierre Duhem, 'cacique général' for 1884-85. Had he glanced at the

29. See the opening paragraphs in Hadamard's discussion of Duhem's work under its mathematical aspect in *L'oeuvre scientifique de Pierre Duhem* (Paris: Blanchard, 1928), pp. 467-68. A little over thirty years later, Hadamard, already ninety-three, recalled his first impression of Duhem in just as warm words: 'To devote a little effort to evoke the memory of a friend of my youth and of the savant whom I have admired is a real pleasure for me and at the same time a duty in which I do not want to fail, as there emerges in my mind the memory of that spontaneous good will with which, from the very first moment of my arrival at the Ecole Normale, he received fraternally the newcomer' (from a letter of Hadamard to Donald G. Miller, received on July 18, 1958).

30. 'La vie et l'oeuvre de Pierre Duhem,' p. 4 (see note 53 to Ch. 7).

31. *Ecole Normale Supérieure*, p. 66.

table of contents of the latest issue of the *Annales*, a tome of 435 quarto pages, he might have seen his erstwhile words about student curiosity in the Ecole come through on a grand scale in the pages of the *Annales*. Jaurès would have been astonished to see among the contributors Pierre Duhem, identified as 'élève de l'Ecole Normale Supérieure.'³² Such an identification was startling in a publication reserved for distinguished alumni and professors. Pierre's contribution must therefore have been of outstanding merit. It was indeed conspicuous already by its extent, 48 pages, longer than any of the twenty other contributions, all by academics well established in various parts of Europe.

Pierre's memoir, 'an application of thermodynamics to capillary phenomena,' was neither his first publication, nor his only one in that year. The same volume contained also a twenty-page-long essay of his 'on the application of thermodynamics to thermoelectricity and pyroelectric phenomena.'³³ Moreover, these long publications were the first installment of a vast program which the young Normalien announced before no less a conspicuous forum than the Académie des Sciences. Pierre was not yet half way through his third year when he submitted to the Académie a brief note on 'thermodynamic potential and the theory of voltaic pile.'³⁴ The note, presented on December 22, 1884, by Hermite, throws much light both on Pierre's intellectual development at the Ecole Normale and on the theoretical physicist he was to become. The note reveals, as do his astonishingly extensive and incisive publications during his third year as a student at the Ecole and during the additional two years which he spent as an agrégé there, that from the very start he showed a complete familiarity with and a mastery of the latest publications of the foremost physicists of the day. For most professors of physics, in Europe and America, Gibbs was still a largely unknown entity when the second-year student of the Ecole Normale informed the Académie des Sciences that neither Gibbs nor Helmholtz offered sufficiently general formulations of thermodynamics. A startling declaration it must have appeared because Helmholtz had been world-famous for some time. While Helmholtz's explanation of the workings of the voltaic pile, warned the young Normalien, agreed with the experimental evidence, it was by no means a rigorous theory.³⁵

Seeing the insufficiency of a theory does not necessarily mean the sighting of a better form of it. Had Pierre not been successful in that latter respect, he would have hardly dared to ask any of his teachers to sponsor him before the Académie des Sciences. That august gathering heard him set forth in a nutshell a theory which in a sense became his most basic and far-reaching discovery. He gave it right there and then the name 'thermodynamic potential.' About its sweeping applicability he had no doubts: 'By this method, which dispenses in the study of thermodynamics with long and cumbersome considerations of cycles, one can comprise in one simple formula all the results obtained until now in the application of the theory of heat to changes of physical or chemical state and to a considerable number of new results

32. 1885 (3), p. 207.

33. 1885 (4).

34. 1884 (1).

35. 1884 (1), p. 1114.

. . . . But these results are too numerous to be summarized, even succinctly in this note.'³⁶

The note would not have been a full reflection of the thinking of its young author had it not come to a close with a paragraph as cryptic though as ominous as are all dramas at their inception. Not a few of those present at that meeting of the Académie and of the readers of the note, printed immediately in the *Comptes rendus*, must have been struck by the young Normalien's claim that 'the fundamental theory enunciated at the beginning of this note becomes the *third principle of thermochemistry*'³⁷ (Italics added). There was a further element of surprise, if not of irony, in the circumstance that, after Hermite presented Pierre's note, a note was read by another young researcher who was sponsored by none other than Marcelin Berthelot. The latter could hardly have failed to sense what was at stake. For almost ten years the expression 'third principle of thermochemistry' had been associated, in France at least, with Berthelot's name. An undisputed arbiter of French chemists, a member since 1863 of the Académie des Sciences, Berthelot was greatly interested in the political control of academic life. In 1886 he eagerly accepted the post of Minister of Public Instruction in the cabinet of Goblet.³⁸ Berthelot now could impose acceptance of his 'third principle' which he had enunciated in 1873 and considered as his most important scientific achievement. According to that principle, 'every chemical change accomplished without the intervention of energy from outside tends toward the production of a body or system of bodies which produce the most heat.'³⁹ The principle was equivalent to what Berthelot also called 'the principle of maximum work' in the same publication. Partly because many though not all chemical changes seemed to obey it, and partly because of Berthelot's powerful status, his 'third principle' remained immune to sustained criticism. But even in France it was known for some time that the Danish chemist, Hans Thomsen, best remembered today for his prediction of five noble gases, had been claiming to himself the credit, and not with-

36. *Ibid.*, p. 1113. Expressed mathematically, the thermodynamic potential Φ is equal to $E(U - TS) + P$, where E is the mechanical equivalent of heat, U the internal energy of the system, S its entropy, T its absolute temperature, and P the potential of external forces.

37. *Ibid.*, p. 1115.

38. Berthelot served in that capacity from December 1, 1886, until May 30, 1887. It was during that time that Duhem applied for a teaching job, a move which, in view of Berthelot's animosity toward him, could not obtain the hoped-for result, a post in Paris. Berthelot's close connection with the governing circles of the Third Republic is also attested by his serving as minister of foreign affairs in the Bourgeois cabinet (1895-96). Berthelot's life and work is still to receive an objective portrayal. Even a touch of criticism is absent in the most often quoted works, such as A. Ranc, *La pensée de Marcelin Berthelot* (Paris: Bordas, 1948), L. Velluz, *Vie de Berthelot* (Paris: Plon, 1964), and R. Virtanen, *Marcelin Berthelot: A Study of a Scientist's Public Role* (Lincoln, NE: The University, 1965). Only the last work contains a brief reference to Duhem (p. 54) in a context in which Virtanen tries to exculpate Berthelot of the charge of scientism. One wonders whether Virtanen could be unaware of Berthelot's scuttling of Duhem's career.

39. Quoted in the translation of M.P. Crosland, 'Berthelot, Pierre Eugène Marcelin,' *Dictionary of Scientific Biography* (New York: Charles Scribner's Sons, 1970-78), 2:63-72. Duhem does not figure in Crosland's article which at times resembles a panegyrics.

out good reasons, for having anticipated by two decades Berthelot in formulating that principle.⁴⁰ Those aware of all this must have also sensed that the thrust of the young Normalien's claim went far beyond an already notorious dispute concerning priority. The claim struck at the principle itself. The closing paragraph of his note indicated that he not only had the proof of the basic inadequacy of that principle but was also working, and on a vast scale, on its replacement by something better.

An ill-fated thesis

In a Paris where gossip, scientific or other, propagates with almost the speed of light, rumors quickly spread from the Ecole Normale concerning particulars as to what Duhem was working at. Further fuel to those rumors was the fact that two days before his first note was read to the Académie Pierre had, as will be seen shortly, submitted his doctoral dissertation to the Sorbonne. A potential bombshell must have been in the making even in the eyes of those unaware of the explosive character of the dissertation's topic, thermodynamic potential. No student of the *grandes écoles*, let alone a student not yet through the first half of his third year, was known to have presented himself for the doctor's degree. For the time being the young Normalien added suspense to suspense. At the very first meeting of the Académie, in the new year of 1885, Pierre presented, again under the aegis of Hermite, a note on the theory of electromagnetic induction.⁴¹ The less than three pages of that note were sufficient to show the salient features of that mental physiognomy which were to become the characteristics of Duhem, the theoretical physicist. The starting point of the note was the application by Helmholtz and Thomson to Joule's law of Neumann's integral of electrodynamic induction. Without the slightest concern for the fact that Helmholtz and Thomson (later Lord Kelvin) were the foremost exponents of the physics of the day, the young Normalien flatly declared that their declarations 'leave something to desire from the viewpoint of rigor.' In addition to unremitting commitment to rigor there was Duhem's firm confidence in the sweeping validity of his brainchild, the thermodynamic potential. In it, he stated, 'one finds the most general law that can be related to these electrical actions.' One can see, so the concluding paragraph of the note stated, that 'thermodynamics throws a new light on the controversial question of the elementary law of electrostatics.' This new light consisted not only in the possibility of deriving from the thermodynamic potential, as particular cases, the results obtained by Helmholtz, Weber, Riemann and Clausius and of accounting for the latest in experimental findings. The new light also showed the law of electromagnetic induction to be 'independent of all hypotheses concerning the *nature* of the electric current' (Italics added). Long before Duhem articulated

40. In his article, 'Thomsen, Hans Peter Jorgen Julius,' *Dictionary of Scientific Biography*, 13:358-59, S. Veibel points out that while Thomsen publicly admitted the inexactitude of the principle, Berthelot kept insisting on its correctness to the bitter end.

41. 1885 (1). The meeting took place on January 5.

at length in a classic monograph the features of an ideal physical theory, based on thermodynamics and free of any speculation about the 'nature' of things and their interaction, he was most consciously committed to that ideal. That such was indeed the case is further evidenced by his remark on the hypotheses of Weber, Riemann, and Clausius. They all based the mutual action of electric charges on *forces* acting among them. 'But since these forces,' Duhem noted, 'can in any case be considered only fictitious, the hypotheses based on them cannot be viewed as necessary.'

Commitment to rigor, attention to the most relevant publications in current literature, a fearlessly critical reading of the papers of the most 'authoritative' physicists of the day, a firm confidence in his own insights, were features also evident in Duhem's note 'on the reversal of spectral rays,' published in the same year 1885 in the *Journal de physique théorique et appliquée*,⁴² a periodical of international repute. The same characteristics set of course the tone of those two memoirs in the *Annales Scientifiques de l'Ecole Normale Supérieure* to which reference has already been made. Yet those characteristics appear there in ever fresh shades. This is particularly true of the first and longer of the two memoirs. It contains the first reference in Duhem's publications to Jules Moutier, his beloved and revered teacher of physics at Stanislas. The reference shows a student fiercely independent, his admiration notwithstanding. While Moutier's recent monograph on the theory of capillarity was ranked by Duhem as a major improvement on Poisson's work which in turn had taken its starting point from the 'molecular attraction' on which Laplace and Gauss had based their classic studies of capillarity, he declared in the same breath that 'the application of the principles of rational mechanics to the problem leave some doubt persisting in the mind.'⁴³ The source of those doubts was revealed by Duhem with a reference to the notion of 'virtual velocities,' a notion which in Duhem's thinking was to retain a capital importance. Rational mechanics and virtual velocities meant one and the same thing to him. If the latter was inapplicable in a particular phenomenon (changes of state in a capillary fluid, for instance), then theories based on the former would not be applicable. Thermodynamics, Duhem continued, not only helps fill the lacuna which mechanics cannot, but also 'emancipates that part of physics [capillarity] from the hypothesis of molecular attraction.'⁴⁴

Duhem, who was to state two decades later that he entered, under the impact of Moutier's teaching, the Ecole Normale as a 'convinced mechanist,'⁴⁵ began to drift within a year or so, far beyond a physics reduced to mechanics. Moreover, he surpassed mechanics by relying on that very thermodynamics of which Moutier was a foremost exponent in France in well known, though hardly acknowledged, publications, without, however, seeing thermodynamics in a light in which his former student began to see it. Pierre quoted Moutier's publications on thermodynamics with gratitude and admiration. He was at the same time most conscious of the originality and independence of his own reflections.

42. 1885 (2).

43. 1885 (3), p. 212.

44. *Ibid.*, p. 210.

45. 'Physique de croyant' (1905); see English translation, 1954 (3), p. 276.

Originality and independence beckoned in those paragraphs of his longer memoir in which he listed half a dozen theories on capillarity.⁴⁶ In addition to the well known names of Thomson (Kelvin) and Helmholtz, mention had to be made of other today lesser names. Most historians of physics today would be slightly embarrassed to be asked to say more than a few words about Gabriel Jonas Lippmann (1845 – 1921), one of those physicists whose theory on capillarity Duhem recalled to illustrate that ‘divergence of opinions’ in view of which, as he put it, ‘it may not appear perhaps useless to attempt a new solution to that important problem.’⁴⁷ Lippmann, recipient in 1908 of the Nobel Prize for his work on color photography, was no secondary figure around 1885 and for some time afterwards. A native of Luxemburg, Lippmann was a Normalien himself before he went abroad to study with Kirchoff. As a professor of mathematical physics since 1883 at the Faculté des Sciences in Paris, he became part of the board to which all doctoral theses in physics had to be presented. To include Lippmann and in particular Lippmann’s doctoral thesis on capillarity in that list of ‘divergent opinions’ was hardly a ‘prudent’ act on the part of Duhem still to earn his doctorate.

With Pierre considerations of ‘prudence’ counted for nothing when it came to standing up for the truth as he saw it. Although Lippmann was not on the editorial committee of the *Annales Scientifiques de l’Ecole Normale Supérieure* which had to approve manuscripts for publication, it is most likely that Pierre’s perfectly polite reference to Lippmann must have reached the latter’s ears while editorial judgment was passed on his memoirs. At any rate, before the printed text of the memoirs was on Lippmann’s desk, he had, as will be seen shortly, already passed a memorable verdict on a much more systematic form of those two memoirs’ main argument. In that argument Pierre worked out, after separating painstakingly the true capillary phenomena from the apparent ones, the application of thermodynamics to the emission of heat and to changes of state which take place in the former. The prowess of a born theoretical physicist was in view in Pierre’s showing how the formulas obtained through those ‘divergent opinions’ were particular cases of his more general theory which also accounted for all the experimental data however recent. It was also the theoretical physicist in Pierre who rejoiced in finding that thermodynamics reveals its fecundity and power as it shows ‘the close relatedness among various parts of physics which appear, at first look, to deal with essentially different phenomena.’ Again, it was the consummate theoretical physicist in him who traced that fecundity to its very source and noted with obvious satisfaction: ‘The interrelation which this theory discovers is not founded on hypotheses more or less plausible. They are rigorous consequences of the principle of equivalence [of heat and work] and of Carnot’s principle.’⁴⁸

Full rigor in analysis, painstaking avoidance of spurious hypotheses, unrestricted generality in conclusions, and firm unification of apparently separate branches of physics consituted the ideal which Duhem, the theoretical physicist pursued from

46. 1885 (3), pp. 211-12.

47. *Ibid.*, p. 213.

48. *Ibid.*, p. 254.

the very start of his career. He was also convinced from his days at the Ecole Normale that the historical survey of a notion or theory of physics was an integral part of implementing that ideal. The concluding paragraph of his longer memoir shows all too clearly the theoretical physicist in Duhem to call for the support of the historian of physics. The paragraph started on a note of exemplary modesty, prompted by his customary and genuine appreciation of the work of others. He held up Kelvin's application of Carnot's principle to capillary phenomena and to changes of state taking place in them as the work which opened new avenues. Behind the perspective of very recent history opened up through Duhem's reference to Kelvin's work, there lay, however, a much deeper historical vista which the young Normalien felt best to illustrate with the words of Gabriel Lamé, a leading French physicist of the previous generation: 'When a branch of mathematical physics has thus succeeded in eliminating all doubtful principles and all restrictive hypotheses, it really enters into a new phase. And that [new] phase appears definite because the *historical series*, which is rational [logical] at the same time, signals a constant tendency toward independence from any preconceived law' (Italics added).⁴⁹ It was Duhem's robust belief from the very start in the indispensable instructiveness of historical sequence that enabled him, two decades later, to seize on the significance of a cryptic reference to an obscure medieval figure in a largely forgotten book by a Renaissance author. Surprised he certainly was but, unlike others who had already seen that reference, he did not take it lightly nor did he try to slight it. Duhem the physicist blossomed naturally into the historian of physics.⁵⁰

In concluding his second, shorter memoir in the same volume, Duhem expressed his conviction that the successful application of the thermodynamic potential to thermoelectric phenomena 'leaves no doubt whatever concerning the reliability of the procedure.'⁵¹ The second memoir revealed that the procedure in question not only had been in the process of being worked out in full but already appeared in print under the title, *Le potentiel thermodynamique et ses applications*.⁵² It was referred to in the first memoir three times as *Théorie du potentiel thermodynamique* (en cours de publication).⁵³ Quite possibly it was under this title that he had presented it on December 20, 1884, as his doctoral dissertation.⁵⁴ In doing so Pierre

49. The quotation, whose provenance Duhem did not give, was from the preface of Lamé's *Leçons sur la théorie analytique de la chaleur* (Paris: Mallet-Bachelier, 1861), p. vi. In that preface Lamé gave a survey of the conceptual history of two approaches to the problems of elasticity. In all likelihood Duhem was familiar with Lamé's *Cours de physique* (3 vols, 1836-37), the text of Lamé's lectures at the Ecole Polytechnique, in which Lamé emphasized such notions, dear to Duhem, as the progressive elimination of arbitrary hypotheses in physics and the error of applying at any price the method of mechanics in every branch of physics.

50. A point to be discussed later in detail.

51. 1885 (4), p. 424.

52. The work was referred to at the very outset of that second memoir and mentioned also on pp. 407, 409, 410, and 415.

53. 1885 (3), pp. 239, 249, 252.

54. The official form containing the essential details about Duhem's first thesis is in folder AJ¹⁶ 5804 in the Archives Nationales (Paris). The thesis is specified there as 'ayant pour le sujet le potentiel thermodynamique.'

was much encouraged by Jules Tannery, professor of mathematics and, from October 1885 on, also vice-director of scientific studies at the Ecole. Tannery knew all too well the qualities of his protégé, who at the end of his second year passed within one month not one but two exams for *licence*, one with flying colors in mathematics on July 4, and another in physics on August 1, 1884.⁵⁵ Still Tannery's encouragement of Pierre was unusual because as a rule candidates for doctorates earned first their *agrégation* which qualified them to teach in the lycées. Unfortunately, the perspicacity of Tannery was not matched by Lippmann, president of a committee of three examiners (the others were Hermite and Picard), who on June 12 of the next year submitted a wholly negative report.⁵⁶ Lippmann first stated that the author of the thesis not only misunderstood the true meaning of Clausius' formula of entropy but also ignored substantial reservations made to its validity by Clausius himself. At any rate, Lippmann added, even if the formula were taken as a mere postulate 'one cannot admit the ensuing reasonings and the applications made by the author on their basis.' Worse, Lippmann argued, all the results calculated by the author should be zero: 'One can easily verify that all terms of the final formula, to which the author arrives, contain as a multiplier the logarithm of unity [which is zero].' Lippmann found all the conclusions drawn by the author 'too vague to be submitted to verification; they all are applicable to an infinity of different formulas.' Lippmann saw nothing novel in the second part of the work relating to electrical phenomena which, he insisted, 'has no logical connection with the first part or even with thermodynamics.' It was then a foregone conclusion that Pierre's work was 'of such a nature as not to be worthy of being defended as a thesis before the Faculty of Sciences of Paris.' Lippmann wrote on June 12 to Pierre to come and collect his thesis which the latter did on June 19th.

Since the thesis Pierre presented is no longer extant, the merits of Lippmann's judgment on it cannot be directly weighted. Indirect evidence suggests, however, grave lack of objectivity on Lippmann's part. The principal aspect of that evidence relates to those at most three summer months which could have elapsed between the retrieval by Pierre of his thesis and his presentation of a manuscript with the title 'Le potentiel thermodynamique' not later than the early Fall of 1885 to A. Hermann, a world-renowned publishing house of scientific books in Paris. The firm, which brought out the manuscript in the form of a substantial and handsome book by the fall of 1886, needed at least ten months for evaluation, copy-editing, type-setting, proof-reading and printing. Since it would have been impossible to turn within the summer months of 1885 a thesis, allegedly faulty in all its essentials and unreliable in all its details and inferences, into a masterpiece which ultimately earned a place in the series 'Landmarks of Science,' the thesis and the book should be considered identical.

This makes inescapable a probing into the reasons for Lippmann's evaluation of the thesis which among other things contained such gems as the formula later known

55. His poor mark in physics had been, as noted earlier, long remembered by Picard.

56. Also in folder AJ¹⁶ 5804. The absence of reports by Hermite and Picard makes the whole affair even more suspect.

as the Gibbs-Duhem equation. Pierre himself could easily surmise the reasons as Lippmann handed him his thesis and his evaluation of it. In the latter a fairly overt defense was made of the interpretation of the process of dissociation in terms of 'thermochemistry' whose chief spokesman was Berthelot. In view of Berthelot's powerful status in the French academic establishment, it is safe to assume that Lippmann led him to read the thesis and see something of Berthelot's inability to tolerate the prospect of the rising sun of a young genius, ready to demolish his favorite thesis. Lippmann also referred to two papers of his former teacher Kirchoff, which were, according to Lippmann, given a wrong interpretation in the thesis. Lippmann could all the more make these points with no fear of being challenged as the two other members of the jury, Hermite and Picard, were pure mathematicians. While the failure of the former, who personally knew Pierre, had more than enough stature to risk a dissenting opinion if he cared at all to look into the experimental intricacies of the thesis, the apparent silence of Picard, still a beginner in the academic ranks, is more understandable. Neither of them was present when Lippmann handed Pierre back the thesis with apparently some comment. Its thrust can be surmised from Pierre's reply: 'Well, [if such is the case,] I will not present another thesis in physics.'⁵⁷ His further 'reply', which could not remain unnoticed by Lippmann, was the highest rank accorded a month later to Pierre in the *concours* for agrégation in physics.⁵⁸ A little over two years later he defended with great success a doctoral thesis which, though formally presented as a thesis in mathematics, had the same thermodynamic potential for its basis, though applied to that electromagnetics with which, according to Lippmann, it had nothing to do.⁵⁹

Lippmann's attitude would have deserved being classed as the 'academic scandal' of 1885.⁶⁰ The story must have reverberated all the more strongly in the *grandes écoles* because Moutier, by then maître de conférences at the Ecole Polytechnique, was identified in the dissertation as the one whose advice profited most its author, a Normalien.⁶¹ The matter could provoke but further comments when the disserta-

57. *Un savant français*, pp. 145-46.

58. First rank was all the more noteworthy because the nationwide *concours* was the means whereby one became 'aggregated' to the entire system of French higher education, in the sense that the successful candidate had the right to be considered for a teaching post in the lycées, académies (universities), and *grandes écoles*.

59. Wrote Lippmann in his report: 'In the second part of his work, the author sets forth various theoretical researches relating to electricity, without adding to them new conclusions. He also deals with the actions-at-a-distance of electrical currents: electro-dynamical actions and induction. This part is without logical connection with the preceding part and also with thermodynamics in general. It is known that actions-at-a-distance of electrical currents are independent of the material of the circuit and consequently of the temperature and calorific actions or other actions taking place in the circuit.'

60. The expression is borrowed from the article 'Tannery, Paul' by R. Taton (*Dictionary of Scientific Biography*, 13:254), who qualifies in such a way the appointment in 1903 of G. Wyrouboff to the chair of the history of science in the Collège de France.

61. *Le potentiel thermodynamique*, p. xi. A dozen of Moutier's publications on thermodynamics are listed on p. 24.

tion was published in 1886 by the firm of A. Hermann in its internationally prestigious series, 'Nouveautés scientifiques.' The almost two-hundred-and-fifty page long book was far more than a criticism of Berthelot, let alone of Lippmann who was mentioned but briefly.⁶² The latter revealed something of his lack of qualification to pass a competent judgment on Duhem's work when in 1886 he exchanged his chair of theoretical physics at the Sorbonne for that of experimental physics. By then Lippmann was giving a final form of his lectures on thermodynamics⁶³ and he could not help noticing the immense superiority of the young Normalien's grasp of the breadth and width of the subject. As to Berthelot, there was some praise for him in Pierre's thesis, though not for his 'third principle.' The latter was the starting point of the thesis whose author tactfully passed over the question of Thomsen's priority. Duhem's fate was now sealed. For Berthelot it was hardly a problem to have the Ministry of Public Instruction respect, even beyond his death in 1907, his verdict on Pierre: 'This young man shall never teach in Paris.'⁶⁴

Anticlericals versus Catholics

Beneath such a verdict there lay much more than the resentment of a scientist's ego wounded by criticism, however well reasoned. From the mid-1880s on, the Third Republic was drawn into an increasingly systematic and virulent campaign to free France from all traces of clericalism as well as to deprive French Catholicism once and for all of intellectual power and social respectability. An early move to that effect was the prohibition of the granting of state-recognized degrees by Catholic institutions of higher learning which were even forbidden, in that euphoria of 'liberalism,' to call themselves universities. In that campaign Berthelot played the role of ideological pundit by extolling the creed of scientism in books now deservedly forgotten.⁶⁵ By the opening of the 20th century the triumph of that campaign appeared well-nigh complete following the ban on crucifixes (small but potent reminders of religion) in State schools and hospitals (all of which had been expropriated by the State), the suspension and expulsion of most religious orders, including the ones devoted to the care of the sick and the poor, and the complete secularization, first of elementary and in 1905 of all secondary education. Viviani, minister of labor, felt it appropriate to announce, on November 8, 1906, the good

62. *Ibid.*, p. 111.

63. *Thermodynamique. Leçons professées à la Faculté des Sciences* (Paris: Hermann, 1888), 251 pp, reprinted 1905.

64. *Un savant français*, pp. 53 and 146. Earlier in that book the same verdict is recalled in the slightly different form of 'this young man shall never arrive in Paris' (p. 26). It was then, added Duhem's daughter in a comment which clearly echoes Duhem's own reflections, that 'there began the struggle of thirty years between him and the Sorbonne' (pp. 146-47).

65. Their tone is well exemplified in a statement of Berthelot made in 1897 in an address on 'Science and Popular Education': 'People begin to understand that in the modern civilization every social utility derives from science, because modern science embraces the entire domain of the human mind: the intellectual, moral, political, artistic domain as well as the practical and industrial.' *Science et éducation* (Paris: Société Française d'Imprimerie et de Librairie, 1901), p. 13.

tidings to the Chamber of Deputies: 'Through our fathers, through our elders, through ourselves—all of us together—we have bound ourselves to a work of anti-clericalism, to a work of irreligion . . . We have extinguished in the firmament lights which shall not be rekindled. We have shown the toilers that heaven contained only chimaeras.'⁶⁶ Viviani should have rather reminded himself and France of the biting remark made not by a cleric but by the famed leftist journalist, 'Sévérine,' at the inception of that campaign waged for a thoroughly secularized state: 'It shut up Heaven, but has not opened the bakers' shops.'⁶⁷

In that campaign, increasingly sure of itself, students of the *grandes écoles* were carefully watched concerning their views on Church and State. They were expected to play an ideological role as the elite of the teaching body of the 'Université,' that is, the entire French educational system. They were to be imbued with the logic that 'being the daughter of the Revolution, the 'Université' teaches the Revolution.'⁶⁸ The political and religious views of those students could not be a matter of indifference to a government more and more caught in an ideological crusade on behalf of a thoroughgoing secularization of life in France. This is not to suggest that in the 1880s the establishment solicited confidential information on Normaliens. But policies clearly headed in the direction of the famed 'affaire des fiches,' a huge dossier collected on army officers by Freemasons of the Grand Orient who wanted to deserve well of the Republic. Pierre's unostentatious though firm Catholicism hardly earned him good points in some bureaus of the Ministry of Public Instruction. It may even have been suspected there that he contributed the series of biting illustrations for the satirical poem, 'Au pays des gorilles,' written by the father of Joseph Récamier, who became Pierre's close friend at Stanislas and kept in touch with him afterwards. The poem, a lampooning of Jules Ferry, who pushed through and implemented the law which secularized elementary education and who also made France embark on colonial adventurism, was printed as an album of 60 folio pages by the prominent Parisian publishing house, E. Dentu, with its main offices in the Palais Royal.⁶⁹ It

66. Quoted by G. Goyau in his article, 'France,' *CE* 6:189.

67. Quoted in D.W. Brogan, *The Development of Modern France*, p. 266. 'Sévérine' was the pseudonym of Caroline Rémy, Dame Guerhard (1855-1929).

68. A remark of D. Halévy, *Histoire d'une histoire esquissée pour le troisième cinquantenaire de la Révolution française* (Paris: Bernard Grasset, 1939), p. 64.

69. The album, published in 1883, had a size of 38 x 28 cm. In addition to a prologue and an epilogue it contained 21 strophes with responses and refrains to be sung by choir to one of five tunes, set for voice and piano in the last four pages. The author of the poems (Etienne Récamier) was given as Esteban de Richermoz, the illustrator (Pierre) as Ch. Clérice, and the music was attributed to A. Josset. The sumptuous character of the printing can be gathered from the fact that the verso side of each page was blank. The upper half of 23 recto sides was occupied by an engraving (16 x 20 cm) made by 'Fernique Ph' after Pierre's drawings. The lower half contained the strophes. No copy of that album is listed in any of the major libraries in Paris. I would like to express my appreciation to Mr. Norbert Dufourcq for letting me study the copy of the album given to him on March 2, 1937, by Hélène Duhem, who inscribed the gift with the words: 'A Monsieur Norbert Dufourcq et à Madame Norbert Dufourcq, cet album de dessins 'anti-républicains' d'un viel ami des Machurés, plus connu sous le nom de Pierre Duhem, que sous le pseudonyme de Ch. Clérice!'

was Pierre's idea to strengthen the poem with illustrations which added a cutting edge to the poem's thrust: a disclosure of the duplicity of Ferry who eagerly solicited the help of the Church in the new French colonies by giving her those very rights of which he was depriving her at home. The illustrations depicted the endless puzzlement of the gorilla family 'Joko' over the double standards of the International Simiophile Commission sent to equatorial Africa to study the transformation of men into gorillas and to promote Simian mores in Europe. Pierre was advised to think it over twice before signing his sketches. 'He laughed at me in the face,' Récamier recalled, 'and signed them all; it was against his desire that his signature was not retained in the album. He never wanted to appear as one hiding his religious convictions.'⁷⁰ Needless to say, with respect to the Revolution Ferry's convictions and those of the forces he represented were no less 'religious.' While the co-existence of two very different religious convictions could be a ready source of conflicts, endless warfare was in store when the former convictions ceased to include respect for consciences, and the latter tried to hide its crusadingly 'religious' character. While the former failure never ceases being a welcome topic, very little is aired about the latter. It had a classic manifestation in a speech which Ferry delivered on April 19, 1881, to a gathering of teachers who had become, Ferry told them, through the law of 1880, members of the University system and also of the bourgeoisie! To be sure, teachers were not to be militant and partisan representatives of Republic and Revolution. Nothing would have hurt the government more in the upcoming elections in November. But Ferry warned:

God forbid, and for two reasons, that there should be in your teaching no ideology, no political trend whatever. First, are you not charged, according to the new programme, with civic instruction? This is the first reason; there is a second, and even more elevated: you are the sons of 1789. You have been enfranchised as citizens by the French Revolution. You will be emancipated as teachers by the Republic of 1880. How could you not love and not bring yourself to love in your teaching the Revolution and the Republic? This policy is a national policy and you can and you must — the thing is easy — make it a part of the minds of young children in unimposed forms and channels.'⁷¹

It was of course obvious that the policy was religion and there was nothing unimposed about those ways and channels. At any rate, Pierre could not help chuckling when the military reversal in Tonkin brought down the Ferry cabinet, on March 30, 1885, amidst journalistic vituperations of the one who certainly did not deserve the vicious words of *Figaro*: 'Beneath a storm of hootings, amid the contempt of his own majority, with his posterior kicked, M. Jules Ferry has passed away pitifully, wretchedly, like a bladder that bursts.'⁷²

70. *Un savant français*, p. 48.

71. See M. Reclus, *Jules Ferry 1832-1893* (Paris: Flammarion, 1947), p. 220. Ferry's favorite statement that 'the teacher is no substitute either to the priest or to the father of the family' (*ibid.*, p. 221), is difficult to reconcile with his spirited promotion of Jules Simon's 'natural theology' and 'lay ethics,' two direct throwbacks to Voltaire's crusading deism.

72. Quoted in E.A. Vizetelly, *Republican France 1870-1912. Her Presidents, Statesmen, Policy, Vicissitudes and Social Life* (London: Holden & Hardingham, 1912), p. 289.

Pierre was among those whom the student jargon classified as ‘talas,’ that is, those who, unlike the ‘antitalas,’ went to mass.⁷³ The ‘talas’ attended Sunday mass in a body in the parish church of Saint-Jacques-du-Haut-Pas, two short blocks west of the Ecole. The church, which according to the rather severe judgment of a lavish description of Paris is not worth a visit,⁷⁴ was not for Pierre without some attraction. A chain of paintings in the left transept depicted scenes from the life of his patron saint, the Prince of the Apostles. Pierre certainly did not miss the plaque recalling the desecration of the church during the Revolution.⁷⁵ He could hardly suspect that fifty years later he was to become the center of the reminiscences of Joannes Wehrlé, two years his junior at the Ecole, about the ‘talas’ attending Sunday mass: ‘One could see there, at Delbos’ side the dear and great Duhem, *cacique générale* of the science section, who pulled from his pocket a good-sized rosary and prayed it plainly during one part of the mass.’⁷⁶ The piety of Pierre was as plain as it was deep. It would have done justice to a phrase of Georges Pompidou, himself a graduate of the Ecole: ‘If a Normalien believes in God, he does so with the faith of Pascal.’⁷⁷ While many a Normalien was an admirer of Pascal, probably few were imbued more with the prayerful spirit of the *Pensées* than was Pierre Duhem.

Devout as Pierre was as a Normalien, he was not ostentatious about his faith although he made no secret of his deep religious convictions, an increasingly risky attitude at a time when Church-State relations in France took a turn for the worse. The wit and sharpness of his mind were more than a match to any challenge which ‘antitalas’ could pose. He was not, however, to be a part of organized ‘defense,’ not even to the extent of joining the St. Vincent de Paul Society, devoted to charitable work, in which most ‘talas’ were active.⁷⁸ He could not, of course, be unaware of the turning, in the late 1880s, of the Ecole Normale into a bastion of doctrinaire republican and socialism,⁷⁹ both seeking intellectual support in some sort of

73. The name ‘tala’ may have originated either in the phrase ‘va-t-à la messe,’ or in Voltaire’s calling Buddhist priests *talapoin*, or most likely in *Atala*, the title of a work by Chateaubriand (see *Rue d’Ulm*, pp. 403-04).

74. A. Dauzat et F. Bourgnon, *Paris et ses environs* (Paris: Librairie Larousse, 1925), p. 51.

75. Pierre may have learned that Edouard Branly, who as professor of physics at the Institut Catholique was soon to distinguish himself with the invention of wireless telegraphy, was a member of the parish. Pierre and the other ‘talas’ noticed, of course, the presence at Sunday mass of Pasteur, whose memory is now commemorated in the church by a marble plaque, which recalls also the solemn mass celebrated there by Cardinal Dubois on December 27, 1922, the centenary of Pasteur’s birth.

76. J.J. Wehrlé, *Victor Delbos* (Paris: Bloud & Gay, 1932), p. 26. Wehrlé, who later became a priest, was a classmate of Edouard Jordan, who is mentioned in the same context as the inseparable companion of Delbos in their ‘peripatetic’ walks during recreation.

77. *Rue d’Ulm*, p. 16.

78. *Ecole Normale Supérieure*, p. 90.

79. Not without the help of some fellow students, such as Lucien Herr, from 1887 the librarian at the Ecole, who with Jaurès functioned as the ideologue of French socialism. Clearly, although 13 of the 20 students, who entered the Ecole with Pierre in the science section, declared themselves ‘Catholic,’ some of them were hardly practising. One declared himself Jewish, while six refrained from making any declaration, a requirement soon abolished.

scientism. Pierre could easily see that the ideal of physics for which he worked ever more strenuously had an ideological bearing. A physics as a mere mathematical systematization of experimental data could not be called upon, as scientism would have it, as an arbiter in essentially philosophical and theological disputes. There is no evidence whatever that his strenuous work as a physicist had ever been motivated by such considerations of apologetics.⁸⁰ The word strenuous deserves emphasis in view of the depth and width of his publications that appeared already during his years at the Ecole. Nothing would indeed be more tempting than to picture him trapped in his room or in the laboratory day after day until the wee hours. Yet, although Pierre worked long hours, he was too disciplined to become a prisoner of an exacting work routine.

Sailing on waters and events

As in later life, at the Ecole Normale too, Sunday was for Duhem a day of relaxation. This often meant a trip in the company of Joseph (Joe) Récamier, his former schoolmate at Stanislas, to Argenteuil, a place also frequented by Sisley, Renoir, Monet, and a crowd of lesser painters. One wonders what their reaction would have been had they seen the little cards, illustrated by Pierre's drawings of sailors, which he sent during the week to Joe to get confirmation about their Sunday program.⁸¹ On one of the cards, Pierre asked 'vieux Jo' whether he would be going to Argenteuil on Sunday in spite of the steamboat race to be held there. On another he wrote: 'I have returned healthy and safe. How did you fare? If you have drowned, inform me. If not, and if you are back, send me a signal for Sunday noon.' One card carried his signature, 'Your quarter-master,' another 'your baggage-master.' Two cards specified the train leaving Gare St. Lazare at 9:05 in the morning. Another card seemed to indicate that exams were over: 'I am through. At what time Sunday at Argenteuil?' Pierre was madly in love with sailing: 'My commander, I am always ready to walk up and down the platform at Gare St. Lazare, Sunday at 9:05 in the morning. I will keep open the barriers until the semaphor signals your arrival. In case of a counter-order, send me your new orders to the Ecole. Duhem. Master of equipage on board of fleet dispatch-boat *Kitty*.'⁸²

Once at Argenteuil, Pierre and Joe had a bite at the bistro of Mère Frébourg, famed for her fried goudeons, before they went sailing on the Seine. Récamier, who during those years was a student of medicine,⁸³ recalled how quickly Pierre

80. More about this in Ch. 9, 'Duhem the Philosopher.'

81. Ten of those handmade postcards of thick cardboard are in the possession of Mr. Pierre Récamier, Joseph Récamier's grandson, who kindly permitted my utilization of them.

82. A patently joking remark about *Kitty*, a boat of about four meters in length with one mast and sail.

83. Joseph Récamier, the grandson of Mme Récamier immortalized by the painter David, was born in 1861 in the ancient Récamier residence, 1 Rue du Regard. Owing to the ties of the Récamier family with the house of Orléans, Joseph Récamier accepted in 1894 the post of personal physician with the Duc d'Orléans and accompanied him on his arctic and central-African expeditions. Although fifty-four at the outbreak of World War I, he volunteered as military surgeon in the front line and left service heavily decorated. For these and further details, see 'Eloge funèbre du Docteur Joseph Récamier, membre associé de l'Académie des Sciences, Belles-Lettres et Arts de Lyon, présenté à l'Académie dans sa séance du mai 1935,' par Mr le Docteur P. Gouillioud (Lyon: Société anonyme de l'imprimerie A. Rey, 1935), 12pp.

learned the art of sailing. This revealed more concrete qualities in Pierre than his thorough familiarity with the law of dynamics involved. Yet, several times, as their boat tilted heavily, Récamier heard Pierre say half-aloud to himself: 'How interesting it would be to investigate the exact laws of the water's resistance to the plane of the boat's keel!' Prompted by such remarks, Récamier bought him an old manual on sailing in which such questions, rather arcane for Récamier, were discussed. Pierre delved with delight into the book only to find, very characteristically of him, that, to quote Récamier, 'from the point of view of physics, the questions were not unfolded with sufficient precision.'⁸⁴ Pierre's bent on exactness could evidence itself in most varied places and times.

Sailing was first done in a fairly large boat owned by a group of students. One of them, whose name (and death in the sea) remained fixed in Récamier's memory, brought along on occasions his mistress, 'a brave but not too intelligent girl.' To this remark Récamier added that Pierre, who kept a certain reserve, never acted a puritan: 'He maintained cheerful company with all, laughing more than anyone else at student jokes.'⁸⁵ Later, when Récamier was given by his parents a small yacht, *Kitty*, he and Pierre went sailing on their own. 'Of *Kitty* Pierre made many sketches and manœuvred it with remarkable control. He was happiest when a strong breeze tested us as sailors. He had but contempt for the amateur yachtsmen, decked out in beautiful apparel. As soon as Pierre arrived in Argenteuil, he changed, as he did later at Ouessant, into the garments of ordinary sailors.'⁸⁶

Regrettably, no details were recalled by Récamier about his and Pierre's sailing around the island of Ouessant off Bretagne's westernmost tip jutting far into the Atlantic. He used such occasions to make sketches in India ink of the rough coastland, dashing sailboats, splashing waves, and of the strong contrast of light and shadow often dominating there. The precise lines of Pierre's drawings could easily be reinforced through the advice he received in the early 1880s from Louis Janmot,⁸⁷

84. *Un savant français*, p. 46. Quotations are from Récamier's letter to Duhem's daughter.

85. *Ibid.*, p. 45.

86. Many of these sketches, made on the spur of the moment, were pasted by Joseph Récamier into an album, in the possession of Mr. Pierre Récamier, which also contains dozens of sketches by Pierre of sailors and steamboats.

87. According to Jordan, 'Notice biographique, Pierre Duhem' (p. 168), Pierre 'had the opportunity to watch at work a good painter, Paul Jaumot [sic] and get advice from him.' Jordan obviously meant Louis Janmot (1814-1892), a Lyonnaise painter, mostly devoted to religious and allegorical themes, who lived in Paris 1864-83, decorated several churches there, and contributed to the Salon regularly until 1888 (see Thieme und Becker, *Allgemeines Lexikon der bildenden Künstler*, Vol. 18 [Leipzig: E.A. Seemann, 1925], (p. 390). Pierre undoubtedly was familiar with Janmot's magnificently illustrated *L'âme-Poème* (trente-quatre tableaux et texte explicatif avec le portrait de l'auteur et trente-quatre photographies d'après les originaux; Saint Etienne: Théolier et Cie, Imprimeurs-Éditeurs, 1881), in which the second part of the First Series contained allegorical illustrations of the various fields of learning, including astronomy, philosophy, and science. Through conversations with Janmot, Pierre could easily receive advanced glimpses of the contents of Janmot's *Opinion d'un artiste sur l'art* (Lyon: Vitte et Perussel; Paris: Victor Lecoffre, 1887), a volume of 555 pages. There Janmot developed themes which recur later in Pierre's writings. Janmot insisted on doing art according to one's national character, extolled the Flemish, Dutch, and English painters who, unlike some of their French counterparts, never became the slaves of the Greco-Roman style. Duhem's fondness for Flemish painters may have been sparked by Janmot's influence, although his father's Flemish background must not be forgotten. Janmot could also indirectly reinforce Pierre's early conviction that physics was to be cultivated according to one's national background. Janmot's love of Catholic tradition and his detestation of the French Revolution found a sympathetic listener in Pierre.

a painter well known in his days, but the bent on stark strength reflected Pierre's personal firmness and masculinity. Some of his sketches of the Ouessant area decorated the walls of Jules Tannery's office in the Ecole Normale.⁸⁸ Years later, when Pierre was writing of the astonishment of the Greeks of old upon learning about the huge tides of the Atlantic,⁸⁹ he must have recalled his youthful braving the waves of those tides which washed the shores of the many small islands reaching as a chain from the Cap du Finistère far into the ocean. These exploits demanded sinews and stamina which were hardly the forte of the typical Sunday-sailors at Argenteuil, to say nothing of those immortalized in Renoir's 'Luncheon at a boating party.'

This is not to suggest that Pierre was not fond of parties. In fact, Récamier pointedly recalled that Pierre found very amusing the Ecole's New Year parties and added that 'he certainly collaborated in them.'⁹⁰ In fact he wrote the text for one of those parties, including the poems to be sung by the chorus.⁹¹ He did not seem to be bothered by the low taste of some of his camarades who found in those parties an outlet for improprieties. Not that he could be pulled into such excesses. 'On account of his scientific prominence,' Récamier recalled, Pierre had such status among his fellow students that 'he was thoroughly respected and could make himself respected when necessary.'⁹² In visiting Pierre on occasion at the Ecole, Récamier found him 'to be on good terms with all his camarades.'⁹³ Had Pierre not enjoyed himself thoroughly at the Ecole, he would have hardly begged Récamier to give him that small crocodile, or rather caiman, which Récamier brought back from the Mississippi delta. Caiman was the nickname of proctors at the Ecole and Pierre wanted to raise the baby caiman into a full sized mascot. He kept it alive for several months in a basin in the chemistry lab until the first winter when overheating of water proved fatal to the exotic pet.⁹⁴ Undoubtedly, the caiman was on more than one occasion the target of the pencil of Pierre whose sketches were in as high a demand in the Ecole as was the case in Stanislas. He stopped drawing caricatures when a camarade, known for his repetitious diction, failed to take for a laughing matter his having been portrayed by Pierre as a barber who, with a huge razor in his hand, entices customers with the words: 'Today gratis, tomorrow free.'⁹⁵

Tellingly enough, Récamier and others, who recorded their reminiscences about

88. As recalled by Chevrillon; see *Un savant français*, p. 66.

89. *Le système du monde*, 2:269-71.

90. *Un savant français*, p. 46.

91. Information obtained from Mr. Paul Brouzeng, maître de conférences at the University of Bordeaux.

92. *Un savant français*, p. 49.

93. *Ibid.*, p. 46.

94. *Ibid.*, pp. 48-49.

95. In making that sketch Pierre broke a promise he had already made to Colonel de la Laurencie, father of Jean and Lionel, Pierre's two schoolmates and close friends at Stanislas, who kept bringing home his cartoons of students and teachers. 'My young friend,' the colonel said one day to Pierre, 'you have a nice talent, but, believe me, you must renounce it. There are in the world many idiots who do not understand jokes and whom, through your caricatures, you will make your mortal enemies' (*Un savant français*, pp. 105-06).

Pierre as a Normalien, never mentioned any of the great events which were so many highlights in the lives of most Parisians between 1882 and 1887. Pierre would not have sacrificed useful hours of study and research to catch a glimpse of the lavish state funeral of Gambetta on January 6, 1883, or that of Victor Hugo on June 1, 1885. As one who kept close ties with Stanislas in the capacity of 'examineur' in physics for three years after his graduation from there, Pierre certainly attended the memorial service held on November 13, 1884, in Notre-Dame-des-Champs for the Abbé de Lagarde who died on September 1st.⁹⁶ What Pierre felt when the Comte de Chambord died on August 24, 1883, could easily be guessed by his friends, who, however, remembered no special utterance of his to recall in this connection. As a Normalien he was part of the student batallions marching down the Champs Elysées on Bastille Day. His graduation in 1885 freed him of this duty. As long as he was at the Ecole, he was, of course, exempt from military service, of which he would have been spared later also as a university teacher. He had already been given the status of *réformé* on account of his persistent stomach troubles.⁹⁷ It is most unlikely that Pierre went on his own to the Bastille parade in 1886 when a delirious crowd greeted General Boulanger who hoped to become the strong man of France. Yet, although never a Boulangist, Pierre could hardly remain undisturbed by the government's apparent inability to cope with repeated anarchist outbursts that culminated in violent scenes on September 20, 1885, around the Bourse, near the home where he grew up and where his parents still lived. He may have possibly watched in early June 1886 the crating of the Statue of Liberty, a gift of France to the United States for its centennial of independence. Another engineering feat, the laying of the foundations of the four bases of the Tour Eiffel in the spring of 1887 may have been of equal attraction to him.

Under Pasteur's eyes

During his years at the Ecole, a chief and enduring attraction for Pierre was Pasteur's relentless though extremely cautious advance toward developing antirabies vaccine for humans. The climax of that scientific tour de force came toward the end of Pierre's third year at the Ecole, in the early summer of 1885. Students at the Ecole were the beneficiaries of the first and best rumors emanating from the old stables at the Chateau of St. Cloud transformed earlier that year for Pasteur into a laboratory with sixty dogs. Finally the celebrated day of July 6, 1885, came when 'not without feelings of utmost anxiety,' Pasteur began to treat nine-year-old Joseph Meister.⁹⁸ By the spring of 1886 medical history had been made through well over 300 rabies victims who by then had come for help to the Rue d'Ulm.

During that time Pierre followed with keen interest the work of Pasteur who in

96. Following the death of the Abbé de Lagarde, the faculty, students and alumni of Stanislas decided to perpetuate his memory by a marble bust. In executing the project, the sculptor (H. Chapu) relied heavily on sketches made by Pierre (Jordan, 'Duhem,' pp. 159-60). The bust is the chief décor of the 'salon rouge' of Stanislas which contains portraits of its past directors.

97. See note 61 in Ch. 1.

98. 'Pasteur, Louis,' by G.L. Geison in *Dictionary of Scientific Biography*, 10:403.

turn looked for young men capable of giving him first-rate assistance. Pierre, who was given on October 3, 1885, a special and unusual grant by the Ministry of Public Instruction to spend another year in free research at the Ecole, was a prime candidate for Pasteur. As the founder of the *Annales scientifiques* of the Ecole, Pasteur must have been deeply impressed by a student who not only published there first-rate papers in physics but also was up-to-date in the latest in chemistry and microbiology. Pierre was also a familiar figure for Pasteur as he lived for a full year directly above Pasteur's apartment. Having been a neighbor of Pasteur remained for Pierre a special memory to cherish:

A long time ago in Paris I lodged for a full year in a small mansard room . . . On the floor immediately below there was a comfortable bourgeois household. Its head was a small man, of about 65, greying and tidy. An earlier hemiplegic attack had made his walk dragging, his hand impaired, his mood somber and at times irritable. His companion was a model of care and constant devotion. Her invariable preoccupation was to spare of any concern the spouse whom God confided to her. One could not imagine a life more simple, more united, nor a couple who were more like everybody, in at least the sense in which everybody should have been like. Nevertheless, when they went out, always together, the passersby stopped to watch the hobbling walk of that elderly man. Then, as he moved on, one could hear them murmur with awe: Pasteur! He was in fact Pasteur, the man of science, who had just crowned his glorious career with the discovery of the antirabies vaccine.⁹⁹

Pierre was often a visitor at Pasteur's laboratory and on occasion took his friend Récamier along. Pasteur seemed to have thought that Récamier's presence might make his own plea more effective. 'I was present at a conversation,' Récamier recalled, 'when Pasteur strongly insisted that Pierre should come to his laboratory as the head of bacteriological chemistry. Pierre hesitated. I pushed him with all my strength to accept and I believe that he would have done the greatest service to the Institut Pasteur. But the attraction of theoretical physics was greater than his enjoyment of natural history and Pierre declined the offer after a few days' reflection.'¹⁰⁰ In the same context, to illustrate Pierre's interest in biology, Récamier mentioned a notebook which Pierre filled while at Stanislas with drawings of his microscopic observations of infusoria. The notebook, which Récamier deposited¹⁰¹ with E. Picard, perpetual secretary of the Académie des Sciences from 1917 until 1936, prompted the latter to remark in his eulogy of Duhem: 'These reproductions . . . , made by a young man of fifteen years of age, are of a remarkable exactness. The talent of a draftsman

99. Quoted by the Abbé L. Bergereau from an address by Duhem to the Association des Etudiants Catholiques (Bordeaux); see the *Compte Rendu Annuel 1919-1920* of the Association (Bordeaux: Imp. V. Cambette, 1920), p. 33.

100. *Un savant français*, pp. 47-48. Compared with Pasteur, the professors (during Pierre's stay at the Ecole) of zoology (Dastre), of botany (Bonnier), of geology (Munier-Chalmas), and of mineralogy (Hautefeuille) were minor figures who could hardly sway Pierre to their fields whatever his interest in them. Pierre, however, often saw Edmond Perrier, who after teaching zoology at the Ecole for four years (1872-76) became director of the Museum of Natural History in Paris. Perrier's son, René, was a classmate and good friend of Pierre.

101. *Ibid.*, p. 47. When writing down around 1935 his reminiscences on Pierre, Récamier thought that the notebook was no longer to be found. There is, however, a folder of several dozen quarto sheets of drawings in the Duhem manuscripts at the Académie des Sciences which, though not a 'notebook,' would by its contents fit the description.

and the taste for natural history . . . could suggest that he would have found his way in the biological researches.’¹⁰²

Pierre’s visits to Pasteur’s laboratory were all the more frequent as from 1885 there worked his best friend at the Ecole, Bronislav-Etienne Wasserzug, who entered there, as he did, in 1882. Had the friendship between the two not been particularly strong, it would have hardly fallen on Pierre the task of writing Wasserzug’s obituary for the *Bulletin de l’Association des Anciens Elèves de l’Ecole Normale*¹⁰³ after Wasserzug’s sudden death in the spring of 1888. If it is true that every book is autobiographical, this should seem especially true of a biographical essay or book. The obituary reverberates with sentiments which were so many characteristics not only of the subject of the obituary but also of its author. The hurdles which Wasserzug found in his way to the Ecole brought Pierre for the first time face to face with a soulless bureaucracy, which remained for him a lasting source of resentment. He recalled a young man, whose father, a Polish physician, had to escape to France in 1863 from the Russian suppression of a Poland seeking freedom. Fighting against the Germans in 1870 at his own expense as a French army physician earned for Wasserzug senior no recompense whatever although he was gravely wounded in action. Pierre’s patriotic pride was no less deeply wounded on learning about this when he met in the fall of 1882 young Wasserzug, who for months could not be secure, in spite of his brilliant qualifications, about his acceptance to the Ecole. The culprit was once more the soulless bureaucracy unwilling to consider the difficult circumstances which prevented Wasserzug from spending with no interruption three years in the same town to qualify for citizenship. ‘Wasserzug’s camarades were indignant . . . They remembered that his father shed his blood for an invaded France. But what was the value of this to deserve the title of being a Frenchman in comparison to a few paper stamps and to a few hundred francs in legal fees?’¹⁰⁴

The bureaucracy of academic regulations interfered no less with young Wasserzug’s enormous capacity for learning, another fact to spark Pierre’s indignation. His friend’s mastery of five major modern languages (to say nothing of Latin and Greek), his versatility in biological science, his aptitude for mathematics as well as for literature, and above all the incredible ease with which he absorbed vast amounts of information, could not be accommodated within the academic cubbyholes. Rules of higher education were formulated with a view, Pierre wrote, to assure

to the utilitarian and calculating individual the banal triumph, void of common sense, in exams. Our friend had to realize this repeatedly at his own expense. His was however a too lofty intelligence to nurture the slightest regret. He never for a moment played two sides: that of the egotistic and safe work of a student who prepares for exams and that of a disinterested cultivation of the sciences . . . He was convinced that a few aggravations were not at all a high price for the pure and powerful satisfaction of the lover of truth.¹⁰⁵

Wasserzug, whom Hermite wanted to choose mathematics and who was eagerly accep-

102. Picard, ‘La vie et l’oeuvre de Pierre Duhem,’ pp. 3-4.

103. See Tome 1884-1889, pp. 57-62; 1889 (7).

104. *Ibid.*, p. 58.

105. *Ibid.*, p. 59.

ted by Perrier, director of the Museum in Paris, who had previously organized the section of natural history at the Ecole, was much more than a wizard of intellect. 'I have seen seven classes come and go at the Ecole,' wrote Pierre. 'I have seen there many and solid friendships form, because the youth of France has a wide open heart, but I have not seen, nor any of those, whose camarade I had the good fortune to be, has seen anyone so intensely, so profoundly, and so universally loved as Bronislav-Etienne Wasserzug.'¹⁰⁶

Before long Wasserzug was Pasteur's assistant. 'Those who at that time lived in the Ecole Normale, will they ever forget that crowd where Russians elbowed Arabs and Brasilians, all pressing toward the narrow door of the laboratory from which they exited cured to spread the praises of a great Frenchman among the nations? . . . But at the side of the great figure of Pasteur, will they not see forever Wasserzug, busy and overwhelmed, speak in their native tongues to men coming from all corners of Europe and encourage them all?'¹⁰⁷ Although charged by Pasteur with the supervision of the effects of inoculations, Wasserzug found time to produce a number of important papers. A few days after Wasserzug's death on March 30, 1888, the editor of the *Annales de l'Institut Pasteur* pointed out that Wasserzug was one of the first to study in a laboratory the rate of transformation in species, centering on various mushrooms.¹⁰⁸ Wasserzug's death came when Pierre happened to return from Lille to Paris to visit with his parents. He looked up at the Institut Pasteur his friend Wasserzug, ready with his doctoral dissertation and bursting with many projects. Next day, Palm Sunday, Wasserzug felt indisposed and stayed, at the urging of his wife, at home on Monday. A day later he was down with scarlet fever. Three days of heroic work by the physicians of the Institut Pasteur were of no help. He left behind also a three-month-old son.

Raised in the absence of any religious notion, Wasserzug at long last learned, owing to some devout friendship, about Catholic teaching, but once he knew it, he loved it with all his customary fervor. This fervor did not fail him in the last hour. Those who led his soul to the faith, those who blessed his marital union and the birth of his son, came to comfort him in his last trial . . . Accepting with resignation the immense sacrifice which God imposed on him and firmly believing that God would not abandon his spouse and son from whom he was now to be separated, he used the last lights of reason accorded to him to thank his colleagues, friends, and the nuns who cared for him . . . and on Good Friday noon his heart, which resonated with so many noble emotions, with so many pure affections, beat for the last time.¹⁰⁹

These lines were a reflection no less on Pierre than on his friend whose widow of only twenty found a lifelong support in him.

Young man in pursuit of rigor

A detail preserved by both Jordan and Récamier about Pierre, his steely resolve to

106. Ibid.

107. Ibid.

108. Ibid., p. 60.

109. Ibid., p. 61.

keep working even when in the grip of acute stomach pains, may serve as a background for a quick survey of the papers which Pierre published in the two additional years, which he spent at the Ecole following his graduation (promotion) there in the early summer of 1885. In the former of those two academic years, 1885-86, his extra fourth year at the Ecole, he saw through the press his ill-fated doctoral thesis, *Le potentiel thermodynamique*, a work that would have done credit in more than one respect to any leading physicist. During the same academic year Pierre sent three papers to the *Journal de physique théorique et appliquée* and presented himself twice before the Académie des Sciences with notes. In the first of those three papers to the *Journal* Pierre gave a mathematical derivation of the property, noted by Gauss, of Ampère's law that the interaction between two elements of current reduces itself to a single force acting along a straight line connecting those two elements. The next paper was an application of the thermodynamic potential to hygrometric bodies leading to 'unexpected correlations.' Pierre could not be less conscious of the fact that precisely such predictions were the hallmark of genuine theory. The third paper was noteworthy because it had for its target some experimental findings of Berthelot and of a co-worker of his, concerning the variations of the specific heat under constant pressure in hypoazotic acid. Pierre's theoretical analysis of those findings predicted 'slight discrepancies' from the data provided by Berthelot, a result which in turn led Pierre to extol Gibbs' purely thermodynamical approach over Boltzmann's kinetic theory. The latter, Pierre noted, yields simpler formulas but only at the price of simplifications not altogether justifiable, and does not have the advantage, unlike Gibbs' work, to rest uniquely on the two fundamental principles of thermodynamics.¹¹⁰ As if by irony, Duhem's criticism of Berthelot and his defense of the thermodynamic potential was followed in the *Journal* by an article of Lippmann.

By the time Lippmann could notice this curious sequence, he could hear Pierre claim before the Académie des Sciences on June 21, 1886, that the thermodynamic potential renders possible a 'complete study' of any mixture of volatile substances concerning their production of vapors.¹¹¹ Such was no empty boast. The short note, very rich in content, showed in a more general light partial results obtained by Kirchoff, Moutier, Isambert, and Regnault. A week later, on June 28, in another note, again endorsed by Debray, member of the chemistry section of the Académie, Pierre took issue with a recent paper in which Helmholtz noted that 'the formation of fog which indicates condensation does not occur exactly at the point of saturation but only at a lower temperature,' a circumstance which Helmholtz attributed to the influence of the curvature of the surface of the container. Pierre was eager to note with a reference to his longer memoir in the *Annales* that he had already pointed out that influence. Moreover, he added, 'in order to find the results which Mr. Helmholtz had in view to demonstrate it is not at all necessary to make approximations; . . . the reasonings which I have indicated in my memoir are enough for that purpose.'¹¹²

110. The remark was part of the article's concluding paragraph, devoted to a criticism of Boltzmann's kinetic theory of gases.

111. 1886 (2).

112. 1886 (3). The reference is to 1885 (3).

The stress on rigor was as much a piece of Pierre's mind as was his effort, though in vain, to have his priority recognized. It was not the last time that he failed in that respect. Immediately after Pierre's note, there followed, again as if by irony, a note endorsed by Lippmann who, as will be seen, chose to ignore a challenge by Pierre in a note to the Académie.

The productivity of Pierre during 1886-87 may have been expected to be less explosive as he had to spend part of his time as agrégé préparateur. Originally he hoped to have that year spent again exclusively in his own researches within the framework of Hautes Etudes. He was, however, persuaded by Georges Perrot, director of the Ecole since 1884, to take there the post in question. In his letter to the Ministry of Public Instruction Perrot described Pierre not only as one 'ready to put himself at the disposition of his younger camarades at the Ecole,' but also as one 'whose publications single him out in the judgment of competent persons as one of the young men whose work will advance science.'¹¹³ The post to which Pierre was appointed on October 20, 1886, was his first paying employment with a salary of 2400 francs per year or 200 francs per month, supplemented with room and board at the Ecole.¹¹⁴ Although his job was time-consuming, Pierre's productivity did not slacken. No sooner had the academic year 1886-87 got under way than he went before the Académie with a note, again supported by Debray. He called attention to a very recent publication in a leading German periodical on chemistry whose author, in apparent unawareness of his longer memoir, obtained 'through synthetic reasoning' results identical to the ones already published by Sir W. Thomson. 'May I be allowed,' wrote Pierre, 'to point out that the reasoning of Mr. Warburg, as well as those of Sir W. Thomson and of Mr. Robert [sic] von Helmholtz, does not take any account of the influence of capillary tension, whereas my formulas put in evidence the influence which this pressure exerts; from the fact that this pressure introduces in the formulas terms whose magnitude cannot be known *a priori* one cannot legitimately conclude that the latter terms are negligible.' Pierre drove home his point relentlessly: 'At any rate, the discrepancy of results obtained on the one hand by Sir W. Thomson and Mr. Warburg, and by Mr. Helmholtz on the other, shows how necessary it is to apply the greatest possible rigor to considerations concerning this complex topic.'¹¹⁵

113. Perrot's letter (Dossier Duhem) was dated October 16. He was to take the post of Pionchon, who will be met again later and was described as one whose nomination 'will not lend itself to the well-founded objections provoked by the candidacy of Mr. Poincaré.' The letter also mentioned that Duhem finished first in the concours for agrégation in 1885.

114. About Duhem's salary, then as later, it should be kept in mind that France was spared of inflation during the four decades prior to World War I, the period of his education and career. Around 1910 a student could comfortably live in the Quartier Latin on 200 francs per month. At that time some agricultural products cost less than in the 1870s. The price of one kg of butter (2 fr 90 centimes) was, for instance, exactly the same in 1913 as in 1860. Coffee, sugar, and tea could be had cheaper in 1913 than forty years earlier (see Recouly, *The Third Republic*, tr. E.F. Buckley [London: William Heinemann, 1928], pp. 348-49). Duhem's salary as an agrégé préparateur compares favorably with the 150 fr per month which Langevin received ten years later as Lippmann's préparateur and even with the 300 fr per month which Curie drew about the same time as a researcher who had to provide for all his living expenses.

115. 1886 (4).

Pierre's notes to the Académie on March 7 and 14, 1887, offered corrections to Kirchoff's formulas concerning saline solutions.¹¹⁶ In two notes, presented on June 6 and 13 respectively,¹¹⁷ he submitted that the application of thermodynamics potential to the Peltier effect makes possible the elimination of certain difficulties inherent in Sir W. Thomson's theories. In the second of the notes Pierre traced the erroneous conclusions of Göckel to his misinterpretation of Gibbs' ideas on the difference between chemical heat and voltaic heat. Far more important than another communication by Pierre to the *Annales de chimie et de physique* should seem his almost fifty-page-long essay on Gibbs' thermodynamics published in two installments in the June and July 1887 issues of the *Bulletin des sciences mathématiques*. The essay would have rendered a pioneering service in disseminating Gibbs' ideas in France even if it had been but a summary of the contents of Gibbs' papers in the *Transactions of the Connecticut Academy of Science*, a publication hardly accessible in France. Pierre's were vaster vistas. 'We shall try to show in the first place,' he wrote, 'how the basic principles of thermodynamics lead to the new method of Gibbs; and in the second place, we set forth the history of attempts made prior to Gibbs in the same direction and of the applications made since of that method.'¹¹⁸

The essay contained a specification of the respective contributions of Clausius, W. Thomson, Gibbs, Helmholtz and came to a close with an insistence on Gibbs' priority over Helmholtz concerning the fundamental rule of voltaic piles, a rule which was already being referred to as Helmholtz's theorem. In his sense of justice Pierre was quick to note that 'a work which we have published on this question at a time when we had unfortunately an incomplete knowledge of Gibbs' publications, is possibly not entirely free of responsibility for having introduced this erroneous label.'¹¹⁹ The work was his own *Potentiel thermodynamique* which, in a display of striking modesty, Pierre did not mention by name, as he showed how Gibbs' ideas invited the notion of thermodynamic potential. Clearly, Pierre was motivated above all by his desire to promote the cause of physics itself. He certainly was not to be bogged down in unnecessary polemics. As he surveyed the historical antecedents of Gibbs' theories he referred to Berthelot as the first who addressed himself, by formulating the maximum work principle, to the question as to what corresponded in thermodynamics to the role which the principle of virtual velocities, or potential, played in mechanics. Coupled with Pierre's silence on Thomsen such was a most generous appraisal of the contribution of Berthelot who could hardly take offence for Pierre's claim that although the principle of maximum work was 'easy to apply . . . it was most useful in the study of energy exchanges in chemical reactions, . . . it admitted many exceptions.'¹²⁰ The remark was all the less offensive as it formed part of a historical survey of previous efforts to achieve as much rigor as possible on the subject. In fact, Gibbs was not spared of criticism as Pierre, in his quest of rigor,

116. 1887 (2) and (3).

117. 1887 (4) and (5).

118. 1887 (16) p. 123.

119. *Ibid.*, p. 174.

120. *Ibid.*, p. 163.

pointed out at the very start that Gibbs' theories were not developed with enough rigor to please the mathematicians. The experimentalists in turn were reluctant to test theories whose cogency was in dispute. An appraisal of Gibbs' theories involved therefore a careful look at the very foundation of thermodynamics. But, Pierre asked, 'is it not useful to submit to a rigorous discussion the basic principles of the various branches of physics, if one wants that this science should approach more and more the precision of the mathematical sciences?'¹²¹

The same volume of the *Bulletin* contained a precious insight into the horizons within which Pierre saw the accomplishment of the task of perfecting physics. In a review of the French translation of Maxwell's *Treatise on Electricity and Magnetism*, he wrote: 'Maxwell's *Treatise* faithfully represents what the science of electricity is in the country of Green and Faraday. The fundamental ideas and the manner of presentation notably differ from the doctrine and mode of exposition adopted in the country of Coulomb and Ampère as well as in the country of Gauss.' From this it would have been most tempting to draw a conclusion savoring of chauvinism at a time when French science eagerly sought to recover its erstwhile leadership. But Pierre was committed to the fullness of truth regardless of national provenance. 'Perhaps the [French] reader of Maxwell's work will regret the absence there of the clarity of French physicists and of the rigor of German geometers; yet, the methods of the English mathematician will help him in the discovery of new consequences by forcing him to retrace the principal theories of electricity in an order different from, and sometimes inverse to, that to which he is accustomed.'¹²² These lines were so many anticipations, in a nutshell, of a famed analysis to be given by Pierre two decades later of the colouring of the physicist's reasoning and discourse according to his national origin. In this connection too, Pierre, still in his mid-twenties, had a keen consciousness of ideas that were to distinguish his work for the rest of his life. The same lines certainly prove that whatever his insistence on the cultivation of physics in a French spirit, it meant the very opposite to an intellectual isolationism. At any rate, it was a recognition of Pierre's excellence that Darboux and Tannery, editors of the prestigious *Bulletin*, committed to a mere agrégé préparateur the review of a translation to which Cornu, member of the Institut, and Potier and Sarrau, professors at the Polytechnique, wrote lengthy notes and clarifications.

As an agrégé préparateur, Pierre was in correspondence with the famous Dutch physical chemist, Van't Hoff, a future Nobel laureate, whose work on osmotic pressure he subjected to a critical analysis in the March and September 1887 issues of the *Journal de physique théorique et appliquée*.¹²³ The analysis was a reinterpretation on the basis of the thermodynamic potential of Van't Hoff interpretation of his own findings. As one could expect, Pierre was not afraid to point out the shortcomings of Van't Hoff's reasoning whatever its importance. That such a procedure

121. *Ibid.*, p. 123.

122. 1887 (17), pp. 11-12.

123. 1887 (11) and (13). Pierre had already been in correspondence with Clausius who in a warm letter (Oct. 26, 1885) expressed his delight about Pierre's readiness to translate his works into French.

was in no way offensive, except for men of science too conscious of themselves, was witnessed by a letter of Van't Hoff to Pierre which the latter quoted with obvious satisfaction at the end of his second paper: 'If I am not mistaken in this opinion, the thermodynamic potential presents in its application a route much simpler to arrive at relations presented by the osmotic pressure than the one which had to be followed so far, and will not fail to signal new relations.'¹²⁴

Another article of Pierre published in the August issue of the *Journal* dealt with the work of Pierre Curie, another future Nobel laureate, on piezo-electricity. The gist of Pierre's approach concerned the finding of the mechanism which establishes an equilibrium within a turmalin crystal the various layers of which are at different temperature. The mechanism was such only in name. In reality it was a thermic phenomenon and the grand conclusion readily followed: 'In terms of that theory, the piezo-electric phenomena are but pyro-electric phenomena in which the crystalline surface is heated by compression; indeed the pyro-electric phenomena produced in conductors are but thermoelectric phenomena produced in conductors whose lack of homogeneity is due to their reticular structure; consequently, if this theory is exact, these three chapters of physics, thermo-electricity, pyro-electricity, and piezo-electricity, are found united in one chapter which thermodynamics allows to treat in a manner entirely rational.'¹²⁵ This rational manner consisted in being free of the arbitrary hypotheses of mechanics.

A minor but telling part of Pierre's paper was a reference in it to Lippmann's verification of the inverse of piezo-electricity, namely, that the electrification of crystals must issue in a change of their volumes.¹²⁶ Clearly, Pierre had no intention of being silent about achievements even though they did credit one who had already displayed toward him an attitude hardly commendable. Recognition of a definition given by Lippmann was also part of Pierre's essay on Gibbs in the *Bulletin*. One can only guess Lippmann's thoughts on seeing in the fourth volume of the *Annales scientifiques de l'Ecole Normale Supérieure* published in 1887 a memoir of fifty pages by Pierre, in comparison with which most doctoral theses in physics at that time and for a long time afterwards paled in significance. The memoir, on vapors emitted by the mixture of volatile substances,¹²⁷ started with a reference to Moutier as the only one to have applied previously to that problem the principles of thermodynamics. The memoir contained several references to Pierre's rejected thesis, for a year in print, hardly a pleasure to Lippmann to see. Here again, as was the case with the volume of 1885 in the *Annales*, Pierre's was the longest of the more than a dozen contributions, all by professors or maîtres de conférences. The volume not only started with Pierre's memoir but also came to a close with another, twenty-five-page-long memoir of his on some formulas concerning saline solutions.¹²⁸ Its first chapter was entitled 'Historique' and contained a survey of the question from a memoir Kirchoff published

124. 1887 (13), pp. 413-14.

125. 1887 (12), p. 373.

126. *Ibid.*, p. 372.

127. 1887 (14).

128. 1887 (15).

in 1858 to a communication by G. Chancel and F. Parmentier in the *Comptes rendus* on Feb. 21, 1887, a remarkable attention to the very latest. Pierre's quoting two years earlier Lamé's words on the instructiveness of the history of conceptual development was not a gesture of rhetoric.

While the *Annales scientifiques* of the Ecole Normale were widely read in scientific circles in Paris, the same can hardly be said of the *Acta* of the Scientific Society of Finland. The impending publication in its volume for 1888 of a hundred-page-long memoir completed during his fourth year at the Ecole was in all likelihood mentioned by Pierre in his application for a teaching post which he must have submitted to the Ministry of Public Instruction sometime in late spring 1887. Quite possibly Pierre's enormous productivity during his two extra years at the Ecole, a total of over six hundred pages in mathematical physics and physical chemistry, was motivated in part by the hope that his impressive list of publications would more than offset the rejection by the jury presided over by Lippmann of his doctoral thesis. He may even have referred to his having completed another thesis, in 'mathematics,' to enhance his prospects. He was of course given a teaching post and a far better one than most new graduates of the *grandes écoles* could hope for. While they were usually given a post in a good lycée, on rare occasions in Paris, Pierre received on October 13 a university post, though not in Paris but in Lille. He also learned that his salary was to be 4500 francs per year as suited a beginner, however eminent. Had he suspected that his assignment meant the beginning of a life-long exile from Paris, his disappointment would have known no bounds.

3. LECTURER IN LILLE

Citadel against citadel

On taking the train, sometime in late October 1887, in the still-to-be-completed Gare St. Lazare from Paris to Lille, Pierre Duhem knew all too well, in more than one sense, where he was going. He may have heard a thing or two from Joseph Boussinesq, who took a chair at the Sorbonne in 1886 after serving for fourteen years as professor of mathematics in Lille and who soon developed a keen appreciation of Duhem's work in theoretical mechanics. At any rate, it was all too obvious that for the previous seven years the Third Republic had been busy turning Lille into a bastion of secularism. The campaign was launched by none other than Jules Ferry, often referred to in those times as the 'apostle of laicization.' Duhem could hardly help recalling that by volunteering cartoons to an anti-Ferry album he had already been in the ranks of Ferry's active opponents. These were numerous in Lille, the great industrial capital of the North and also a stronghold of French Catholicism, where Ferry's arrival, on April 24, 1880, at the main railroad station provoked huge demonstrations.¹

Many of the demonstrators were students of the Institut Catholique of Lille, a flourishing establishment though only five years old, to which the title 'université' was denied by law since it was not under state control. (The discrimination became rudely offensive from the 1890s on when the title 'université,' reserved by a decree of Napoleon to the entire French higher education system, was bestowed on provincial French universities which until then had been mere 'Académies'). The students could hardly be sympathetic to the laying on that day of the cornerstone of new and lavish buildings for the faculty of medicine, part of a state university, officially still the 'Académie de Lille,' slated for a great expansion. They knew that the move was also aimed against them as the Institut's strongest branch was its medical school

1. Described vividly in P. Pierrard, *Lille et les Lillois: Essai d'histoire collective contemporaine (de 1815 à nos jours)* (Paris: Bloud & Gay, 1967), p. 201. Demonstrators of the same persuasion celebrated Ferry's death in 1893 with a night-long serenade under the windows of the *Progrès du Nord*, the chief Republican daily of Lille.

and clinics. They also knew that the state university in Lille was not much older than their Institute. The center of higher education in the North had for centuries been Douai, but only modest instruction was offered there in the sciences and none in medicine. An imperial decree of 1854 established in Lille a science faculty as a branch of the 'Académie de Douai' to which in 1875 a faculty of medicine was added. Located in cramped accommodations it was no match for the corresponding faculty at the Institut Catholique. At any rate, since the art of healing has always demanded more than knowledge, the devotion, which Christian faith inspired toward the sick, assured a special appeal to hospital clinics in care of the religious. Ferry must have had this too in his mind as he went to Lille and, with an allusion to the pride of Lille, the famed citadel built by Vauban, he fulminated: 'It has been said that the city of Lille had been a city of clericalism. Gentlemen, we now raise here a citadel against a citadel in the vast field of liberty.'² It escaped Ferry that the field in question was soon to shrink rapidly because of a long series of new laws of which he was the erstwhile champion. Similar was the tone and inconsistency of speeches delivered later that day at the banquet given in Ferry's honor in the Hôtel de Ville where he received a petition calling for the transfer from the old university town of Douai to Lille of the faculties of law and letters.

Although the petition was on behalf of a foregone conclusion, its implementation had to wait further strengthening of the Republican regime. When Berthelot became president of the Conseil Supérieur of Public Instruction, the hour of decision struck. In January 1887, the editor of *Progrès du Nord*, the leading Republican daily of Lille, felt encouraged to plead unabashedly: 'The elected representatives of higher instruction will rise above the level of the belfries of Lille and Douai . . . If the Faculties of State University had formed a tight unit ten or so years ago, instead of being scattered, the clericals would have hesitated before creating a Faculté Catholique . . . The reuniting of the Faculties is a must if one is to fight successfully the teaching given under the auspices of clericalism.'³

Not even fervent Republicans in Douai were ready to sacrifice the last portion of their ancient university to the 'sacred cause.' Léon Maurice, the deputy from Douai, tried to prevent the transfer even at the last minute with a speech in the Chamber of Deputies. He depicted Lille as a systematic exploiter of Douai since the time of Napoleon: 'If Lille could have asked for the transfer of the mines of Anzin [near Douai], she would have done it.' Furthermore, he argued, with even less persuasiveness, 'from Lille to Douai it is only 35 minutes by train, the time it takes to go from the Panthéon to the Gare St. Lazare.' He hardly made a better impression with his next point: 'The students of the State University, whom the Government wants to oppose to the students of the 'Catho' [Institut Catholique], will be lost through exposure to the pleasures of the big city.'⁴ In Douai feelings ran high. When in early

2. Ibid.

3. Quoted in L. Trenard, *De Douai à Lille, une université et son histoire* (Lille: Université de Lille III, 1978), p. 84.

4. Ibid., p. 87.

November 1887 a group of notables travelled from Paris to Lille, gendarmes had to be posted along the tracks in the Douai area, lest some angry citizens of Douai make good their threat to derail the train.

The transfer of the faculties of law and letters was made official by a government decree on October 22, 1887, just about when Duhem arrived in Lille. He went there full of ambitious plans which he carried out, as will be seen, brilliantly. A clue to his success was his keeping aloof of politics. He could hardly suspect that one day he was to transgress, however slightly, the absurd administrative line drawn between free (Catholic) and State education and much less that it was to be the start of an unfortunate, abrupt ending of his stay in Lille. He was undoubtedly present at the banquet at the Hôtel du Maisniel, which witnessed the installation, on Sunday, November 6, of Henry-Auguste Couat as rector of the 'Académie de Lille.' The words exchanged on that occasion between Couat and Duhem very likely included a recall that both were alumni of the Ecole Normale.⁵ Couat had already earned fame not only as a classical philologist, but also as a militant leftist who received several reprimands under Napoleon III. His fortunes took a turn for the better with the advent of the Third Republic when he obtained a chair in Bordeaux. His prospects further improved when the Republicans came into power in 1880. He became member of the Conseil Supérieure of Public Instruction and was put in charge of drafting the decree which on December 31, 1885, restricted the liberties and privileges of Catholic establishments of higher education. The appointment of Couat as the first rector of the four faculties in Lille was in part a political reward and a token of further services. Duhem could hardly suspect that Couat would again be his rector at another place (Bordeaux) where he was to witness an unusual incident at Couat's funeral.

What Duhem certainly knew was that in a sense he was more accountable to the dean of his own faculty than to the rector of all faculties. Prior to the unification in 1896 of the Faculties of local Académies into Universities properly so-called, their respective deans had considerable control over them and such was certainly the case in Lille during the six years when Duhem served as maître de conférences (lecturer) and later as chargé de cours (assistant professor). He was, of course, under no official obligation to help build 'a citadel against a citadel,' a task which was not easy to implement in spite of official and vigorous support from Paris. As to the citadel to be opposed, it achieved during its first ten years a degree of excellence which prompted Ernest Lavisé, professor of history at the Sorbonne and a chief theoretician of the educational policy of the Third Republic, to remark that the new State University of Lille should view it an honor to be in the vicinity of the Institut Catholique.⁶ As to the support coming from Paris, it could not necessarily be harnessed for the purposes of anticlericalism. There were, of course, some eager crusaders. An elderly professor of Greek, inherited from Douai, was renowned for his

5. Couat was fifteen years Duhem's senior.

6. Quoted by G. Goyau, 'Lille', *CE* 9:253. Lavisé was a chief target of the rightist Action Française; see P. Lasserre, *La doctrine officielle de l'Université* (4th ed.; Paris: Garnier Frères, 1913), pp. 358-60.

anticlerical antics. One day, as he was discoursing on the Gnostics, he stood up and cried out: 'Thunder Jehovah, thunder, if you exist!' And there he stood silently, with his arms folded, for half a minute, waiting for the thunder from on high.⁷

The source of this story is also a chief source of information on Duhem's years in Lille, a long letter sent in the 1930s to H el ene Duhem from Andr e Chevrillon, member of the Acad mie Fran aise. Chevrillon came to Lille to teach English literature in February 1889, or a little over a year after Duhem arrived there. Chevrillon, a nephew of Taine and soon to earn fame with his *Dans l'Inde* (1891), was one of several of unusual brilliance among the younger faculty whom Paris was eager to secure for the State University in order to offset the eminence of the Institut Catholique. Another was Paul Painlev  who entered the Ecole Normale two years after Duhem and quickly made a name for himself with his papers in mathematics.⁸ Between Duhem and Painlev , who were appointed at Lille at the same time, there developed a close rapport the basis of which was not so much a personal harmony as an admiration for their respective intellectual appetites. Through his ties with Painlev , Duhem made good acquaintance with Gustave Demartres, already for a year in Lille in charge of the courses in mathematics as Boussinesq's replacement. In October 1888 Demartres became professor and dean of the science faculty and thus Duhem's immediate superior. Demartres could not help being impressed by Duhem's grasp of mathematics, by his productivity, and last but not least, by the electrifying impact Duhem made as a teacher from the start. Duhem befriended the thirteen-year-old Demartres to the point that the latter asked Duhem to 'tutoyer' him,⁹ a custom reserved in France only to family members and close friends.

The same number of years, thirteen, was the difference between Duhem and Beno t Damien, who had been teaching physics in Lille since 1880 and had the rank of associate professor (adjoint) when Duhem arrived. The death on July 16, 1887, of Paul Augustin Terquem,¹⁰ an able experimenter, left the chair vacant. The sudden need for a teacher of physics prompted the apparently last-minute appointment of Duhem in Lille, a circumstance suggested also by the absence of his name from the official list of programs of the 'Acad mie de Douai' for the year 1887-88, a forty-one-page booklet, which lists Painlev , equally a new arrival there.¹¹ While Damien

7. *Un savant fran ais*, p. 62.

8. It was with an eye on Painlev 's series of notes published in the *Comptes rendus* in 1887, the year Painlev  started teaching in Lille, that after his death in 1933 Hadamard eulogized him with the words that 'continuing [the work] of Henri Poincar  was not beyond human capacity' ('Painlev , Paul,' *Dictionary of Scientific Biography*, 10:275).

9. As pointedly noted by the rector, Bayet, in his letter of July 12, 1893, to the Minister of Public Instruction concerning Duhem's clash with Demartres, which will be discussed later (Dossier Duhem, p. 183).

10. Terquem, who first served at the universities of Strasbourg and Marseilles, became occupant of the chair in physics in Lille in 1880. His research interests included the construction of apparatus to demonstrate the propagation of sound in gases.

11. See *Acad mie de Douai. Programmes annuels des cours d'enseignement sup rieur. Ann e 1886-87* (Douai: Imprimerie O. Duthilleul, n.d.). Terquem's name is already omitted in the list of physics teachers, but he is still listed as one directing the program for licence (p. 34).

certainly showed talent in developing in the 1890s a new physics building with up-to-date laboratories, as a lecturer and a theoretician he could in no way match Duhem's brilliance. By 1887 Duhem published more than Damien did during his teaching career of almost forty years,¹² which ended in 1916 with his retirement from the chair of physics in Lille. Such contrast could easily keep personal rapports on the formal level and could readily be noticed by students. These could not help noticing in the subsequent years that Damien, in charge as professor of preparing the list of publications by physics faculty for the university yearbook, not only failed to list all of Duhem's publications, but never elaborated on their contents, although he did so with respect to his own, rather insignificant papers.¹³ On being exposed to Duhem's teaching, students could sense that in physics at long last, Lille would live up to that standard which Pasteur, the first dean there of the science faculty, set in 1854 with a ringing declaration well remembered there: 'When one is third, one must become second, when one is second, one must become first, and when one is first, one must remain first.'¹⁴

Encomiums from officialdom

About Duhem's first year in Lille as about almost every year of his career as a teacher, priceless details are contained in the annual reports which his dean and rector had to send, as was the case with every other faculty member, to the Ministry of Public Instruction in Paris. As the years went by, these reports could easily grow into a thick dossier and this is what happened in Duhem's case. The yearly reports consisted of two parts. One contained data on the teacher's courses and salary and was certified by his signature. The other, the teacher's confidential evaluation as a person and as a professional by his dean and rector, was sent to Paris without being shown to him. Duhem's official workload, throughout his career, was very light by present-day standards. During 1887-88, he taught, according to the report, one course on electrical theory to 27 students three times a week for an hour and a quarter. As to his comportment, Couat, the rector wrote: 'Duhem is a very brilliant professor, offers additional courses for students for agrégation. He devotes himself entirely to his teaching. His character is somewhat lively. An impressive thinker.'¹⁵

In the list of courses for 1888-89 as printed in the *Livret de l'étudiant*, Duhem is identified as 'agrégé des sciences physiques, maître de conférences,' again with only one lecture per week, on Monday at 2:15. The subject of his lecture is only generally

12. Damien co-authored with R. Paillot (whom we meet later) a laboratory manual (1896). The half a dozen articles of Damien listed in Poggendorff (1904) fall between 1885 and 1891. Nothing new is listed from Damien in the next edition of Poggendorff covering the years 1904-1922.

13. The situation was particularly glaring concerning the year 1890-91. See *Académie de Lille. Séance de rentrée des Facultés de Lille, 21 novembre 1891* (Lille: L. Darnel, 1891), pp. 90-91. This was the yearbook which contained the rector's account of the previous academic year, the text of a speech (discours d'usage) delivered on the occasion by a faculty member, and the various statistics concerning courses and the financial and physical state of the university.

14. *Académie de Douai. Installation solennelle de la Faculté des lettres de Douai et de la Faculté des sciences de Lille* (Douai: Adam d'Aubers, 1854), p. 25.

15. The report was dated, June 30, 1888 (Dossier Duhem, p. 163).

described as ‘matières du programme de licence.’¹⁶ According to the yearly report sent to the Ministry, Duhem taught in the same year a course on the mechanics of fluids twice a week to 7 candidates for agrégation. In the confidential part of the report, Demartres as dean wrote that Duhem’s ‘zeal and punctuality were above all praise,’ and that although his ‘straightforward and honest character’ could at times be ‘not entirely correct’ these faults were ‘insignificant in comparison with his qualities.’ Demartres filled the entry, ‘does he have right for advancement?’ with the words: ‘It would be desirable that once Duhem reached the regulatory age [of thirty] he should be given a professor’s chair.’¹⁷ Couat’s appreciation of the brilliant young teacher was no less enthusiastic:

Since my arrival in Lille Duhem devoted himself to his duties with extreme zeal. Neither the vast amount of his personal research, nor the poor condition of his health have impaired his teaching. In spite of his preference for the difficult problems in mathematical physics he knew how to enable his listeners to savor their studies which at the start could appear to be above the expected level of teaching. Apart from some defects of mere formalities, in respect to his character, everybody recognizes his rectitude and his moral qualities.¹⁸

A year later, on June 5, 1890, Couat sent to Paris the following report on Duhem:

His teaching is both profound and brilliant. This professor is absolutely devoted to his students, and in order to make himself useful to them, he never recoils from any additional work. The small faults of character that could be charged against him are rather on the decrease. Among the maîtres de conférences of the entire Faculty Mr Duhem is the only one who never obtains additional remuneration. Yet he is not the youngest among them and he is certainly one of the most distinguished. I request for him an increase in salary.¹⁹

For another three years Duhem’s salary stayed at 4500 francs per year, the lowest possible level for a maître de conférences. Berthelot’s sentence on Duhem seemed to be obeyed in more than one way, even when a trusted Republican pleaded on his behalf. Duhem’s salary was not raised even though on July 30, 1890, he was officially given the assignment of an additional course of mathematical physics and crystallography (chargé d’un cours complémentaire).

Duhem’s teaching load still could not be considered heavy, at least by modern standards, when in 1890-91 he lectured on Monday and Wednesday afternoons at 2:15 on hydrodynamics, elasticity, and acoustics in the program for licence, on Tuesday afternoons at 3:15 on rotatory polarisation to candidates for agrégation, and on Wednesday mornings at 9:30 he supervised lectures given by those candidates on the methods for ascertaining chemical equivalents and atomic weights. Duhem’s

16. Right there (p. 19) Damien was listed as giving a course on optics twice a week.

17. Dossier Duhem, p. 124.

18. Ibid., p. 125.

19. Ibid., p. 119.

performance prompted Demartres to superlatives:

Mr. Duhem is certainly one of the most distinguished professors of the higher education. It would be most desirable that through the creation of a chair he may be attached definitely to the University of Lille. I insist above all that his salary be raised to a higher figure. It is regrettable that he should be less favored in that respect than most of the chargés de cours or maîtres de conférences at the University who have neither his seniority nor his scientific qualifications. His devotion to his duties and to his teaching is absolute. The very important personal researches, to which he devoted himself during this year, did not prevent him from being to the immediate service of his students for whom he published his course of mathematical physics.

So wrote dean Demartres in his confidential report on Duhem on May 20, 1891, which was effective in that Duhem's modest salary was niggardly raised from 4500 to 5000. Couat, the rector, added in his turn: 'Duhem is an outstanding savant. He is not viewed as one with a very easy character and he had some difficulties with some of his colleagues. [But] since I have been in Lille no such incident has been [found grave enough to be] brought to my notice, and the dean asserts that Duhem's character improves as does the condition of his stomach.'²⁰ The significance of Demartres' additional remark, 'Never involved in any activity foreign to his functions at the University,' will be clear shortly. The foregoing portrayal shows Duhem, association with whom may have been on occasion uneasy, as a most valuable teacher and scholar. Official recognition of this came during the year 1891-92 from Paris in the form of granting Duhem with five other faculty members the 'palmes académiques.' It must not have been therefore mainly Duhem's fault when suddenly his shortcomings began to be recalled by his superiors with a distinctly different emphasis. At any rate, those shortcomings had to be all the more tolerable as otherwise he would not have been called to serve from 1890-91 as one of the four faculty advisers to the Student Union,²¹ an evidence of his popularity with students who hardly ever take kindly to 'uneasy' teachers. Among the four was his good friend Paul Fabre, professor of medieval history, whom we are going to meet later. Duhem was all the more accessible to students as during his first two years he lodged in the heart of old Lille, at 12 Rue Masurel, just behind the Cathedral called Treille. He was about ten minutes' walk from the cramped accommodations of the physics department and its laboratories on the Rue des Fleurs, just two blocks south of the Place de la République, Lille's main square, following the city's modernization during the Second Empire.

The list of courses for 1892-93 is of special significance. One of Duhem's two courses is described there as 'Mécanique chimique fondée sur la Thermodynamique.' As was the case with his courses on hydrodynamics, elasticity, and acoustics, which quickly appeared in lithographed form,²² Duhem's course on chemical mechanics

20. *Ibid.*, p. 115.

21. *Livret de l'Étudiant, 1890-91*, p. 107. The four places on the committee were distributed among the four faculties of philosophy, letters, law, and medicine.

22. 1891 (2).

also showed the utmost care with which he prepared the text of his lectures. His students were invariably treated to a discourse ready for the printer. They could easily catch a glimpse of Duhem's extraordinarily even and beautiful handwriting in large letters which hardly ever showed a trace of change or erasure. In that year Duhem's courses were announced under the special heading, 'physique mathématique et crystallographie.'²³ The heading was an on an equal footing with 'physique' under which there were listed the courses of Prof. Damien and of Mr. Paillot. The latter, promoted in 1890 from assistant, which he was when Duhem arrived, to the head of the laboratories, remained of course subordinate to Duhem who by then handled all forms of instruction relating to more than introductory physics. Damien limited himself to introductory courses and laboratory exercises as the best policy to avoid competition with Duhem, too brilliant a theorist. Paillot, as will be seen later, may have tried to endear himself to Damien by making life difficult for Duhem whose superiority could easily be a thorn in the side of Paillot who in 1892-93 did not yet have his doctorate.

A brilliant doctorate

From 1889-90 Duhem was no longer described as *agrégé des sciences physiques* but as *docteur ès sciences*. Strictly speaking, he should have been described as *docteur ès sciences mathématiques*, although the subject of the (second) doctoral dissertation was genuine theoretical physics. It must have been ready by October 1887, when he departed to Lille, because its main results were presented in a series of four brief communications to the Académie des Sciences between October 24 and December 19, 1887.²⁴ Demartres, as well as the rest of the science faculty, must have been familiar with the story of Duhem's first effort. The eventual outcome of his second effort may have been subject to some speculation on their part though not for long. On February 15, 1888, the thesis was officially approved for publication by E. Hébert, dean of the Faculty of the Sorbonne.

That Duhem was permitted to present another thesis within two years, and essentially on the same topic, was an indirect admission by the Sorbonne that a signal injustice was to be redressed. Faces had, of course, to be saved and protected. The title of the thesis, *L'Aimantation par influence*²⁵ (magnetization by induction),

23. *Livret d l'Etudiant, 1892-93*, p. 18. One of those courses was on capillarity. The text of that course is most likely the manuscript, 'Leçons sur les théories de la capillarité,' of 434 pages, written on sheets of 30cm x 23cm, now in the Archives de l'Académie des Sciences. The manuscript is conspicuous by the very few references in it to published works. The latest publication mentioned there (p.422) is a work of Helmholtz from 1883. Had Duhem intended the manuscript for publication, he would have certainly included the very latest with detailed documentation. The handwriting with its elongated letters is characteristic of Duhem's younger years. From 1900 or so on the letters of Duhem's writing were increasingly more roundish and at times indicative of the shaking of his right hand. Of the 20 chapters, the first 6 give a survey of theories from the precursors of Laplace to Mathieu. The remaining 14 chapters give a theory of capillarity based on thermodynamics, with emphasis on various aspects of the formation of very thin layers of liquid and their interactions.

24. 1887 (6, 7, 9, 10).

25. 1888 (1).

did not include the word 'thermodynamics,' the field of Berthelot and Lippmann. Yet the topic of the thesis was not only thermodynamics throughout, but its very backbone was the 'thermodynamic potential' which caused the rejection of Duhem's first thesis through its application to chemical phenomena. In the new thesis Duhem could easily avoid any reference to Berthelot's maximum work principle, and no less importantly, he could put the 'thermodynamic potential' in a much broader light, as a means of allowing generalization over separate branches of physics. Demonstration of that broader applicability depended of course on a penetrating analysis of mathematical formulas governing electromagnetics and thermodynamics, a task that certainly suited Duhem's talents. It also allowed the classification of the thesis as one in mathematics and the selection of a jury of three of which the president and at least one member were professors of mathematics at the Sorbonne. Since Hermite, professor of higher algebra, and Picard, professor of calculus, were members of the jury of Duhem's first thesis, they could not be called upon again. Fortunately, the Faculty of Science had also on its roster Darboux, as professor of higher geometry, and Henri Poincaré, as professor of calculus and of mathematical physics. The addition to the jury of Edmond Bouty, Lippmann's colleague as professor of physics, did not therefore change its 'mathematical' character.

The sole satisfaction which Berthelot and Lippmann could derive from the report of Darboux, the jury's president, was that it had to remain unpublished. In an almost direct contradiction of Lippmann's highhanded and hollow dismissal, two years earlier, of the notion of thermodynamic potential, Darboux extolled the profundity and manifold application which it obtained through Duhem's 'long researches carried out in a manner worthy of a savant' on a subject which is 'one of the most difficult and arcane in mathematical physics.' Bouty, who prior to his appointment at the Sorbonne served as 'maître des conférences' at the Ecole Normale, described the thesis as having 'incontestable originality and importance.'²⁶ Unfortunately, Poincaré's report seems to have disappeared. That the thesis earned for Duhem not a doctorate in physics but in mathematics (a circumstance which later caused him difficulties) was part of an inevitable 'maneuvering.' Its chief strategist was Jules Tannery to whom the thesis was dedicated as 'hommage de reconnaissance et de respectueuse affection.' In reviewing Duhem's thesis in the prestigious *Bulletin des sciences mathématiques*, Tannery listed it under the title, 'Théorie nouvelle de l'aimantation par influence fondée sur la thermodynamique.'²⁷ By this departure from the printed title Tannery obviously wanted to make a point which could not be lost either on Berthelot or on Lippmann. They could be even less pleased by Tannery's characterization of Duhem's thesis as an 'important work which permits to clarify the contradictory ideas submitted on the question by several authors.'²⁸ Among these listed by Tannery were no less prominent names than Kirchoff and Sir W. Thomson.

26. Dossier Duhem, p. 128.

27. 13 (1889):252-55.

28. *Ibid.*, p. 254.

As a director of scientific studies at the Ecole Normale, Tannery was of course familiar with the reports of the jury and also with their satisfaction with Duhem's written discussion of the secondary theses assigned to him by the Faculty. One was on Massieu's characteristic functions, the other on Bertrand's formulas on vapor tension. In the name of the jury Darboux wrote that its members 'by placing only white marbles [in the balloting urn] wanted to reward as much as it was in their power, the long and remarkable work of Mr. Duhem.'²⁹ Shortly afterwards, on October 4, the physicist P. Joubin, who functioned also as Inspector of Higher Instruction, sent to the Ministry of Public Instruction his report which ended with the phrase: 'The Faculty declared with unanimity Mr. Duhem worthy of the degree of doctor by casting all white marbles.'³⁰ The importance of this remark was properly noted by the Ministry, where the clerk was instructed to write in big letters on the margin of Joubin's report, 'Toutes blanches.'

To defend his thesis on Tuesday, October 30, 1888, at 3 in the afternoon, in the grand auditorium of the Sorbonne, was hardly a problem for Duhem, already a master of oral exposition. Joubin was visibly impressed: 'Duhem as a professor has eminent qualities which he had already demonstrated at the competitive exams for agrégation in 1885. His oral presentation of his research was done in a remarkable manner and his replies to the questions posed by the Faculté were in every respect satisfactory.'³¹ About the satisfaction of Duhem's parents and his sister Marie little needs to be said. One can easily picture them watching Pierre's performance with admiring eyes, holding in their hands a copy of the freshly printed thesis, an impressive volume of 140 quarto pages published by no less prominent a house than Gauthier-Villars.³² It mattered not that they could hardly understand a line in it.

Students in awe

Even among the learned there were not too many who could have delved with ease into Duhem's thesis. Among the very few who in Lille could read it were Demartres and Painlevé, and some of Duhem's own students. As he was to recall almost twenty years later, a compensation for his being exiled to Lille was an elite body of students ready to appreciate his lectures with creative participation in them.³³ One of those students was Lucien Marchis, future colleague of Duhem in Bordeaux and the first occupant of the chair of astronautics in the Sorbonne. His reminiscences of his teacher, recorded in a letter to Hélène Duhem,³⁴ were vibrant—even from a distance

29. Dossier Duhem, p. 132.

30. *Ibid.*, p. 127.

31. *Ibid.*

32. The publication of the thesis was facilitated also by its inclusion in the *Annales de la Faculté des Sciences de Toulouse pour les sciences mathématiques et physiques Tome II. Année 1888*, where place was also given to a forty-page essay by Duhem on the history of the question which was brought to a close by a list of sixty memoirs, articles, and books published between 1824 and 1886.

33. 'Physique de croyant,' 1905 (7); see English translation, 1954 (3), p. 277.

34. For the French original of the passages here translated from Marchis' letter, see *Un savant français*, pp. 81-84. In addition to Marchis, Hélène Duhem also recalled there (p. 78) Lenoble, Monnet, Pélabon, and Zwingdeau (sic), as her father's best students, who became 'his disciples.' All these will be met in Ch. 5, with the exception of René Swyngedaew, who finished his career as professeur honoraire de l'électrotechnique at the University of Lille.

of forty years— with an immediacy that kept its freshness. First, he painted the background which should be priceless for any historian of the state of physics and its teaching in France in the closing decades of the nineteenth century:

At that time physics was, for the most part, taught in a deplorable manner, in the provinces as well as in Paris. Whereas the teaching of mathematics had by then achieved a high degree of perfection and exactness, the teaching of physics consisted in reasonings which were very often but rough approximations. Nobody spoke of the hypotheses on which the theories of physics rested. On the most fragile foundations shaky constructions were erected. Young people, like myself, coming from classes of mathematics, were quickly disillusioned and many abandoned physics and turned to chemistry or mathematics. The courses of electricity, for instance, even the best ones, were developed from the books of Mascart,³⁵ consisting of chapters taken without order from English or German books and memoirs. Did Mascart understand Helmholtz or the English? I have no idea, but the structuring of his books did not seem to indicate that he did. Of these works of Mascart, some extracted résumés completely incomprehensible to students for whom they were intended.

It was against such a background of disaffected and perplexed students that Duhem, only twenty-six, appeared on the scene:

And now this young professor, coming to us directly from the Ecole Normale, gives us his first lecture on electricity in which we recognize the qualities of precision and clarity of our courses in mathematics. We were given an exposition of astonishing lucidity on questions which appeared to us until then utterly nebulous. It is superfluous to say anything of the enthusiasm we felt on leaving that first lecture. Physics now had solid basis; it was no longer a sequence of formulas with no connection among them. Needless to say, our enthusiasm only increased and we have found too short the lectures of our teacher. By contrast, the courses of that poor Prof. X³⁶ . . . appeared to us very boring as he was stammering through topics of which he did not understand a word; it was in fact he, who, when a page fell out of his notes, continued, without noticing anything, to write on the blackboard formulas which had no connection whatever with the ones which he had just stated.

This unfortunate taught thermodynamics, and in what a fashion! Thus we were not slow in turning to our young teacher to ask for clarifications. There, again we have noticed that these were given right away. From then on we have been swearing by our teacher which earned him fits of jealousy on the part of the one of whom I have just spoken.

What should I say of his lectures [given to those preparing] for agrégation? They were

35. Marchis must have had in mind the *Leçons sur l'électricité et le magnétisme* of E. Mascart, first published in two volumes in 1882-86. It was during Duhem's stay in Lille that Mascart published his massive three-volume *Traité d'optique* (1889-92) in which Maxwell's electromagnetic theory of light was not discussed at all!

36. Marchis' subsequent reference to 'fits of jealousy' makes it clear that he did not have in mind Terquem, but Damien. On the other hand, his reference to 'thermodynamics' would better fit Terquem, though an earlier course of his on heat (thermodynamics) than the one which he was supposed to give in 1887-88. Damien did not lecture on heat and thermodynamics during the six years Duhem was in Lille. However, the courses on electrostatics, which Damien gave during those years, could give more than one opportunity for students to notice the superior quality of Duhem's courses.

marvelous and opened to us unsuspected horizons. Our teacher was not only a savant of the first order. He was also an incomparable popularizer. He knew, without sacrificing precision, how to bring out the essential in a question of fundamental physics, and, by means of well chosen examples, to put within the reach of all the most refined questions. He knew how to set forth the most difficult theories, by expressing in ordinary language their foundations and development . . . In Duhem there were united a set of qualities which are met but rarely. He was a savant in the entire meaning of that word and an admirable professor. Unfortunately, jealousy did not allow him to exercise his influence in a sufficiently vast area. If he had been at the Sorbonne or at the Collège de France he would have attracted students from all countries and would have renovated the teaching of physics.

In the same letter Marchis also spoke of some, 'unfortunately few,' articles which Duhem published in the *Revue des deux mondes* on thermodynamics and optics as masterpieces of popularization.³⁷ That they remained 'unfortunately few' was, as will be seen later, a small though telling misfortune of Duhem's career. Curiously, Marchis did not mention Duhem's introductory lecture on mathematical physics and crystallography which he undoubtedly attended and which saw print in the January 1892 issue of the *Revue des questions scientifiques*.³⁸ In that article Duhem gave a foretaste of what he was to say in a fully articulate form a dozen or so years later in his great classic, *La théorie physique*. In the same year there appeared in the same review another article by Duhem, the contents of which Marchis must have often heard, in and out of the classroom, from the lips of his teacher. Duhem dealt there with the question of atoms, a crucial issue for his philosophy and methodology in physics. This article too came to a close with a quotation from the work of a prominent French scientist of the previous generation, Henri Sainte-Claire Deville: 'They [atomic weight, valences, etc.] are harmful when one forgets their origin and their entry into science; they then lead us into that scientific mysticism of which, at this moment, chemistry gives a dangerous example.'³⁹ Marchis should have referred also to the publication in July 1893, when Duhem gave his last lecture in Lille, of the essay, 'Physique et métaphysique,' in the same periodical.⁴⁰ A reference to the latter would have been all the more appropriate as Duhem there presented, in defense of his introductory lecture, the main results of his having been for some years in the grip of formulating a logically unobjectionable form of physical theory.

Duhem generously acknowledged what he owed in that respect to his students in Lille. He did so, twelve years after he had left Lille, in his famed reply to the charge that his physics was rooted in his religious beliefs. Rather, Duhem argued, it was rooted 'in the exigencies of teaching.' To be sure, sometime before Duhem had arrived in Lille he had sensed the weaknesses of a physics resting on the hypotheses of mechanics. Yet the lure of the apparently full (Cartesian) rationality of mechanics presented traps at almost every turn. To ward off once and for all that specter Duhem

37. 1894 (7) and 1895 (5. 6. 7).

38.. 1892 (6).

39. 1892 (7). The work in question was *Leçons sur l'affinité*, a series of lectures delivered in 1867 and published in 1869.

40. 1893 (8).

needed a brilliant group of students whom he obviously encouraged to remind him of the slightest inconsistency which might have crept into his reasoning through a tacit reliance on mechanics. Here follows his famed tribute to those students of his:

We had the good fortune to teach before an elite audience in the Faculty of Science in Lille. Among our students, many of whom are today colleagues of ours, the critical sense was hardly asleep; requests for clarification and embarrassing objections indefatigably indicated to us the paradoxes and vicious circles which kept reappearing in our lectures despite our care . . . Little satisfied with the exposition of the principles of thermodynamics they had encountered 'in books and among men,' several of our students asked us to edit for them a small treatise on the foundations of that science. While we tried hard to satisfy their desire, the radical impotency of the methods then known for constructing a logical theory came home to us more persistently each day.⁴¹

Marchis' enthusiasm can easily be understood by a look at Duhem's lecture-notes. They were models of clarity, meticulous care, and originality. That they had the potential of renovating, at the highest level, the teaching of physics in France is attested by the almost immediate interest taken in them by the publishing firm, Hermann, in Paris. It brought out in 1891 in two lithographed quarto volumes the text of Duhem's course in hydrodynamics, elasticity and acoustics.⁴² In the same year the firm Gauthier-Villars, the leading scientific publishers with Hermann in France, began to publish Duhem's course in electricity and magnetism in three volumes comprising over fifteen hundred pages.⁴³ Its introduction contains passages which not only are highly characteristic of the direction pursued by Duhem, but also evoke the inspired manner in which he made his students perceive the broadest possible perspective in which a branch of physics could be studied. There must have been a sense of keen anticipation in the classroom as Duhem began pointing out that

ever since 1811, when Poisson inaugurated the theoretical analysis of electrical phenomena, the subject had been relentlessly investigated by a crowd of great physicists whose discoveries constitute today one of the vastest scientific corpus, and thus the moment seems to have arrived to co-ordinate the results of so many efforts; to unite in one single bundle the investigations conceived among the most diverse ideas, written in various languages and dispersed in countless periodicals. It seems that if one succeeded in achieving such vast synthesis, one would be in the presence of the most beautiful system of natural philosophy which has ever been formed by the human mind.⁴⁴

While courses often start with words conjuring up vast vistas, Duhem's students knew that they were not being treated to hollow rhetoric. The fifteen hundred pages to follow proved all too clearly that Duhem's was no empty promise as he declared at the outset:

What we have proposed to ourselves is to write an exposition as logical as possible of

41. 1905 (7), quoted in English translation, 1954 (3), p. 277.

42. 1891 (2).

43. 1891 (1) and 1892 (2).

44. 1891 (2), p. v.

theories of electricity and magnetism and not a compilation of theories. One is not going to find here all that has been said on electrical and magnetic phenomena: we only want that one may find here truly clear and fruitful ideas that have been proposed on the subject. The ore, within which science is enclosed, always contains gang as well. We have rejected much of that gang. The quality of what we have kept will be all the richer.⁴⁵

The recasting of electricity and magnetism into a 'most beautiful system' which Duhem conjured up was, of course, to be based on thermodynamics. Enamored as Duhem was of the prospect of a fully logical presentation of his topic, he was no less aware of the duties of a teacher, brilliant though his students might be:

To present first these fundamental theories of thermodynamics in an abstract manner by separating them from the applications which demand and consequently justify this luxury of precautions, would make them difficult to comprehend and perhaps even obnoxious. We have therefore believed that it would be good to reverse the logical order. In the present work we have decided to let the tool of thermodynamics function under the very eyes of the reader, to let that tool carry out the work for which it was necessary to refine its machinery to such a high degree.⁴⁶

This was, however, not to be taken as a suggestion that the book was to be a manual of experimentation. The purpose of the book, and of the course, was to 'make clear the theoretical bond which unites the different parts of the science of electricity.'⁴⁷ From the start of his career he was a theoretical, and therefore heavily mathematical, physicist and never wanted to be anything else.

A vibrant faculty group

Duhem's life as a faculty member at Lille had of course other aspects as well as his engrossment with theoretical physics or his advisory role for the Student Union. When Chevrillon arrived in Lille in early 1889, he found Duhem already part of a small informal group of younger faculty which he described in the 1930s in a long letter to H  l  ne Duhem.⁴⁸ One in the group was Paul Fabre, who graduated from the Ecole Normale just when Duhem entered it. Fabre was remembered at the Ecole not only as the best student of its director, Fustel de Coulanges, but also as the one to marry in 1893 Fustel de Coulanges' daughter. Almost a decade earlier, Fabre electrified the world of medieval historians through his discovery in the Vatican Library of the *Liber censuum*, a 12-century compilation of papal revenues since Carolingian times. A reward of the discovery was a long private audience with Leo XIII who inscribed to Fabre a book decorated with the pontifical coat of arms. Fabre, a devout Catholic, almost a mystic, was wont to regale his visitors with a glimpse of that book as his most cherished possession. Frequent among them was Duhem, who could not help being elated when in 1895 a special chair was created for Fabre in recognition of his excellence. Chevrillon, who for three years lodged

45. *Ibid.*, pp. v-vi.

46. *Ibid.*, p. vi.

47. *Ibid.*, p. 8.

48. The letter runs over twenty pages (55-78) in *Un savant fran  ais*.

with the Fabres in the northwest suburb called Cantelou-Lambersart, described Fabre in this same letter as one who had a particularly deep affection for Duhem: 'I was always struck by the special emphasis used by him . . . as he referred to the 'little Duhem'. This came from the depths of his heart. Fabre, so kind and understanding, an idealist transfused with Christian love, had chosen Duhem among all 'for his noblesse of soul, for his moral intransigence, for his resolute firmness in distinguishing between moral good and evil, and for all that was unbending in that noble personality.'⁴⁹

The group included Emile Artur, a rising authority on administrative law, and Auguste Angellier, Chevrillon's assistant in teaching English literature, renowned by then for a book of sonnets and other poetry. Duhem's keen interest in the characteristics of the English mind could often surface in his conversations with Chevrillon and Angellier.⁵⁰ A book on Karl Marx and his doctrine had already earned fame for Maurice Bourguin, future professor at the Ecole de Droit in Paris, another member of the group. Tall, pale, outwardly cold, Bourguin was in several respects the very opposite of Duhem, who was however often the Bourguins' dinner guest together with Fabre and Chevrillon. A happy band, though some of them were marked for early tragedies. Bourguin and Fabre were to die within a decade or so. Fabre's death in 1899 was precipitated by the passing away of his young wife. The latter tragedy was in store for Duhem as well.

A latecomer in the group was Eugène Monnet, lecturer in chemistry at the Institut Catholique in whose house Chevrillon used to take his meals. Monnet, Chevrillon wrote, 'was a rather strange man, secluded all day in his laboratory, absorbed in his research of which he had published nothing, not even talked of it to anybody. He did not seem to have any future, not having even his licentiate [master's degree]'. No sooner had Duhem been introduced by Chevrillon to Monnet than the latter changed decisively. Duhem, Chevrillon recalled, 'overpowered that rigidly shut-up personality and, by understanding that it was bursting with repressed energies, he penetrated and conquered it right away.'⁵¹ Monnet began to attend Duhem's courses,

49. *Ibid.*, p. 59.

50. It was during Duhem's years in Lille that Auguste Angellier (1841-1911) completed his doctoral dissertation on the poetry of Burns. Duhem most likely heard Angellier argue its principal thesis: abstract categories are useless for literary criticism which rather must take account of the 'immense complexity of things, of their inextricable confusion, and of their apparent contradictions' (see 'Angellier' in *Dictionnaire de biographie française*, 2:1073). This reminder of the complicatedness of the historical record could strike but responsive chords in Duhem. Another, though very different topic, on which Duhem must have eagerly listened to Angellier, thirteen years his senior, concerned details of Angellier's hiding in Paris during the Commune. Angellier returned to Paris in his officer's uniform in late March 1871 and became the immediate target of the communards' hostility. Rather small should seem the measure of Chevrillon's influence on the formation of Duhem's ideas about the characteristics of French, English, and German thinking, to be discussed in Ch. 9.

51. *Un savant français*, pp. 60-61. Monnet was eight years Duhem's senior and died in 1924. He became full professor in 1901 at the Institut Catholique to which he was attached from its very start. That he earned his doctorate under Duhem, 'whose scientific eminence and high standards were well known,' was pointedly noted in Monnet's necrology in *Les Facultés Catholiques de Lille. Revue Mensuelle*, 15^e Année. Octobre 1924 – Septembre 1925 (Lille: Société Anonyme d'Imprimerie et Editions du Nord, 1925), p. 258.

work for his licentiate, which he passed with success, and later was one of those who went to Bordeaux to earn his doctorate under Duhem's mentorship. Monnet, as will be seen shortly, was to play a decisive part in bringing about a major change in Duhem's life.

In Monnet's house, 18 Rue Charles de Muysart, two blocks northwest of the Institut Catholique, Duhem also met others from the Faculty of the 'Cathol.' These encounters, Chevrillon remarked, would have shocked many in Lille where it was generally believed that an atmosphere of hostility had of necessity to prevail between the faculties of the State University and the Institut Catholique. Protagonists of the 'citadel against citadel' would have been astonished had they known of the meetings in Monnet's house where Duhem, Chevrillon, Artur, Fabre, Bourguin met with professors of the Institut, such as the Abbé Bourgeat, a geologist, and the Abbé Mourot, a theologian. Of course these five were all practicing Catholics and, as such, secret renegades from the 'countercitadel.' Before long they were joined by such freethinkers as Painlevé and Fougères. The latter was a chargé de cours at the Faculty of Letters.

At the urging of Artur the meetings soon took the shape of a formal course in Catholic doctrine, under the direction of the Père Fristot, a Jesuit renowned for his preaching. Not that he was to have any success with the two freethinkers. Painlevé, for one, did his best to give to the discussions a purely scientific air. He argued against the doctrine of the resurrection of bodies on the ground that there was not enough phosphate in the entire earth to provide enough material for all the risen bodies and, at any rate, available phosphate had already entered into the composition of bones of a great variety of individuals so as to make impossible the resurrection in corporeal identity. In response, the Père Fristot referred to some recent discovery of enormous amounts of whalebone deposits as a source of enough phosphate. The reply was perhaps 'scientific' but hardly to the point either with respect to persuasiveness or to dogma. The course, which to the freethinkers was a 'lark' from the start, was not resumed when, after half a dozen sessions, the Père Fristot had to depart for a preaching tour. In commenting on the fiasco of the course, Chevrillon noted that such an outcome had been foreseen by both Fabre and Duhem. Fabre with his mystical proclivities 'based religion on the need of believing and on a tendency of the heart, whereas Duhem was imbued with Pascal who bases religion on grace and humbles reason.'⁵² Duhem, Chevrillon noted later in his letter, 'seems to have made a special study of Pascal.'⁵³ This was undoubtedly true. But, as will be seen later, there was an aspect to Duhem's Pascalianism with respect to philosophy which separated Duhem from fideism and made him a realist. This too became clear in Duhem's writings published during his years in Lille, which further confirms a point already made, namely, that the main features of the mental physiognomy of Duhem, though still in his late twenties, had been firmly shaped.

⁵² *Ibid.*, p. 64.

⁵³ *Ibid.*, p. 76.

About Fougères, an archeologist who had already made a name for himself through his excavations at Mantinea in the Peloponnesus, Chevrillon's letter tells nothing more. The same letter is very detailed concerning Duhem's ties with Painlevé. The two, both alumni of the Ecole Normale and members of the Science Faculty, met almost every day. They were attracted to one another by their intellectual brilliance, although in many respects they were very different. Both loved to dispute though not at all in the same fashion. Painlevé aimed at amusing himself, whereas Duhem looked for a demolition of the opponent. Duhem, Chevrillon wrote, 'loved the battle and joined it with a persistent and cool passion.' He defended his views 'to the excess' and as such could become that partisan spirit who 'seems at times to ruin his own judgment.' Chevrillon made this comment with reference to a discussion of which he was a witness. There Duhem and Painlevé locked horns over a question which could hardly be a matter of dispute. The dispute was touched off on a night when the crescent moon was particularly bright, with its darker portion bathed in pale light. Duhem, Chevrillon's account goes, 'seemed to me to deny the obvious as he maintained that this pale light, which has its source in the light reflected from the sunlit earth, was an illusion of the eye which, provoked by the [sunlit] curve of the crescent moon, completes that curve and believes to see the rest of the moon's disc.' Although Duhem's explanation, Chevrillon noted, was contrary to everything one finds in books on astronomy, 'nothing could shake Duhem in his opinion: he maintained it unperturbed though without being irritated.' The contrary was true of Painlevé. He became so mad as to get up suddenly and leave. The next day Chevrillon heard him talk about challenging Duhem to a duel. Of course, it failed to take place. Painlevé, Chevrillon added, calmed down as quickly as he lost his temper.⁵⁴

The rapport between Duhem and Painlevé, which survived the incident, was a good camaraderie and mutual admiration. The two at one point even vied with one another in writing poems.⁵⁵ Painlevé was a man of the world whose tastes, ambitions, and exploits were often the target of Duhem's barbs. Chevrillon himself thought that the foregoing dispute was preceded by a disagreement between the two on some truly serious matter. Many years later Duhem was to remark to a friend that Painlevé could not be trusted.⁵⁶ By then Painlevé had volunteered a panegyric for Berthelot's funeral in 1907.⁵⁷ Duhem was just the opposite by never concealing where he stood, and he was wont to specify his position with sharp remarks. Part of this characteristic of Duhem was his indulging in mimicking others to amuse his friends. In Chevrillon's words 'he reproduced in an astonishing manner the idiosyncrasies, the voice, the gesture, facial peculiarities and amusing features of people and drew of them priceless caricatures.'⁵⁸ All this must have

54. *Ibid.*, pp. 71-72.

55. Personal communication of Mr. Paul Brouzeng.

56. The friend was Albert Dufourcq, who reported this in a letter to Hélène Duhem (*Un savant français*, p. 211).

57. Painlevé was again deeply involved in the festivities commemorating in 1927 the centenary of Berthelot's birth.

58. *Un savant français*, p. 70.

impressed a novelist and critic of the stature of Chevrillon who particularly remembered Duhem imitating 'papa' Desrousseaux, favorite crooner of Northern France, whose lullaby (L'Canchon-Dormoire) starting with the words, 'Dors, min p'tit quinquin,' was the rage of the day.⁵⁹ Desrousseaux, who died in 1892, at the age of 72, was impersonated by Duhem as one "blowing his nose with the noise of petards and chanting in a nasal tone that flat and prosaic nursery tune which carried the people of Lille to an enthusiastic pitch."⁶⁰ Then it was the turn of the Jesuit Fristot 'crossing his hands in the large sleeves of his cassock and receiving us with a laughter which had something of a skeleton's rattle and revealed his enormous yellow dentures.'⁶¹ Even Painlevé was put on the spot with his mundane manners.

Portrait of a mind

In the concluding part of Chevrillon's letter, which is a testimony also to the master stylist Chevrillon was, Duhem is portrayed as a friend ready to share his enormous intellectual riches. The passage which deserves to be given in full is also noteworthy as a witness of the clarity with which Duhem had already then formulated his philosophy of physics and its relevance for theology and the history of science.

Concerning his advocacy of what I would call partisan position, I have never seen there but an effect of the energy of his thought, of a forceful conviction which corresponded entirely to the inflexible vigor of his character, and led him to maintain with an indomitable logic what seemed to me indefensible when it came to the consequences of an idea which he had made his own. He told me one day that one could conceive of a cosmological system which would explain scientifically the miracle of Joshua stopping for a while the apparent motion of the sun. He did not convince me, but he made me learn at the same time that the ancient [Ptolemaic] theory, which represented the earth immobile and the sun moving around it, was not logically absurd and that it was impossible to prove that the Church was wrong in condemning Galileo. Duhem, I realized, was absolutely right on this point. The ancient system was only a much more complicated representation of things but no less logical and, at any rate, as he further convinced me, there was no absolute motion. The motion of a body is always with respect to another and one cannot say, and much less prove, that *this* body is displaced with respect to *that*, or vice versa. I owe to him also to have perceived that scientific systems, the different explanations of physical phenomena, are never more than one form, among many other possible forms, to represent us the things – representations comparable to those by which one can project a sphere on a plane, such as the orthogonal projection or Mercator's projection, or any other, utilized in geographical atlases. And also that all the great hypotheses of physics contain contradictions, either among themselves or each within itself, so that one must consider them not even as approximations of truth but as mere conveniences of thought. He gave me an example: the theory of the ether, as it existed then, which assumed the ether to be both elastic and absolutely incompressible, a contradiction.

59. For text and melody, see *Chansons et pasquilles Lilloises par Desrousseaux* (new ed.; Paris: Nouvelles Editions Ch. Gras, 1928), 2:64-67.

60. *Un savant français*, p. 70. Indeed, the enthusiasm was so great that soon after Desrousseaux's death a statue (showing a mother with a small child sitting in her lap) was erected in his memory in the park at the intersection of Avenue Foch and Rue Nationale.

61. *Un savant français*, p. 70.

How many conversations I had with him on this subject! They have always led back to to this grand question: Are the laws of nature conformal to the logical necessities of our minds? Do they constitute an order to which everything is connected logically and therefore mechanically? Since logic only unfolded the consequences of the principle of identity, $A = A$, about which it seemed to me impossible that it should not be eternal and universal, I could not conceive that anything could escape it in nature. It seemed to me that the ultimate stage of science (or of the so-called positive sciences – a stage perhaps infinitely removed, but towards which our experimental, methodical, organized knowledge tends and will tend forever through successive approximations – was a classification of laws corresponding to their hierarchy [embodied] in reality and that all those laws were mutually subordinated under that principle. Duhem replied that such an idea governed indeed the effort of physicists, but that it was based on only one hypothesis, namely, that the order of things is conformal to the laws of our minds and that this hypothesis was metaphysical and that it was an invincible illusion of the human mind to attribute to that belief an absolute objective value. He seemed to me to be right and I did not see that it was possible at all to say anything to the contrary. But what astonished me was that he still kept applying the word *metaphysical* or *transcendental* to the order of things of which science tries to form a comprehensive logical picture. This picture, an object of hope, did not seem to me to be different from the various pictures which the various sciences actually draw and undoubtedly in a provisional manner. This picture would be simply total and entirely logical. It would not touch on realities in themselves, that is, on metaphysical realities, but only on the sensible or physical realities.

How many times in our nightly comings and goings in the fields of Cantelou-Lambersart or in my apartment at Boulevard Vauban, have we discussed this question: is nature subject to the chain of rigorous laws? The 'laws of nature,' these words came back incessantly. One day I told him: My friend, it is two o'clock in the morning, the laws of nature demand that we go to bed. These words made him laugh and he recalled them several times as our discussions went on too late.

He had an admirable intellectual equipment. About French and ancient classics he knew more than most of us, professors of literature. He read Greek with greater facility than we did. He knew thoroughly the physics, the metaphysics and the logic of Aristotle; he recited by heart Lucretius; he seemed to have made a special study of Descartes and Pascal. When one recalls that in addition to these all the sciences properly so-called, mathematics, physics, chemistry, geology, crystallography, biology were familiar to him, a measure can perhaps be taken of the extraordinary extent of his culture. He must have been a marvelous teacher. I have witnessed the enthusiasm which his lectures touched off in his students. He brought to the discussion a clarity, an ease, a precision of expression which I envied. I had in my hands some of his manuscripts: a magnificent unperturbed handwriting with never a correction. He seemed not to search for his thought. He wrote on big sheets of paper which accumulated with an unparalleled rapidity. All this witnessed a quality, the impression of which dominates all the memory I have kept of him: vitality, incomparable spiritual energy . . . He was as much a philosopher as he was a scientist . . . What a vast mind! . . . In the art of philosophical reasoning Duhem was a master, and I dare to say, he was a great writer.⁶²

Coming as it does from a great French writer, this accolade paid to Duhem the stylist should seem of particular value, although hardly a surprise to those relatively few who not only speak of his writings but do so from a first-hand knowledge of them.

62. *Ibid.*, pp. 72-78.

Politics: ordinary and academic

In Chevrillon's long letter there is no reference to any of the big crises which rocked France during the years when Duhem taught in Lille. This is not to suggest that Duhem's conversations with his friends were always limited to questions of science and philosophy. Not at all in sympathy with Socialism, Duhem could hardly fail to make a sharp comment or two about the violent confrontation which took place in the town of Fourmies, only 15 km from Lille, between troops and workers in the spring of 1891.⁶³ With distinctly Royalist sympathies, he must have discussed with some perplexity the rapid rise of General Boulanger's popularity which reached a peak in early 1889. As a threat to the Third Republic, Boulanger must have been good news for Duhem who, however, could not ignore the simultaneous threat posed by Boulanger to the prospects of legitimists. The latter saw their strength increased in the measure in which government followed government in quick succession in the wake of endless political scandals of which that connected with the building of the Panama canal is the best remembered.

Apart from the ideas and actions of the radical leftists, Duhem could find something good in any major criticism of the Republican system especially when the criticism had some touch of Catholic ideology. Thus Duhem viewed favorably the virulent though not principally anti-Semitic campaign which Edouard Drumond began in 1886 and carried on for the next two decades in books as well as in newspapers. When started by Drumond in 1892, *La Parole Libre* found Duhem among its first and avid readers.⁶⁴ He was also on one of the first lists of subscribers to *La Patrie Française*, the organ of the Action Française,⁶⁵ also principally an opponent of the Republic and secondarily of its Jewish supporters. Duhem's 'antisemitism' must, of course, be seen in its historical context, lest it be taken for something which it certainly was not. Deeply attached to the idea of a France steeped in Christian faith and culture, Duhem was all too aware of the almost miraculous growth of French Catholicism in two short generations, that is, during the half a century stretching from 1830 to 1880, a growth which he certainly wished to be protected from increasingly hostile forces.

In 1830 the condition of the Church in France was such as to prompt not a few to predict its imminent demise.⁶⁶ The important thing to note here is that those predictions were never in the tone of a detached registering of fact. In various degrees the touch of an ideological triumphalism was always unmistakably in evidence. At one end of the spectrum was the cultivated aloofness of the

63. See *Histoire de France contemporaine de 1871 à 1913* (Paris: Larousse, 1916), pp. 170-71, with illustrations.

64. The recollection of Hélène Duhem of her father's patronage of *La Parole Libre* (see *Un savant français*, p. 131) refers to his years in Bordeaux, but the 'scandal,' which her father occasioned there in the eyes of some of his colleagues by reading that newspaper openly in the streets, may have very well occurred already in Lille.

65. *Ibid.*, p. 130. Hélène Duhem was in the 1920s and 1930s high on the list of women adherents to the Action Française.

66. For quotations in this paragraph, see Philip Spencer: *Politics of Belief in Nineteenth-Century France: Lacordaire, Michon, Vuillot* (London: Faber and Faber, 1954), pp. 50-51.

philosopher, Victor Cousin for instance, who offered a 'helping hand to almost the whole human race lying prostrate in the arms of Christianity.' In the middle of the spectrum was the state official, say the Inspector General sent from Paris to the University of Rennes, who gave there the assurance that the hour of the 'obsequies of a great religion was rapidly approaching.' At the other end of the spectrum was the crusading author, such as Heinrich Heine, ready to overdraw 'the average Frenchman' who 'doesn't want to hear a word about the corpse; he puts his handkerchief to his nose when the Church is mentioned.'

Only six years later, in 1836, the scene was markedly different. The number of practising Catholics increased more than tenfold; Catholicism became so fashionable as to be taken seriously in circles well-known for their readiness to claim rationality as their exclusive fiefdom. Jouffroy, philosopher at the Ecole Normale, who had just written about the demise of the Catholic dogma, now found himself face to face with a vigorous Catholic camp.⁶⁷ Fifty years later, the number of male religious stood over 30,000 (an increase of more than tenfold) and more than two million out of the five million schoolchildren were educated in Catholic *écoles libres*. French Catholicism could take additional pride from the expansion of the Church in faraway lands where French missionaries were often setting the pace of advance.

Although the cultural influence which Catholics regained was all too often linked with a Romantic nostalgia for pre-Revolution times, Catholics could not be expected, any more than any comparable group elsewhere with any persuasion, to let themselves be swept from a position of strength they had gained by sincere dedication to their beliefs. Although French Catholics were rapidly losing ground from 1880 on, the situation for the next twenty-five years remained that of a contest between them and their antagonists. French Catholics, whatever their inherited 'antisemitism,' could not help noticing that there was a conspicuously larger number of Jews in the campaign waged against the Church. Only cheap journalism would lump all their reactions under the catchword 'antisemitism,' which is a least appropriate label when, say, in the case of Duhem, it never manifested itself in personal attack or hatred. A Jew like Jacques Salomon Hadamard, brother-in-law of Captain Dreyfus and a founder of the Ligue des Droits de l'Homme, would have hardly kept a lifelong friendship with Duhem had the latter been a 'Jew-baiter,' and not merely one who happened to disagree with the convictions (political, cultural, and religious) of many a Jew and was resolved to hold his own. Duhem's attitude toward Jews in general must not be evaluated by standards different from those by which one ought to judge the resolve, say, of many Jews to keep the State of Israel under the rule of the Mosaic Law, or the resolve of most Dutch and British to enforce by law the adherence of their royal families to Protestantism as the established religion.

That Duhem's 'antisemitism' was above all a byproduct of his anti-Republicanism is strongly suggested by the fact that devout a Catholic though he was, he

67. Ibid., p. 52.

found it impossible to go along with the program of *ralliement* which Leo XIII enjoined in his Encyclical 'Inter innumeras sollicitudines' of February 10, 1892, on French Catholics after two years of less explicit exhortations to them. On this point too, Chevrillon's long letter is silent, although Duhem must have voiced in his friends' circle his sympathy with the icy silence with which senior naval officers visiting in Algiers greeted on November 12, 1890, Cardinal Lavigerie's toast that made headlines all over France. The toast, in which French Catholics, among whom officers of the Army and Navy were numerous and notable, were urged to give generous support to the Republic, was the result of a long consultation between Leo XIII and the French government, including President Carnot himself, with the Cardinal being the chief go-between. To be sure, it is difficult to envision Duhem as one unable to see the merits of the Cardinal's warning that anarchy was in store for Catholics as well if the edifice of the State was not supported by them from within. Indeed, the anarchist actions began to multiply from May 1, 1891, for two or three years. Yet, in his refusal to go along with the *ralliement*, Duhem could easily refer, and he undoubtedly did when talking to such friends as Chevrillon, Fabre and others, to the adamant refusal on the part of the Republican government to yield even an inch on the program of a complete laicization of education. Much less than Duhem's acumen was sufficient to make one perceive the gratuitousness of the claim that there could be a strictly neutral laicization which would not inculcate some countertheological ideology.

There were of course notable events with no touch of 'ideology' during Duhem's stay in Lille, events which must have prompted him to some memorable comments, unfortunately not preserved by Chevrillon or others. As one who lived for twenty years in the vicinity of the Bourse, Duhem could easily envision the scene there following the financial debacle of 1889. Keenly interested in the physics of explosives, he must have been excited by the news in April 1890 that the French Army had just been equipped with a gunpowder that produced hardly any smoke. In all likelihood he visited in Paris in 1889 the great Exposition dominated by the newly completed Eiffel Tower. Such and similar details could have provided Chevrillon with rich material had he ever decided to put down his reminiscences on Duhem in a systematic and extensive manner. While Chevrillon arrived in Lille after the government's decision in August 1889 to push for the unification of faculties and to turn them thereby into full-fledged universities, he must have heard many comments from Duhem who, as will be seen, wanted France to attract as many foreign students as did Germany.

Chevrillon made no mention of a matter which must have been a frequent topic of conversation between him and Duhem, namely, the latter's joining in 1891 the Société scientifique de Bruxelles in 1891.⁶⁸ The step, unexpected in view of

68. The chief source of information on the origins and the first twenty-five years of the Société is *Annales de la Société Scientifique de Bruxelles. Table analytique des vingt-cinq premiers volumes 1875-1901, précédée de l'histoire documentaire de la Société Scientifique et de la liste générale de ses membres* (Louvain: Secrétariat de la Société Scientifique, 1904). Duhem is listed on p. 68 as member since 1891.

Duhem's aversion to anything organized, was rather natural. By 1891 the Société, only 15 years old, was a flourishing enterprise, the fruit of the efforts of the Jesuit I. Carbonelle of Bruxelles, who in 1875 made a tour of the Groups Cauchy, informal and local associations of Catholic scientists all over the French-speaking parts of Europe, and made them join forces.⁶⁹ With its headquarters in Bruxelles, the aim of the Société was to demonstrate by its very existence that the cultivation of science and the practicing of faith were anything but irreconcilable. This aim of the Société was promoted by quarterly meetings of all the main branches of the Société and the publication of a quarterly, the *Revue des questions scientifiques*. Immediately 450 scientists joined, a fact which provoked a plaintive article in a positivist periodical edited by E. Littré and G. Wyrouboff, the former the 'pope,' the latter a high official in the 'positivist Church,' a brainchild of Auguste Comte's. It must have been very difficult for them to countenance the fact that from the start the Société counted among its members such luminaries of the French Académie des Sciences as Hermite, Pasteur, Sainte-Claire Deville, and Hautefeuille. To these were added later the names of Picard, Appel, d'Ocagne, Boussinesq, de Lapparent, Amagat, Le Chatelier, and Barrois. Paul Tannery, the historian of science, and Henri Fabre, the famed entomologist, were also members.

The Société had from 1890 on Paul Mansion, the noted mathematician from the University of Gand, as its secretary for twenty years, the golden decades of the Société. As attested by their correspondence, Duhem and the fifteen-year-old Mansion soon became friends. Duhem's antimechanistic 'scepticism' was very much to the liking of Mansion, who in his letter of February 11, 1892, to Duhem spoke of his own scepticism even in geometry with a reference to its non-Euclidean types. Duhem may not have found entirely to his own liking Mansion's friendly suggestion in the same letter that he should tone down his criticism of others. Duhem's joining of the Société may have owed much to his personal contacts with the Père Bourgeat, himself a member of the Société, or with Charles-Eugène Barrois, professor of geology at the university, with whom he developed a lifelong friendship. The six papers, which Duhem contributed during his last three years in Lille to the *Revue* were in part a response to a request which Mansion conveyed to him on February 11, 1892, to relieve the momentary drop of contributions to the *Revue* following the death of Gilbert, its editor. The speed with which Duhem contributed was also a proof of the depth to which he had already plumbed the question of the respective competence of scientific and philosophical methods. Whatever defense of Catholic faith he wanted to make, it never went beyond the careful delimiting of those competences, a task which is no less in the best interest of science than of other fields of inquiry.

Just as Duhem was ready in theoretical matters to combat the infringement

69. The article, 'Science et religion,' (*La philosophie positive*, 19 [1877]:321-38 and 20 [1878]:40-56), signed X, was written by Littré who deplored the fact that the first volume of the *Annales* of the Société had such prominent scientific contributors as Hermite, Secchi, and de Lapparent. Littré's article was answered by the Père Carbonelle, 'Une entrée en campagne,' *RQSc* 3 (1878):225-47.

of one method on the other (also a manifestation of his sense of justice), he was no less adverse to the infringement on due process in matters relating to the academic life. In this respect Chevrillon's letter contains a hint which, however brief, casts a vivid light on Duhem's readiness to vindicate truth and justice with a verve and in complete disregard of his own interest. Chevrillon provided no information about the particular issue which brought to a peak Duhem's resentment toward Félix-Henri Lacaze-Duthiers, professor of zoology at the Museum and the Sorbonne, member of the Académie des Sciences, founder-editor of the *Archives de zoologie expérimentale*, and a leading scientist-pontif of crusading Republicanism. Chevrillon merely mentioned that Duhem finally could not refrain from acting: 'Now it really gets on my nerves! I will write my letter to Lacaze-Duthiers.'⁷⁰ The letter, of which Duhem kept a copy,⁷¹ suggests that he had written it after Lacaze-Duthiers, whose career started in Lille in 1854, attacked in print a 'reactionary' professor there who blocked the promotion of a protégé of Lacaze-Duthiers. Being at the very start of his professional career, and not even a doctor yet (the letter was written on May 13, 1888), Duhem showed extraordinary courage as he minced no words:

Monsieur! The series of slanders and lies which a *new generation propagates* (this is your prose, indeed) has brought its fruits; the balloting turned into a defeat; the *insidious suggestions* which kept in their grip a professor *even in the course of the second balloting* have not remained useless. The new generation greatly rejoices; this first success will encourage them to propagate even more the small slanders and lies which you attribute to them. They will be intent on attaching enough proofs to those slanders and lies in order to transform them into well-founded accusations. They will not be satisfied until they have reduced to nothing your sinister influence. In the hope that this will hardly be delayed, I have the honor of being your irreconcilable adversary

Pierre Duhem

Maître de conférences at the Faculty
of Sciences of Lille

Lacaze-Duthiers did not keep this letter to himself. He communicated it to the Ministry of Public Instruction where it was deposited, possibly at the instruction of Liard, head of the Bureau of Higher Education, in the official dossier on Duhem.⁷² The act constituted a breach of elementary propriety, but crusading Republicanism had its own convenient interpretation of norms whenever necessary. Very likely the letter was shown to others as well, and above all to Berthelot, the subject of the second point in question in Chevrillon's letter. Chevrillon recalled that whenever Duhem's little daughter needed a little disciplining, her father showed her a picture of Berthelot as the one who would bring punishment.⁷³ Such was a priceless

70. *Un savant français*, p. 68.

71. The letter was made public by Hélène Duhem, *ibid.*, p. 68.

72. Dossier Duhem, p. 198.

73. *Un savant français*, p. 66. The words accompanying the display of Berthelot's picture, 'si tu n'es pas sage, j'appelle Berthelot,' were recalled by Hélène Duhem in 1971, as she was interviewed by a journalist on the occasion of the fifty-fifth anniversary of her father's death. The newspaper was not identified in the clipping, a photocopy of which was kindly sent to me by the maire of Cabrespine.

proof of the measure of Duhem's conviction about Berthelot's role in thwarting his career. It was a conviction really calling for the word 'absolument,' a word which graces the conversation of French intellectuals even when there is absolutely no need for it. Little Hélène was not yet two when the word had already entered her vocabulary. In coming back from the garden she reported her encounter with a snail: 'I have *absolutely* pushed back its horns.'⁷⁴ Later she learned from her father that Berthelot was 'absolutely' adamant in blocking his road back to Paris. When she received Chevrillon's long letter it was hardly a surprise to her to read in it that unassailable evidence against those who tried and still try to downplay or simply ignore Berthelot's crucial role in the academic exile imposed on Duhem. A word which Berthelot uttered in 1892 or 1893 about Duhem in a conversation with Chevrillon, 'made me feel,' the latter wrote, 'that there was in evidence that irreducible opposition which never let him go back to Paris.'⁷⁵ Those mindful of this would know what to think on reading accounts of Berthelot's life and work in which Duhem appears at best only as a crusader against scientism. At the same time Berthelot is wholly exculpated of scientism and is turned into an apostle of anticlericalism and secularism who never sinned against his own precept that freethinkers must act with far greater fairness than do their religious antagonists.⁷⁶

It is most likely that Chevrillon informed Duhem immediately. Indeed Chevrillon seemed to have recalled Duhem's reaction as he added: 'Duhem had but contempt for considerations of advancement. Provided he could work, teach, carry on with his projects and say aloud what he thought, it mattered little to him whether he was in a provincial university or at the Sorbonne, or the Collège de France.'⁷⁷ This, as will be seen, was not entirely true. But Chevrillon's ensuing comment has remained as timely as ever: 'Life justified Duhem. While so great is the number of professors at great universities who have produced nothing durable, his work as a physicist in thermodynamics, as a historian and philosopher of science, appears to the whole learned world to have an ever higher value.'⁷⁸

If the conversation between Berthelot and Chevrillon took place somewhat later than the early months of 1893, then Berthelot's ominous remark was a sign of an increase of animosity on his part toward Duhem. The latter fueled that animosity by writing on September 8, 1892, the Preface to his book, *Introduction à la mécanique chimique*, which being only 177 pages long, was probably in print early

74. Ibid.

75. Ibid., p. 69.

76. As done, for example, by R. Virtanen in his *Marcelin Berthelot: A Study of a Scientist's Public Role* (Lincoln: University of Nebraska, 1965), p. 22. There Duhem is mentioned fleetingly as a critic of scientism, readily used by some Catholic critics of Berthelot (p. 54). According to Virtanen, Berthelot was not a physicalist, let alone a spokesman for scientism (p. 55)! It is difficult to assume that Virtanen was ignorant of Berthelot's utopistic encomiums of science, such as, for instance, his 'En l'an 2000' (1894), and of the widespread awareness in France of Berthelot's scientism (see note 27 to Ch. 7).

77. *Un savant français*, p. 69.

78. Ibid.

the next year.⁷⁹ In that book chapter iv is a survey of the entire history of the principle of maximum work. Duhem's carefully documented summary of Thomsen's work from 1854 on is followed by a similar summary of Berthelot's publications from 1865 until 1873, when he enunciated in his own name that principle, in none of which, as Duhem pointedly remarked, is a single reference to Thomsen. After a survey of the dispute ensuing between Thomsen and Berthelot concerning priority, Duhem gave evidence that not a few propositions in Berthelot's papers resembled almost word for word Thomsen's earlier statements. 'These various propositions, provide a clear and complete formulation of the system of thermochemistry [based on the principle of maximum work]. Only the name of Julius Thomsen is missing.'⁸⁰

Married and widowed

If Duhem wrote this after the conversation between Chevrillon and Berthelot, it may have been his way of fighting back. The dispute, already history, between Berthelot and Thomsen, could have been ignored in a book on thermodynamics but hardly when its author was one, like Duhem, intent on the history of his topic. There was, in addition, his keen sense of justice and personal experience. From almost the moment he started publishing he noticed more than once the curious failure of some to refer to his work and acknowledge his priority. At any rate, in receiving word from Chevrillon about Berthelot's adamant hostility toward him, Duhem felt the blow all the less as by then he had been stunned by the greatest blow of his life. It put an end to two years of extremely happy married life. At first he had had to be coaxed into marriage. His sister recalled how her brother was urged by his parents, especially by his mother, to get married. Such suggestions were obviously more frequent after Duhem's mother and sister moved to Lille in the early summer of 1889. It was then that Duhem exchanged his bachelor apartment on Rue Masurel for the two-story house, Nr. 78, in Rue Caumartin, a quiet residential street even today, only at a five minutes' walk to the south from the physics department and not much more from the heavy traffic on the Place de la République. Behind the move of Duhem's mother and sister to Lille, there lay a family tragedy. Duhem's father fell seriously ill in early 1889. When his condition took a turn for the worse, Pierre rushed to Paris to watch over his father's last days together with his dear friend, Récamier, now his father's physician.⁸¹ Pierre-Joseph Duhem died on April 7, 1889. 'Under a quiet and reserved exterior he hid a great

79. 1893 (1).

80. *Ibid.*, p. 51.

81. 'As the best of brothers, . . . Dr. Récamier did not leave his friend alone to keep watch over his dying father and helped him with all affection to bear this first great blow [in his life]' (*Un savant français*, p. 86). Nothing personal about Pierre-Joseph Duhem is contained in the dozen or so letters (now in the Archives de l'Académie des Sciences), which he wrote and received between February and September, 1887, in connection with his wife's inheriting the house and property of Timothée Fabre in Cabrespine. Those letters (and the handwriting) dealing mostly with legal fees and taxes, show, however, the same traits of punctuality, clarity, and discipline which became a distinctive feature of his son.

soul, all goodness and tactfulness which one will admire in his son.' So wrote from a distance of half a century Marie Duhem who added: 'Mother and sister will soon leave Paris and will find in Lille the one who will henceforth become the object of all their loving concern.'⁸²

Part of that concern of theirs was that Pierre, already almost twenty-eight, was still single. Mother, sister, and friends speculated on how to coax him into marriage. 'But he refused; all is to be kept for science, there should be nothing between science and him,'⁸³ a phrase which may very well have been an echo of some of his replies to his sister's suggestions about marriage. He was even resolved to foil any stratagem devised by friends to introduce him to potential brides. Thus he arrived much too early at a party thrown by his friends, the Monnets, so that he could safely depart before the arrival of the Chayet sisters, one of whom, Marie-Adèle,⁸⁴ had been described to him, not without some ulterior motives, in glowing terms. The Chayet sisters had already arrived when Pierre showed up. Marie-Adèle, only a year younger than Pierre, was the fifth in a family of eight children. The Chayet's main residence was in Fourchambault, a town about 150 km south of Paris on the Loire where the father, Alexandre Chayet, was director of the famed iron works. The Chayets had close connections with the academic world. Marie-Adèle herself was the niece of René-Gaspar de Taillandier, member of the Académie Française and a chief disseminator in France of the works of outstanding foreign authors. Marie-Adèle was also the cousin of Léon Ollé-Laprune, who as professor at the Ecole Normale was well-known to Pierre. In addition, Marie-Adèle was the sister-in-law of Dr. Ernest Baltus, professor of physiology at the Institut Catholique in Lille. The friendship between the Baltus and the Monnets is the explanation of Marie-Adèle's visit at the Monnet home where her first meeting with Pierre took place. Afterwards, as Marie Duhem relates, the two met in the home of Dr. Baltus.⁸⁵

It was late spring 1890 and for the first time in half a dozen years Pierre changed plans as far as his summer vacations were concerned. Instead of going to sail around the Ouessants, he went with the Chayets to their favorite resort place, the coastal town of Pouliguen, not too far from the Gulf of Morbihan, where he learned, at the age of fourteen, to love Brittany and the Bretons. He was now learning to love in a far deeper sense. By late summer he and Marie-Adèle were engaged. Their wedding came just as quickly. It took place in Paris, on October 28, 1890. Tragedy cut short their happiness almost as rapidly. The only glimpse into Duhem's marriage is preserved in his sister's letter⁸⁶ to her niece. Its relevant sections would lose their intimacy through any comment, interpretation, or even paraphrase:

82. Ibid.

83. Ibid., p. 87.

84. In *Un savant français* (p. 87) Mlle Chayet is called Adèle, but she was registered as née Marie Chayet in the records of the parish St. Michel following her death.

85. Dr. Baltus (1857-1937), author of books on physiological chemistry, lived at that time at 42 Rue d'Angleterre, a short distance from Duhem's first residence in Lille.

86. For the French original, see *Un savant français*, pp. 89-92.

The young woman whom Pierre chose for wife was above all a great Christian; one could guess the rare virtues of this very sincere personality, the charm of this beautiful nature, through her transparent look, perhaps at times slightly that of a dreamer, who seemed already to belong to the life beyond. Their souls were similar. They had the same taste for the arts and for culture. During their honeymoon, which they spent in Belgium with a brief excursion into Holland, Pierre had the joy of seeing his young wife rejoice, as he did, in the beauty of nature, savor the melancholy charm of Bruges, thoroughly appreciate in the museums and churches the art of the Flemish masters, by rereading in the evenings the book of Fromentin.⁸⁷

Adèle's soul had in store for this profoundly Christian husband even more admirable surprises and greater delights. The next year, while expecting the child whom they were to cherish so dearly, they returned to Belgium and chose at the beginning of the summer vacation, as a place of rest, the village of Anserème, on the banks of the Meuse. There they made the acquaintance, in the hotel where they lodged, of a young Belgian seminarian, who being without any resources did not know how to continue his studies. To help make a priest! The thought did not take long to germinate in the young wife's mind: 'Pierre,' she said, 'if you agree, we might give on behalf of that vocation the money which you have deposited among my wedding presents.' The answer was not long in coming from a spouse happy and proud to find so much generosity in her, otherwise distinctly careful with money. He was enchanted. What a beautiful family they were to raise! How much joy was in store for them!

Alas, the happiness in this world is of short duration; for them it had the rapidity of lightning . . .

The birth of little Hélène took place in Lille on September 29, 1891.⁸⁸ During the months that followed they shared their time between the care and tender love heaped on that little creature, and receptions in the circle of their intimate friends. In the beginning of the summer [of 1892], trial entered as a thunderbolt Pierre's household. A heart failure began to show its first signs in his dear 'Maddy.'⁸⁹ The specialists of the

87. The reference is to *Les maîtres d'autrefois. Belgique-Hollande*, which soon established itself as a classic following its first publication in 1876. Both the French original and its English translation, *The Old Masters of Belgium and Holland*, went through many editions. Eugène Fromentin, a well-known painter himself, died at the age of 46, in the year of the publication of his classic work. There he argued that the greatness of painting in the Low Countries lay in faithfulness to the character of the land, a theme which found its echo in Duhem's insistence on cultivating physics in France in a 'French' mentality.

88. In the baptism (see baptismal records of the parish St. Michel, entry 176 for that year) the child was given the name Hélène-Marie-Alexandrine-Adèle. Her mother's name is given there as Adèle-Marie-Alexandrine. Joseph Récamier must have been notified by a telegram about Hélène's birth because already on October 3 he sent a congratulatory letter containing the poem which the happy couple must have relished:

Fin d'été	Qu'à l'instant	Disent à Lille
nait bébé	prudemment	que ma fille
douce chose	le vicaire	si gentille
viseau rose	et le maire	a paru
fleur enfant	baptisant	qu'heureux père
tourterelle	souscrivant	plus surterre
tout en elle	que la cloche	jamais fut
innocent	sur la porche	ouf!
Ah, ma foi	ébranlant	Jo
quelle joie	l'habitant	

89. In all likelihood a contraction of Marie-Adèle.

medical school of the Institut Catholique could but diagnose the malady and try their best without much hope. They assisted at the supreme sacrifice of that young mother, forgetful of her own life, to give the world a second Christian, another little girl, too young to live, but who was alive long enough to be baptized by her father. The mother gave up her noble soul after the passing away of this child of a few hours, a child who was laid beside her for eternity. [Mme. Pierre Duhem died on July 28, 1892].⁹⁰ The young wife did not leave this earth without suggestions and farewell: 'Pierre,' she kept saying to her husband, 'you should not remain alone, you are too loving, you are too young; you will remarry and you will let our daughter be raised by your mother.' We know that the husband obeyed the latter suggestion; his daughter and science had to suffice to him, if not console him.

Comforts and frustrations of science

Duhem's attachment to his daughter only increased as the years went by. And so did his devotion to science. The half a dozen books and almost fifty memoirs and articles he published while in Lille must have made him the object of admiration and envy of all the Faculty. Lille's old and new Faculties were amply provided by the State with funds to have the researches of the Faculty members published in the form of monographs for enhancing the intellectual respectability of a 'citadel against a citadel.' Of the fifteen monographs published between 1888 and 1893, when Duhem left Lille, six, of which only one was shorter than a hundred pages, were by Duhem. It was also in Lille that he began sending articles on the history and philosophy of science to the *Revue des questions scientifiques*, articles which later had much of their contents assimilated into Duhem's great classic *La théorie physique* published in 1906. While in Lille he began contributing to the *Zeitschrift für physikalische Chemie* founded in 1887 by Wilhelm Ostwald, the future Nobel-laureate, who himself translated the first three articles sent to him by Duhem between 1888 and 1891.⁹¹ From Lille Duhem contributed six articles to the *Journal de physique théorique et appliquée* and a second memoir of more than a hundred pages to the Finnish Academy of Sciences. In addition, long memoirs by him appeared regularly in the *Annales scientifiques de l'École Normale Supérieure* and in the *Annales de la Faculté des Sciences de Toulouse*. Again, it was in Lille that he began publishing in the *Journal de mathématiques pures et appliquées* his commentaries on the foundations of thermodynamics in a series of three long memoirs which he considered as one of his most important works. The magnum opus among his publications during those years was of course the three-volume *Leçons sur l'électricité et magnétisme*. For the scarcity of printed reaction to it he could find some comfort in letters from prominent physicists, one of them Heinrich Hertz, who jotted on his visiting cards the words 'mille remerciements pour votre aimable envoi' and wrote on April 18, 1892:

90. Buried with the mother, on Thursday, July 30th, was the child who received the name Joseph, according to the burial records of the parish St. Michel. See pp. 185, 187 and 217.

91. See 1888 (14), p. 568; 1891 (5), p. 337; 1891 (6), p. 367. In a letter of January 15, 1897, to Duhem, Ostwald still signaled his extreme interest in Duhem's writings with the remark that he himself might translate them into German.

You have caused me great pleasure by sending me your *Leçons sur l'électricité* and I thank you for it from all my heart. Such a work must not be read in haste; so far I have only thumbed through it. Nevertheless I have already seen that the clarity and lucidity, which distinguish all French works, dominate it in the highest degree and I will return to it to my greatest profit. The thought of having entered into contact with a savant of your merit was a cause of no less joy for me. In a short while my memoirs on electrical oscillations will be reprinted and I will take the liberty to send you a copy which I beg you to accept in exchange, undoubtedly a very unequal exchange, but the only one I have to offer.⁹²

The forbiddingly technical works listed above provide no insight into Duhem's personal state of mind. The case is different with his Notice on the life and work of Emile Mathieu which, following the latter's death on October 19, 1890, he was asked to write for the *Bulletin* of the New York Mathematical Society. The invitation from New York obviously was prompted by Duhem's magisterial review in the August 1890 issue of the *Bulletin des sciences mathématiques* of the first volume of Mathieu's *Théorie de l'élasticité des corps solides* published in early 1890.⁹³ It would be tempting to speculate about the extent to which Duhem was aware that the perspective in which he put Mathieu's life and work, a thing of the past, was to be the perspective of his own future. As will be seen, for some years to come he seemed to be convinced that, regardless of the hostility of Berthelot and others, the amount and quality of his publications would ultimately pave his way to a chair in Paris. What his feelings may have been had he reread his Notice on Mathieu by the time had known for certain that such hopes were in vain, is a topic for a psychohistorian not for a historian of science. Having the advantages of hindsight, the historian of science cannot help being struck by the applicability to Duhem himself of the most salient themes in that Notice of his on Mathieu.

Like Mathieu, Duhem too pursued a course in science which was not fashionable and he was fully conscious of its unpopularity. The Notice started with a blast on the tyranny of fashions and with the assertion that its hold on science was no less overbearing than anywhere else in any other much more mundane terrain. France was a prime example and a devastating one:

Thus it came to pass that, in mathematics as elsewhere, fashion will sometimes award the laurels to those who have not deserved the triumph and make victims out of men whose lack of success is in fact an injustice. In every country there are such victors and

92. Emile Picard, his former tutor at the Ecole Normale and since 1889 member of the Académie des Sciences, sent him on August 3, 1891, no less appreciative words:

My dear friend . . . Your treatise on electricity seems to me extremely interesting . . . I see that you are familiar with the sophisticated works of theorists and you set forth everything with a marvelous clarity. I had time to study with the greatest care your first volume of hydrodynamics and acoustics . . . We talked of it last Monday with Sarrau at the Académie and we were in agreement in its praises without reservation. You are right in going back to the ideas of Lagrange to establish the general equations. As to Helmholtz's works on acoustics, this was for me an entirely new thing. Your work will do considerable service.

93. 1890 (2).

such victims; but nowhere perhaps are they more numerous than in France. In this country, where centralization is carried to an extreme, nothing is accepted unless it receives the sanction of Paris, or rather of certain constituted bodies, of certain official persons residing in Paris. Those who have been so fortunate as to have their work noticed by these persons and approved by these bodies, those who have been granted admission to the chairs of the capital, form in the opinion of the French public the only men of science worthy of honor. The others, relegated to the provinces, are left to oblivion, almost like those *seigneurs* in the age of Louis XIV whom the caprice of the monarch relegated to their country estates. Such are the reflections suggested to my mind by the contemplation of the life and works of Emile Mathieu.⁹⁴

The course Mathieu followed in science could not be told without being set against the state of physics in France in the second half of the nineteenth century. It consisted, in essence, in a turning away from the great tradition of mathematical analysis to an experimentation aimed at 'the ascertainment of facts . . . without theory, without idea.'⁹⁵ Such was a personal experience for Duhem too, no less than was for him Mathieu's resolve not to take his great forebears' work at face value. Duhem spoke of himself as he wrote of Mathieu that 'while full of respect for the tradition of these men of genius, Mathieu does not allow this reverence to become a superstition; he knows where to depart from their views.' Again, Duhem must have recognized himself as he wrote of Mathieu that he was 'far more mindful of the generality of the methods he uses than was the case with the great mathematicians of the century.'⁹⁶ In recalling with obvious scorn that Mathieu was 'allowed only a few months before his death to adorn his buttonhole with that decoration [Légion d'honneur], which is so stingily bestowed upon those who [truly] honor their country, and so profusely on those who reap honor and profit at the cost of their fatherland,'⁹⁷ Duhem was anticipating his firm refusal, years later, of the same decoration. Duhem could hardly suspect in 1892 that in describing Mathieu's peregrination from one provincial university to another, he was anticipating his own itinerary. His own future was unwittingly prophesied as he remarked, concerning Mathieu's last seventeen years spent in Nancy, that following his arrival there in 1873 'he finds himself relegated to profound and undeserved oblivion. Several times chairs become vacant at the Sorbonne, at the Collège de France; [judged] by his memoirs and his books, he is just the man to fill the place; and yet nobody thinks of seriously considering his candidacy. The Académie des Sciences forgets that, somewhere in France, there lives a man who, through his entire scientific work and the progress produced by it in physics, is fully entitled to its reward and honors.'⁹⁸ Last but not least, how could Duhem have suspected that

94. 1892 (8), pp. 156-57.

95. *Ibid.*, p. 161. That great tradition, Duhem remarked, became 'forgotten, despised and scorned,' because in France 'reactions are abrupt and extreme.'

96. *Ibid.*, p. 164.

97. *Ibid.*, p. 162.

98. *Ibid.* Duhem restricted himself to portraying Mathieu, the scientist. The three lines he quoted about Mathieu the man, were no less applicable to Duhem: 'Of an essentially straightforward, sincere, and generous nature, he was kindness itself. He possessed the devotion that seeks to be ignored' (*ibid.*, p. 168).

the overriding concern for the exams and courses in October which consumed Mathieu as he faced death in September was to become literally true of him as well?

Crushing weight of stacked cards

Duhem obviously found not much comfort in the fact that Lille had many advantages over Nancy. Compared with Lille, relatively close to Paris, Nancy was utterly provincial. Compared with Paris, Lille was just part of the provinces where Duhem never could feel entirely at home. Nor could he stay in Lille. The chain of events that led to his forced departure started innocuously though revealingly. Sometime during the academic year 1891-92 he welcomed, in one of his seminars, somebody from the 'citadel,' that is, from the Institut Catholique, most likely Monnet, for the person in question was later identified as a preparator there. Informal contacts, as was seen, were not rare among members of the two Faculties. Also, nothing could be more natural on Duhem's part than to help as much as possible that very Monnet who introduced him to his future wife. But because Duhem did not clear the matter with the dean, his all-too natural gesture could be construed, with ill-will to be sure, as a breach, however small, in the wall of separation between State and Church, as built and interpreted by crusading Republicans.⁹⁹ As a 'loyal' Republican, Demartres protested, an act which sowed the seed of growing tension between him and Duhem.

No wonder that Duhem's until then 'small faults' of character loomed suddenly large on Demartres' horizon. In continuing to describe Duhem as an uneasy genius, Demartres no longer put the emphasis on 'genius' but on 'uneasy.' He did so in such a way as to hide his change of heart. First he recommended that Duhem's course in mathematical physics be transformed into a chair. He noted 'the extremely high' level of teaching of that 'remarkable professor' whose 'zeal and scientific activity are indefatigable.' Then he added, in his confidential report for 1891-92, a note which cast a novel light on Duhem: 'It is regrettable that Duhem's character includes certain asperities which, without lessening in the least the esteem of all those who know him, are of a nature which make official relation sometimes a little difficult with him.' To this apparently benevolent background Bayet, Couat's successor as rector since 1891, could add subtly destructive phrases: 'It is regrettable that the character of Duhem does not measure up to his scientific merits. He is too self-possessed, ever ready to create problems for the dean and his colleagues. He made the mistake this year by causing, through improper words, a clash with Mr. Petot. He was [already] in conflict with Mr. Demartres because he wanted to let a préparateur of the Facultés Libres [Institut Catholique] participate at a closed conference [seminar] without authorization from the dean.' The final remark spoke for itself: 'Mr. Duhem has frequent rapports with members of the Facultés Libres. Acknowledge as I do his scientific value – which I am unable

99. Ill will was all the more needed, because the 'preparator' claimed to himself the status of 'contribuable,' that is, of someone who attended legitimately some courses and paid the fee (Dossier Duhem, p. 113).

to evaluate — I cannot help finding him embarrassing.¹⁰⁰ Undoubtedly, nothing could be more embarrassing to a good ‘Republican’ than to appear easy on ‘clericals.’

Outwardly nothing changed. The report made no apparent stir in the Ministry. Actually, Duhem was again given the rank of ‘officier de l’Académie,’ on January 1, 1893. But there was a change of heart on the part of Demartres and Bayet, the officials in Lille on whom the Ministry had to rely ultimately. Had these two not begun to see, as witnessed by their confidential report of May 20, 1892, an ‘embarrassing’ foe in Duhem, they would have found more than sufficient excuse in the tragic death of his wife and second child for his occasional asperities. Such a change of heart all too easily evidenced itself in apparently innocent words and gestures which could not escape a man of perception and sensitivity such as Duhem. Had Duhem seen in Demartres a friend and not a tacit antagonist in early July 1893, he would have looked at him as a conciliator in a conflict which caught him as unsuspecting as if suddenly enveloped in a summer storm. The time was a period of excessive heat which forced the rescheduling of all laboratory exams from afternoon to early morning. The prospect of extra work, coupled with some specification added to it by Duhem, was too much for Paillot, head of the laboratories, who disregarded the assignment. Duhem was obviously carried away when he made sharp remarks in the presence of students about ‘the new policy of negligence’ which now rules the academia. He was of course in his right to demand dean Demartres to force Paillot to make formal apologies for his neglect of duty. Instead of satisfying Duhem on this point, Demartres entered in a heated dispute with Duhem and in the presence of others he raised his hand against his junior colleague.

Statements on the clash, written by participants and eyewitnesses at the request of the rector, Bayet, and his own comments on those statements, all of which were sent to the Ministry of Public Instruction to be inserted in the Dossier Duhem,¹⁰¹ contained one supreme touch of irony. In concluding his own account of the incident, Demartres forgot that he was not supposed to write as a dean but as one of the ‘guilty’ parties. He voiced the view that however great a loss the University of Lille might suffer through Duhem’s transfer to another place, nothing short of such a move could close the incident satisfactorily. In view of Demartres’ self-assurance, the rector’s efforts, which failed to reconcile the parties involved, should seem a diversionary tactic. Demartres knew all too well that Duhem, stamped as an ideologically unreliable civil servant, had no chance against a superior who, however guilty of misconduct, was on the ‘right’ side. In fact, he was so eager to be on that side as to keep adding to his portrayal of Duhem’s wrongs.

Demartres did so with obvious effectiveness; Duhem was transferred from Lille to Rennes on July 29th. The new location was not a surprise to Duhem. Through the solicitude of the Abbé Pautonnier, a native of Rennes, who as a young instructor at Stanislas earned Duhem’s lifelong confidence, Paul Morin, professor of

100. Dossier Duhem, pp. 112-13.

101. The reports make up seventeen pages (180-97).

rational mechanics (mathematical physics) at the University of Rennes, became a recipient of complimentary copies of Duhem's publications which led to a warm correspondence between the two. By reading Duhem's lectures on hydrodynamics Morin quickly saw that Duhem was one of those rare physicists who were also accomplished mathematicians¹⁰² and began his moves to obtain Duhem for the University of Rennes. There the physics department was soon to be enlarged with a post of maître de conférences. There were also good chances in Rennes for Duhem to become the occupant of the chair of professor in a few years, a prospect very remote in Lille. Duhem was not at all enthusiastic. He kept pointing out to Morin the absence in Rennes of a good library which, so Morin informed Duhem, lacked even a readily-accessible catalogue.¹⁰³ No less heavily weighed in Duhem's eyes the absence of students in Rennes capable of responding to his teaching and ideas. Worse, Duhem had to learn from Morin that professors at the Science faculty in Rennes had to take part, every year, in the screening of about two thousand prospective students in the Faculty of Letters, a job which Morin noted, 'had the sole advantage of securing one's advancement to the rank of a 12th-degree mandarin in the academic bureaucracy.'¹⁰⁴

In spite of Duhem's distinct coolness to the idea of going to Rennes, Morin did not miss any opportunity to promote the cause. He favorably disposed Gripon, to retire as professor of physics in 1896, to the idea of Duhem's coming (and possibly succeeding him) and contacted in person Liard, when the latter visited in Bretagne in early July 1893, only to learn from him that budgetary constraints forced the postponement of the creation of the post of a maître de conférences until the fall of 1894. Only two weeks later Liard found the creation of that post the best means of resolving Duhem's conflict with Demartres. On learning from Duhem about the sudden turn of events Morin, twenty-five years Duhem's senior, did his best to be at the service of the young physicist who, as he had already written in one of his letters, made him understand 'thermochemistry.'¹⁰⁵ On August 12 Morin informed Duhem that owing to the sudden transfer to Lyons of Prof. Mariejol, a young widower like Duhem, a recently built house would be available to him in a very quiet and pleasant part of the city.

By then Duhem was doing his very best to have his transfer to Rennes reversed. His efforts culminated in his turning to Painlevé, who as a rising star on the French intellectual and political scene, and at the Sorbonne for the past two years, was certainly on the 'right' side and, as a friend of Duhem, an ideal choice for the task. Painlevé felt strongly for Duhem. 'You know,' he wrote to Duhem on September 22, 1893, 'that you can count on me in all that is in my power. But I'm afraid,' he added with an implicit reference to his having explored several avenues, 'your protestations along the official channels will not be listened to.' While agreeing with Duhem that Demartres' behavior was 'outrageous,' he informed Duhem

102. Letter of August 7, 1891.

103. Ibid.

104. Letter of January 5, 1892.

105. Letter of October 22, 1892.

about the professed view in the Ministry on the conflict as being but the mutual detestation of two men. Worse, Painlevé learned that Duhem's transfer to Rennes had already been decided upon. Tellingly, Painlevé also asked Duhem not to let Pélabon intercede for him because Pélabon was viewed as 'an emissary of the Jesuits.'

It may seem fortunate that Painlevé's letter was written three days before Fabre wrote to Duhem. While from Painlevé he could learn that all the cards were stacked against him, it was from Fabre that he received the kind of help which enables one to carry their combined weight. Fabre was prompted partly because of a letter Painlevé wrote to him. 'Painlevé writes,' Fabre wrote to Duhem, 'that Demartres found further means to make more of a villain out of you. I thought that all this was over. Why [should he] agitate against you who chose to leave Lille in order to cut short these hostilities which are renewed endlessly.' Fabre turned to Duhem with words that carried the healing power which only true friends could provide without becoming flatterers:

Ignore all these bickerings. They are beneath you, because they cannot reach you. You should expect much of the future. Painlevé tells me that you want to have an inquiry on the facts of July. What is the worth of the manner in which they are garbed by those who have vested interests in doing so! Would it not be better to shake the dust of your shoes on all that gang? . . . When I recall the notion I have of you and the notion I have of those there, I cannot understand that you should feel hit by all that you should chalk up as mere stupidity. You are worth more than to compromise yourself in quarrels of that sort.

For the rest of his life Duhem kept this letter from Fabre and the one from Painlevé, together with copies of his, the dean's, and the rector's report on the incident, in a special envelope. Clearly, it must have been with a weary heart that he asked for a transfer which was quickly granted. He was to go to Rennes. He was not considered worth a chair in Paris. The price of chairs there was not always measured in the 1890s and even later by scholarly excellence and teaching ability alone. A case in point, which could not be unknown to Duhem, was the rapid advancement of Alexandre-Marie Desrousseaux, who entered as a student of classics the Ecole Normale a year ahead of him. Although Desrousseaux arrived in Lille at the same time as Duhem, he was already in the Sorbonne by 1891. A good scholar, Desrousseaux was even better as a militant Republican. In 1951, at the age of 90, he put in an unabashed light his scholarly career: 'I have only tried to enrich socialism with hellenism.'¹⁰⁶

In being forced out of Lille Duhem was a loser in more than one sense. For one, the physics department was to move in a year or so from its cramped accommodations to a new Institut de physique nearing completion on Rue Gauthier de Chatillon, a spacious building to be equipped with the latest and best instruments. For another, there was a growing awareness in the French academic world that provincial universities were to be given institutional opportunities to attract foreign

106. 'Desrousseaux Alexandre-Marie' in *Dictionnaire de biographie française*, 11:60.

students if France was to compete effectively with Germany. Unlike the Sorbonne, the University of Berlin had no legal advantages over other German universities. Among provincial universities in France, Lille could best exercise international influence by drawing students not only from Belgium, but also from the Netherlands, England, and above all, the United States, countries from which many young men flocked to various German universities. Lille, which had a very small contingent of foreign students while Duhem was there, also had the advantage of being a center of French industrial power with natural channels to the manufacturing world straddling the lower Rhine and Meuse. What a contrast with Rennes, a mere village compared with Lille, far away from Paris, and the seat of perhaps the most somnolent university in France at the time! Duhem's misfortune was the luck of Bernard Brunhes, his successor as maître de conférences, who would have in all likelihood landed in Rennes. In Brunhes Lille obtained an able young physicist but hardly one to match Duhem's excellence as a theoretician.¹⁰⁷ Brunhes' luck was Duhem's misfortune. It was adding insult to injury that the Ministry, which had already underpaid Duhem, did not offer a compensation for the expenses of his moving to Rennes. He had to beg for compensation which came in the form of 400 francs only on the 9th of November.¹⁰⁸ Meanwhile, as the last weeks of the summer vacation droned on Duhem had ample time to ponder adversities, all too often the lifelong lot of a genius. It is not difficult to guess his feelings when in mid-September he received a letter from Paul Mansion, who not knowing about the background of the transfer to Rennes, congratulated Duhem in the belief that 'it was an advancement.'¹⁰⁹

107. The first year of Brunhes (1867-1910) in the Ecole Normale coincided with Duhem's last year there. After only two years in Lille, Brunhes, a former préparateur of Bouty at the Sorbonne, was promoted to the chair of physics in Dijon, and from there, in 1900, to the chair of general physics in Clermont-Ferrand and to the post of director of the Observatory at Puy-de-Dôme. Brunhes, as will be seen, had a high regard for Duhem's philosophy of physics.

108. Dossier Duhem, p. 178.

109. In that letter Mansion also asked Duhem whether Picard, Appel, and Callandreau were Catholics and whether they could be asked to join the Société and endorse the Congrès Scientifique International des Catholiques to be held in September 1894 in Bruxelles, where Mansion hoped to meet Duhem in person at long last. Mansion's question about Picard and others was indicative of the secretiveness of many Catholic academics in France around the turn of the century about their convictions.

4. IN TRANSIT IN RENNES

A not so somnolent town

In arriving in Rennes Duhem could derive some comfort from being much closer to the Isles d'Ouessant, his favorite sailing place, and to the Gulf of Morbihan where he had spent some memorable summers as a teenager. As to Rennes itself he used to speak years later to his daughter about the 'sweet quiet' of Bretagne's capital.¹ To someone like Duhem, living mentally in Paris, the intellectual life of Rennes could but appear a mere somnolence. In 1893 Rennes was a small place even in comparison with Lille.² Time seemed to stand still in the old town, stretching from the church of Bonne Nouvelle to the Cathedral of St. Pierre, where many medieval houses had escaped the great fire of 1720 which forced a rebuilding of much of Rennes. They were quietly waiting for restoration and sanitation which came at long last in the early 1960s when tourism found business value in the picturesque, though rat-infested, winding streets and narrow alleys.

The street, Rue Brizeux, in the northern part of the city, where Duhem found a house (nr 10) to rent, was stillness itself, and still is. Much of the street, not 300 yards long, was lined on both sides mostly by orchards and fields. The two-storey house with a garden in the back was one of the three houses that formed the street toward the northern end. The house was ideal for raising a little daughter, for accommodating a beloved mother and sister, and for providing privacy for study. Last but not least, the house was only a stone's throw from the open fields hugging the turns of the river d'Ille. It was in Rennes that Edouard Jordan, a younger camarade of Duhem at Stanislas and at the Ecole Normale, who went there as

1. *Un savant français*, p. 95.

2. On the following details, historical and geographical, see ch. xi, 'Rennes de 1880 à 1944,' in *Histoire de Rennes*, publié sous la direction de Jean Meyer, in the series, *Univers de la France et des pays francophones* (Toulouse: Privat, 1972), and P. Banéat, *Le Vieux Rennes*, préface de H. F. Buffet, mise à jour par Mme Robert-Maynial (Paris: Editions F.E.R.N., 1972), which gives a history of all streets of old Rennes with photos and maps.

lecturer in medieval history at the same time as Duhem did, often saw him take care of scholarly problems by 'walking them off' as Duhem was wont to say.³

Duhem soon learned that Rue Brizeux, which connected two main roads leading to the northeast – one to Antrain, the other to Fougères – was called Ruelle Pinsonette before having been widened and renamed, in 1880, after Brizeux, a Breton poet. A convent for Poor Claires was established shortly after at the southern end of the street. In going south to the University, Duhem passed in front of the convent's chapel whose door, accessible from the street, must have seen him enter regularly for a short prayer. Just beyond the convent Duhem reached Rue Fougères and turned right near the ancient Maison de Richebourg, demolished in 1903. There were other ancient buildings also in view as Duhem continued his walk to the University. As the Rue Fougères made a sharp turn to the left and began to ascend, he could see to the right the old Grand Séminaire which became in 1875 the Faculté des Lettres. Farther to the south, where the Rue Fougères began to descend toward the river La Vilaine, he saw to the left the baroque facade of the church St. Melaine and the Palais Episcopal, the seat of the Faculté de Droit since 1906. From beyond those buildings beckoned the magnificent trees of the Jardin des Plantes which often saw Duhem walk with his little daughter, now in her third year, or carry her in his arms as she played with his still-dark beard. Farther down, where the Rue Fougères yielded its name to Gambetta, there rose to the left the imposing baroque edifice of St. Georges, an abbey until the Revolution, and army lodgings afterwards. If he looked to the right along Rue St. Georges, he could see the Cathedral Saint Pierre about four hundred yards away. A few more steps and he reached the square soon to be called Place Pasteur. The square's eastern side was bordered by the neo-Greek facade of the new Science Faculty still under construction.⁴ Progress was behind schedule from almost the start in 1885 when planning began, in spite of repeated visits by Liard, director of higher education in Paris, who showed a marked interest in the project. A three-storey building, stretching over a hundred yards from Place Pasteur to Place de Viarme and forming the Quai Dujardin, it more than matched the old Palais Universitaire diagonally across the river which was straightened into a canal in the 1840s. Built between 1849 and 1855, to house not only the science departments but also an art gallery rich in the works of Flemish painters, the Palais soon proved to be inadequate.

The dozen or so professors, assistant professors, and laboratory assistants who made up the physics and chemistry departments must have considered themselves fortunate when in the early Fall 1893 they could move across the river to the new building of which the first floor was made ready for occupancy with some last-minute haste.⁵ Their colleagues in zoology and biology had to remain behind for

3. Jordan, 'Duhem,' p. 164.

4. Details, documents, and illustrations abound in *Histoire de la Faculté des Sciences de Rennes* (Rennes: Imprimerie Fr. Simon, 1900) by L. Joubin, who served as maître de conférences for eight years prior to his appointment in 1896 to the chair of zoology.

5. Duhem was no longer in Rennes when Félix Faure, President of the Republic, visited the building in August 1896. The first floor was to be dedicated by Sadi Carnot, Faure's predecessor, but his visit to Bretagne was canceled in the last minute.

a year or two in the Palais, proverbial for its cramped accommodations. Duhem arrived in Rennes at a time which saw the end of a physics teaching, in which no experiment could be included that had to be run over a day. Lack of classroom space, to say nothing of laboratory and storage space, was so desperate that as a last resort the janitor's little apartment had to be taken over for the purpose of physics instruction. In the new building the maître de conférences in physics not only had a respectable office, but had the very first room to the right of the main entrance. The window of Duhem's office looked to the Place Pasteur and so did the window of the adjoining room reserved for Professor Gripon who had held the chair of physics from almost the time he had arrived in Rennes in 1868. Gripon, who retired in November 1895 with the rank of emeritus, would be classified today as an experimentalist, although he carried out no original investigation. He was diligent in collecting fine instruments⁶ and served well in the organization of the new building. The physics laboratories and lecture rooms occupied half of the ground floor of the wing parallel to the Quai. While the relative spaciousness of the new accommodations was unquestionable gain, the ongoing construction of the upper floors must have caused the loss of minimum quiet. The little daylight which the ornate and thick stone windowsills let into the interior soon gave rise to continual complaints. There must have been hours and days when teachers and students looked longingly back to the Palais cramped as life was there. Duhem went to the Palais regularly not only because of the paintings but also because it still served as the administrative center where each month he had to sign a sheet acknowledging the receipt of his salary, amounting to 5000 francs a year.⁷ Just behind the Palais Universitaire was the beautiful, formerly Jesuit, baroque church, Toussaint. Between Toussaint and the Rue Janvier leading south to the train station, there spread the Lycée. Duhem could not guess that in a few years the eyes of the world would be fixed on the Lycée's auditorium, where Captain Dreyfus tried in vain to exonerate himself in August 1899.

In walking back and forth between his home and the Science Faculty, and visiting bookshops around Rennes' chief decor, the Place du Palais dominated by the old Parliament House of Brittany, Duhem could reflect on past as well as on present. As to the present, Rennes was not altogether somnolent. The city had been in an increasing ferment since the Second Empire when it was connected by rail with Paris in 1857. Ten years before Duhem arrived in Rennes, a city-wide water and sewage system was completed. Duhem could see further evidences of modernization during his daily walks to the Science Faculty. Between the Maison de Richebourg and the Grand Séminaire, the pavement of the Rue Fougères was

6. Five of such instruments are individually described in *Histoire de la Faculté des Sciences de Rennes*, p. 118.

7. In addition to these sheets, the Archives of the University of Rennes contain only two items concerning Duhem's stay there: a letter from the University of Lille attesting Duhem's salary of 5000 francs, and a letter from the Rector of the University to the Dean concerning the sum of 400 francs to be paid at the order of the Ministry for the expense which Duhem incurred in moving from Lille to Rennes.

torn up as it received tramway tracks, a small segment of a vast public transportation system inaugurated in 1897.

Behind such and similar constructions there lay an intense social ferment and political activity in which Duhem was not, however, to be involved. A relatively small city like Rennes, whose population stood slightly below seventy thousand during the first half of the 1890s, could easily be controlled politically by public works and urban renewal projects. From almost the very start of the Third Republic, Rennes was ruled by an alliance of Republicans and Radicals. The vast countryside, or rural Bretagne, was under the sway of conservatives and even of royalists finding all too often a ready ally in the clergy. Herein lay the source of a conflict which came to a head in Rennes, the seat of archbishops since 1859. The first archbishop, Godefroy Brossay Saint-Marc, became cardinal in 1875, three years before his three-decade-long and increasingly less-successful involvement in politics was brought to an end by his death. His successor, Msgr Place, a cardinal since 1886, was too conservative and intransigent even for much of the Breton clergy. When Duhem arrived in Rennes, memories were still vivid of the universally beloved Msgr Gonindart, whose death followed only by a few months the death of Cardinal Place in March 1893. Needless to say, Duhem could not be unaware of the many snide remarks about Msgr Labouret, the actual archbishop and future cardinal, and no less a liberal than Msgr Gonindart, 'as small, thick-set, corpulent, not at all impressive,' in the words of a not-too-sympathetic contemporary.⁸

Frustrated teacher

At any rate, Rennes was fully in control of the distinctly anticlerical politicians two of which, Edgar Le Bastard and René Le Hérisse, ruled successively Rennes as their fiefdom, for almost four decades, until the end of World War I. Happily for Duhem, the University appeared too small a prize for power politics. In Rennes too the four Faculties were not even officially united as a University until 1896 or two years after Duhem's departure. Of the four Faculties, that of law and of medicine were predominant. The Faculty of Medicine, which as late as 1900 comprised almost half of the entire student body (732 out of 1590), could hardly be politicized. The 566 law students naturally allied themselves with the politicians. As to the 177 students of the Faculté des Sciences, and of the mere 115 students of the Faculté des Lettres, they could safely be considered negligible. They merely served, as the saying in Rennes went, to provide 'fourniture' (members) for juries presiding over baccalaureate exams in the lycées.⁹ In the Faculté des Sciences there were only 7 professorial chairs of which physics held two including the chair for applied mathematics (mechanics), a chair occupied since 1877 by Paul Morin, who, as was noted, looked forward to Duhem's coming to Rennes.

As a maître de conférences, Duhem was assigned to give two courses. One, in the large amphitheater, was on physical optics twice a week, Wednesday and Saturday afternoons from 2:30 until 3:30. The other, on Monday afternoons from 4

8. *Histoire de Rennes*, p. 420.

9. *Ibid.*, p. 305.

to 5, was on hydrostatics, capillarity, and acoustics – obviously a survey course.¹⁰ The main courses in physics given by Morin and by Gripon were hardly on an advanced level, a point which can easily be gathered from the lengthy account in the *Annuaire* of the courses offered by Gripon.¹¹ The situation was of course an ‘improvement’ over the state of affairs that prevailed only ten years earlier. A letter of May 9, 1883, from the Ministry of Public Instruction stated nothing less than that ‘the science of chemistry hardly exists [in Rennes], the science of physics does not exist at all; as to geology, it is structured rather badly.’¹² Whatever of Duhem’s hope that his achievements would soon secure him a prestigious post, the almost elementary level at which he had to teach physics in Rennes exasperated him. The thought, that he was sent to Rennes not so much in punishment but as part of Liard’s strategy to raise scientific standards in Rennes, could not seem convincing. Students like the ones who inspired him in Lille were absent. Equally absent were intellectually stimulating professors charged with the teaching of the exact sciences. Morin, who became a lifelong friend, was a good listener to his new and much younger colleague in whom, as his letter of Jan 5, 1892, to Duhem attests, he quickly noticed a rare power of theoretical synthesis. Emile Gripon, whom Morin described in his letter of July 29, 1892, to Duhem as a ‘very good man, excellent character, and very reasonable . . . easy to get along with,’ was not one with whom Duhem could talk theoretical physics. The many textbooks of physics written by Gripon were mostly aimed at students in the higher grades of elementary schools! Gripon did not earn high marks from Duhem even as an experimentalist. Gripon’s main accomplishment in the physics laboratory, so Duhem reported somewhat maliciously at home and to his friends, consisted in the making of napkin rings for his grandchildren.¹³ If the conditions of physics teaching were far from ideal, the university library, still confined to a few rooms in the Palais Universitaire, was an almost lost cause. In reminiscing about Duhem’s year in Rennes, his colleague Jordan felt impelled to remark that ‘about the poverty of the university library it would be difficult to form an idea, although too many on the faculty found it quite normal. I well remember Duhem’s indignation.’¹⁴ On Duhem’s insistence, the library ordered books needed for his research, a novelty which created quite a stir. When a year later Duhem’s stay in Rennes came to an

10. See *Université de France. Académie de Rennes. Annuaire des Facultés et des Ecoles d’enseignement supérieur 1893-94* (Rennes: Typographie Oberthur, 1893), p. 73. Duhem’s address is given on p. 64.

11. *Ibid.*, pp. 71-72.

12. Personal communication of Mr. A. F. Lesacher, of Rennes. Zoology, botany, and biology fared somewhat better, but since its foundation in 1808 the University of Rennes saw until 1899 only three doctorates in the sciences: two in mathematics (1843 and 1877) and one in zoology (1893); see Joubin, *Histoire de la Faculté des Sciences de Rennes*, p. 143.

13. *Un savant français*, pp. 95-96.

14. Jordan, ‘Duhem’, p. 161. The university library was open for an hour and a half in the morning and for five hours in the afternoon. It was never open in the evening hours (*Annuaire*, p. 93).

end, an elderly professor, possibly Gripon, was heard to ask: 'Now that he is gone, what will be the use of all these books?'¹⁵

Duhem the savant made a lasting impression on those of the Science Faculty at Rennes who had the making of savants. One of them was Louis Joubin, who in his history of the Science Faculty at Rennes pointedly referred to 'the brochure, *Usines et laboratoires*, of our savant colleague, Mr Duhem, now in Bordeaux.' The context was an unintended irony on Liard whose motto, 'pas de monument, un atelier de Science,' was not implemented in the construction of the new science building in Rennes.¹⁶ Those who appreciated Duhem the savant also appreciated him as a man. Apart from Jordan, with whom Duhem now developed a lifelong and deep friendship, Duhem was often seen in the company of the brilliant jurist, Emile Artur, professor of administrative law and a poet of sorts.¹⁷ Duhem, who loved to dispute even with friends, could hardly refrain from a cutting remark or two when finding himself in the company of someone whose words or attitude did not seem to him appropriate. He found it unnatural that a young faculty member, whose father, a Hungarian Jew and wholly unfamiliar with the French idiom, should, in a boastful style, keep referring to 'our glorious revolution.' Duhem cut him short: 'Our revolution? *Mine* perhaps . . .; *yours*? that's impossible.'¹⁸

Creating a stir

As usual, Duhem was very direct and he relished the impact which he could make with a straightforward statement on others including those with whom he was in basic sympathy. He was still on the Faculty at Rennes when, despite his dislike of congresses and symposia, he went, in early September 1894, in the company of Jordan, to the Third International Scientific Congress of Catholics held in Bruxelles,¹⁹ and organized by the Société scientifique of which he had been a member since 1891. It was not with his paper, an unsparing criticism of Maxwell's electromagnetics, which he read on Wednesday, September 5, morning,²⁰ that he created a stir. Although there were many among the thousand or so participants of the Congress, in large part ecclesiastics from all over Europe and the United States, who were interested in scientific questions, not too many among those attending

15. *Un savant français*, p. 96.

16. Joubin, *Histoire de la Faculté des Sciences de Rennes*, p. 97.

17. Emile Artur (1852-1921), who was Duhem's colleague in Lille, obtained a chair in the Faculty of Law at Rennes about the same time when Duhem was transferred there. Artur's chief expertise was the distinction between legislative and administrative functions.

18. *Un savant français*, p. 97. Very likely the teacher in question was Jarno, professor of criminal law, but in charge of a course on the general history of French law (*Annuaire*, pp. 17-20 and 61).

19. The text of papers and discussions, together with the list of participants, was published in nine sections, each with its own pagination, under the general title, *Compte rendu du Troisième Congrès Scientifique International des Catholiques tenu à Bruxelles du 3 au 8 septembre 1894* (Bruxelles: Société Belge de Librairie, 1895).

20. Duhem's paper (1895 [10]) was published in *Compte rendu . . . Septième Section – Sciences mathématiques et naturelles*, pp. 246-69.

the lectures in the science section were trained mathematicians and physicists. Charles Hermite, the famed mathematician, who gave a paper on Bernoulli numbers, was one of the few who could follow every detail in Duhem's lecture, heavy on equations of electromagnetics. His was the second lecture in the morning, preceded by a long discourse on the ether by A. Marx, retired inspector-general of Ponts-et-Chaussées, the chief military engineering school in France. Marx's lecture,²¹ which contained little mathematics, but much spurious philosophy and rhetoric, may have already saturated the mental exigencies of most of those in the science section and undoubtedly drained their physical endurance. Quite possibly, Duhem saw people getting up and leaving quietly as he went on with his lecture which had to be limited to a part of his twenty-five-page-long communication on the electrodynamics of dielectric bodies as proposed by Maxwell.²²

Duhem's hour came the following morning when he attended, in the philosophy section of the Congress, some lectures dealing with topics that touched on the relation of sciences to metaphysics. After the Père Bulliot, future head of the philosophy department of the Institut Catholique in Paris, had read his paper on the concepts of matter and mass, Duhem asked, not without the promptings of some present,²³ for permission to make a few remarks. Although his remarks were not reported in the *Compte rendu* of the Congress in the form of a verbatim quotation, the printed text can, partly because of its incisiveness and clarity, be taken for the most part for Duhem's actual words. Duhem, the report begins, 'is convinced that these researches [having for their object the confines of the positive sciences and metaphysics] will, if done wisely and prudently, lead to the reconciliation of Christian philosophy and modern science, but he insists on the extreme difficulty of such studies.' Duhem's reasons were as follows:

Only the principles of the different positive sciences are of interest to philosophers; but, in order to know these principles, it is not enough to read a book of popularization, not even the first chapters of a treatise written by a competent scientist. One does not comprehend the meaning and bearing of the principles on which a science rests except when one has studied that science for years, applied in a thousand ways those principles to particular cases, and mastered in depth the technique of what the Germans call the materials of science.

For example, the obvious sense of Euclid's [parallel] postulate is accessible to a child who studies the first book of geometry. But in order to understand the exact sense of that postulate, to grasp the reasons which give it a special place among the truths of geometry, to see clearly what would become of geometry if that postulate were to be abandoned, one must have a complete mathematical training which requires years of work.

If therefore we want to handle with competence and fruitfully the questions which are of the domain common to metaphysics and to positive science, let us begin with studying the latter for ten, for fifteen years; let us study it, first of all, in itself and for itself, without seeking to put it in harmony with such and such philosophical assertion;

21. The lecture was on the ether as the 'universal principle of forces' *ibid.*, pp. 54-89.

22. A summary of Duhem's paper was given on pp. 337-38.

23. As Duhem himself put it in a letter which he sent from the Congress to his mother, see *Un savant français*, p. 157.

then, as we have mastered its principles, applied it in a thousand ways, we can search for its metaphysical meaning which will not fail to accord with true philosophy.

Anyone who would find exaggerated a similar labor must not forget that every hasty, scientifically incorrect solution of one of the problems relating to the common frontiers of science and philosophy, would result in the greatest prejudice against our cause. The philosophers must imitate the patience of scientists. Once a problem is posed, scientists devote centuries, if necessary, to solving it. They accept only a precise and rigorous solution.

At any rate, the schools we are combatting give us example. The positivist school, the critical school, publish numerous works on the philosophy of science. These works carry the names of the greatest names of European science. We cannot triumph over these schools except by opposing them with researches done by people who, too, are masters of the positive sciences.²⁴

Undoubtedly, a good portion of the thousand or so participants at the Congress were attending the philosophy sessions and many of them could readily recognize themselves as obvious targets of Duhem's remarks. These had to be pointed to produce the hoped for reaction. The latter came inevitably. Duhem wrote with obvious delight to his mother:

Yesterday, I decided to create a big stir. It was in the section of philosophy. The room was full, mostly of ecclesiastics. One brave ecclesiastic had just discussed an objection taken from mechanics. My opinion was asked concerning the scientific part of the problem. Then, I told squarely all these good Catholic philosophers that if they obstinately continued talking of science without knowing of it a single word, the free-thinkers would hold them up for ridicule; that in order to speak of questions where science and Catholic philosophy touch one another, one must have done ten or fifteen years of study of the pure sciences, and that, if they had not become men with deep scientific knowledge, they must remain silent. . . The idea, once launched, will advance; all afternoon one spoke but of this at the Congress. I do not regret having come. I believe that the seed which I sowed will germinate. It is for the first time that those brave people heard the truth spelled out. This does not surprise me much, but I am surprised to see that they respond, or at least several of them do so, with a great deal of good will.²⁵

One of these was none other than the Père Bulliot. He agreed, 'wholeheartedly,' as he put it in the *Compte rendu* of the Congress, 'with the ideal toward which, as indicated by the erudite professor of Rennes with all the competence which is his, all those must aspire who wish to work more effectively for the triumph of scholastic philosophy.' But not everything was sweet harmony, nor could be. Duhem, the Père Bulliot noted, not only declared that *only* the principles of the positive sciences were of interest to philosophers, but also implied that those principles had no metaphysical meaning. Did it then really follow that only a scientific study, let alone such a study carried on for ten or fifteen years, could perceive that meaning? Was not a non-sequitur lurking behind Duhem's startling claim? Convinced, as were most scholastic philosophers of the times, that scholastic

24. *Compte rendu . . . Troisième Section – Sciences philosophiques*, pp. 323-24.

25. *Un savant français*, pp. 157-58.

philosophy must be a 'scientific' philosophy, the Père Bulliot could not fail to perceive that non-sequitur, and make Duhem catch a glimpse of it. While the Père Bulliot insisted that the study of those principles must be personal, suggesting thereby the primacy of common sense in philosophy and its essentially 'non-scientific' character, he showed himself the victim of a specious illusion as he declared in the same breath that the same study must be done 'under the twofold light of experience and metaphysics.' For if the experience meant scientific experiments, then the principles in question were already implied and taken for granted. If experience meant commonsense evidence, then the metaphysics in question could but appear pure speculation devoid of science. Such was hardly the metaphysics advocated by the Père Bulliot, who insisted that scholastic philosophy was essentially 'scientific.' Such philosophy, he declared, 'issues spontaneously from the data of science as a flower does from the stem; it is their final conclusion and their highest crowning.'²⁶ The Père Bulliot could only wonder at seeing Duhem insist on the harmony between science and metaphysics as being essentially negative, namely, the intrinsic impossibility of a conflict between the statements of positive science and of a philosophy taken for metaphysics.

In the center of a debate

If pressed by the Père Bulliot or someone else, Duhem would have undoubtedly engaged in a lively debate. Many of those present would have known in advance the viewpoints he would have stressed, as most participants at the Congress were also readers of the *Revue des questions scientifiques*, the forum of which Duhem first availed himself to make public his views on physics insofar as it related to philosophy. They would have also been familiar with some of the replies which Duhem's views would provoke. One such reply, that Duhem advocated Kantianism, was voiced informally at the Congress to Duhem's chagrin. A chief among those with such a reply was Count Edmond Domet de Vorges,²⁷ who after his retirement from diplomatic service in 1884 devoted himself with uncommon energy, though not with distinction, to the writing of books on scholastic philosophy. The Count had already labeled Duhem a Kantian in the November 1892 issue of *La Science catholique*.²⁸ He was in fact the first to react in print to Duhem's paper 'Quelques réflexions au sujet des théories physiques,' which saw print in the January 1892 issue of the *Revue des questions scientifiques*.²⁹ Even if Duhem had learned of the Count's two-page-long reflection on his paper, he may not have found it worth answering. The situation was different when, in the Spring of 1893, there appeared

26. *Compte rendu . . . Troisième Sections – Sciences philosophiques*, p. 324.

27. The Count was in fact the President of the session at which Bulliot read his paper, which in turn prompted Duhem's remarks.

28. 'We said that Mr. Duhem did not want any metaphysics. Well, we are wrong. He has a metaphysics and this metaphysics . . . is the Kantian metaphysics,' wrote the Count in his survey of recent philosophical publications by Catholics in *La Science catholique. Revue des questions religieuses* 6 (1892): 655.

29. 1892 (6).

in the *Revue des questions scientifiques*³⁰ and in the *Annales de la philosophie chrétienne*,³¹ a long reply by Eugène Vicaire to Duhem's paper under the title, 'De la valeur objective des hypothèses physiques: à propos d'un article de M. P. Duhem.' Vicaire,³² a graduate of the Polytechnique and of the Ecole des Mines, was a worthy match for Duhem in more than one respect. A devout Catholic, Vicaire too was at the head of his class and displayed considerable versatility. A member since 1892 of the Société mathématique de France, Vicaire, twenty-one years Duhem's senior, showed that a brilliant career in the State supervision of French mines was not an impediment to staying abreast with the latest developments in mathematics. Duhem's response was quick and commensurate. It appeared in the Fall of 1893 both in the *Revue* and in the *Annales* under the title, 'Physique et Métaphysique.'³³

The debate between Duhem and Vicaire was strictly on the level of ideas though largely at cross purposes. Duhem's fleeting references to the ontological foundations that had to be presupposed by a physics which, while positivist in method, dealt with reality, could easily give the impression that the positivism he advocated was its Comtean kind. Vicaire in turn gave scant justice to the central role in physics of a purely mathematical systematization of data as he kept returning to ontological causality. Little of all this was perceived by Domet de Vorges as he commented on the Duhem-Vicaire debate in the November 1893 issue of the *Annales*.³⁴ Worse, his comments had an unpleasant personal touch. Duhem, who had just settled in Rennes, must have been partly amused, partly irritated by the condescension and the naiveté of the Count. Being a full generation older than Duhem, the Count held Duhem up as a prime example of a younger generation of Catholic scientists who, having failed to obtain a proper training in Catholic philosophy, took refuge in a radical separation between metaphysics and physics, which the Count traced to Kant, although Kant reduced metaphysics to physics.³⁵ Whatever Duhem's irritation, he could only smile on reading the Count's longing for the good old times 'when physicists, the Count singled out Jamin, could write long treatises without using mathematics, and even without being able to handle an

30. 33 (avril 1893): 451-510.

31. 126 (avril-mai, 1893): 50-80 and 113-37.

32. Vicaire died in 1901 at the age of 62. His obituary, 'Eugène Vicaire,' by the prominent mathematician M. d'Ocagne, was immediately published in the *Revue des questions scientifiques* 49 (1901): 420-31. There d'Ocagne recalled that Vicaire opposed Secchi's claims about the very high temperature of the sun's surface and found supporters in Fizeau and Becquerel. Vicaire not only contended that the temperature of the sun's surface was not higher than that of ordinary flames but that its core was cold, a view previously held by Herschel and Arago.

33. 1893 (8).

34. 'Les hypothèses physiques: sont-elles des explications métaphysiques?' *APC* 127 (nov. 1893): 137-51. See especially pp. 146-47.

35. Kant did so in almost the same breath in which he deplored the reduction of metaphysics to mathematics. For details, see my *The Road of Science and the Way to God* (Chicago: University of Chicago Press, 1978), p. 117.

integral or a differential.³⁶ The irritation was really a problem for the Count, who could not read a page of Duhem's publications in physics, all loaded with differentials and integrals.

Duhem's hour of irritation came when he saw in the December 1893 issue of the *Annales* a two-page-long note in which George Lechalas, ingénieur-en-chef des Ponts-et-Chaussées, came to the aid of Vicaire. Lechalas did so by contrasting Duhem's reliance in his course of acoustics on the vibration of air as the *cause* of auditory sensations and his avoidance of any reference to the vibrations of a medium (ether) in dealing with the sensations of visual perception. Clearly, Lechalas argued, the inability of Duhem the physicist to avoid speaking of causes lent support to Vicaire who insisted that reference to causes was as indispensable in physics as it was in metaphysics.³⁷ In replying to Lechalas, Duhem showed that when irritated he could yield to the urge of dealing a personal blow at his opponent.³⁸ Duhem's indignation that Lechalas made unauthorized use of his lecture notes on optics and that Lechalas thereby was guilty of academic impropriety, was beside the point. Lechalas could readily apologize on this secondary matter and still make the very valid point that Duhem had already made clear in several publications his studied indifference to the question of the existence of the ether, which to Lechalas implied indifference to the question of ontological causality.³⁹

Shortly before the end of 1893 Duhem could take no small comfort in the fact that the Dominican theologian and philosopher, P. B. Lacomme, came to his defense in the pages of the newly-founded *Revue Thomiste*.⁴⁰ Lacomme called attention to the 'hecatomb' of physical theories during the nineteenth century and praised Duhem as the one who had developed an acute and learned awareness of that fact without adopting the sheer commodism advocated by Poincaré. Duhem must have been even more pleased with Lacomme's remark that it was Duhem who had given the first intimations of a vast and important aspect of intellectual history, namely, the history of the influence of philosophies, since the 17th century, on the formulation of physical theories. That history, Lacomme argued, was to be set forth in full for a proper appreciation of the viewpoint which Duhem emphasized. Duhem must have been elated on reading Lacomme's words:

In doing mathematical physics Duhem sensed that many of its problems are obscure and uncertain, because the principles have not been examined closely enough. He has undertaken the revision of these principles and developed a clear awareness of the fact that people [scientists] have continually entertained prejudices. He courageously tried to sift prejudices from truth, to reject the former and start anew scientific work with a small

36. The reference was obviously to the *Cours de physique de l'Ecole polytechnique* by J. Jamin (1818-1886). Its four volumes dominated higher instruction of physics in France as they went through four revised editions between 1858 and 1891.

37. 'M. Duhem est-il positiviste?' *APC* 127 (1893): 312-14.

38. Letter to the Editor, *APC* 128 (1894): 91-92.

39. Letter to the Editor, *ibid.*, pp. 92-93.

40. 'Théories physiques à propos d'une discussion entre savants,' *Revue Thomiste* 1 (1893): 676-92 and 2 (1894): 92-105.

batch of truths that remained. This meant to perform an act of criticism, a critique respectful of all that is true and merciless toward error, be it an error more popular than truth. It was to be expected that many a devotee of science would be irritated and let him know it. Does it matter? If he has truth on his side, the future will not fail to vindicate him.⁴¹

If the first instalment of Lacombe's article justified Duhem's personal work, the second in the January 1894 issue of the *Revue Thomiste* was an eloquent justification of the broader vistas animating Duhem's painstaking analysis of the sense in which a quality like heat could possess 'quantitative' aspects useful for the purpose of experimental and mathematical physics. This analysis became a dozen or so years later that part of Duhem's *Théorie physique* which he considered to be its most important part. Lacombe firmly upheld Duhem in his contention that 'temperature and intensity of heat were two distinct notions and the relation which connects them is not that of a sign to the thing signified or that of a measurement to the thing measured.'⁴² Duhem could but agree on reading Lacombe's declaration: 'It was sufficient for me to show that, judged by scholastic philosophy and reason [science], the notion of temperature is not what it generally is supposed to be.'⁴³ Duhem's own broader vistas and hopes were expressed in Lacombe's concluding paragraph:

Why then should science and philosophy remain alienated sisters forever? Why should science ignore the services which she could expect from her elder sister and continue mistrusting her? Why does philosophy grow opinionated in her isolation? Catholic philosophy has such a beautiful opportunity! She was born with Aristotle's analysis of the sciences known in his time. She reached maturity on the day when she was called to serve the science of divinity. She has marvelously fulfilled that role and still does. But today when in the secular eyes, if not in the eyes of her friends, she is low in esteem, why should she not think of rejuvenating herself? Why should she not sit down at the sumptuous banquet offered by modern science? The place is for the asking. She can take it, everything invites her there. The Church enrolls her and science is waiting for her. Can you think of the strength which truth would possess against modern arrogance if she were to seize the flag of science which that arrogance unjustly detains and with which it covers all its errors and crimes? There are Catholics and thinkers in French Universities, there are in religious orders strong philosophical traditions and enough talent. Why should not some vocations be found for that glorious work?⁴⁴

Scholar in a wrong place

In reading this paragraph, as Rennes was swept by winter winds blowing from the Atlantic and appeared even more isolated a part of France than it was, Duhem must have felt keenly his intellectual isolation. He felt a calling, but whatever his deep concern for Catholicism, the call was not in the direction of Christian apologetics through science. His journey, at the end of the following summer to the

41. *Ibid.*, pp. 682-83.

42. *Ibid.*, p. 104.

43. *Ibid.*, pp. 104-05.

44. 1894 (5).

meeting of Catholic intellectuals in Bruxelles was the first and last of his involvements in that direction. The overriding call he felt was for physics which, if properly cultivated, would, by exemplifying truth in its own way, help make wider other ways as well to truth. His intense commitment to the cultivation of a true physics, as he saw it, could but make him keenly aware of the contrast between the absence of a proper audience for his intellectual prowess and its unabated productivity. His 53-page-long paper, 'Quelques réflexions au sujet de la physique expérimentale,' saw print in the *Revue des questions scientifiques*, shortly before the Congress in Bruxelles was held.⁴⁵ It was in that paper that for the first time Duhem unfolded in detail a central claim of his notion of physical theory, namely, the impossibility of crucial experiment. No less revealing of his way of thinking was a review, again in the *Revue des questions scientifiques*, of the French translation of two collections of Kelvin's essays. The review provided ample opportunity for Duhem to illustrate the difference between the Anglo-Saxon and French minds, or imaginative and rigorous minds respectively, a difference which stands for no less a central perspective concerning Duhem's pleas on behalf of a very specific form of physical theory.⁴⁶ Written as it was shortly after his arrival in Rennes, the review may have reminded him of conversations which he had often had while in Lille with Chevrillon and Angellier, two authorities on the English mind. With no such stimulation in Rennes, the isolation from Paris, from talented students, and from a proper forum to have his voice heard, must have weighed increasingly heavily on Duhem. His intellect was, however, too vigorous to be hampered by circumstances, adverse and inadequate as they could be.

Reflections on physical theory invited reflections on the history of physics. Such was a most natural consequence in the case of Duhem who almost ten years earlier, in his very first publication, made a pointed reference to the historical development of a physical theory as being part of the unfolding of its conceptual completeness, and who had not since failed to recall, at times at length, the history of problems of theoretical physics he had discussed in print. It was during his year in Rennes that he began a series of essays, in the *Annales de la Société scientifique de Bruxelles*, on the history of optics as a means of shedding light on the true nature of theories of light. About the gist of these essays he gave an advance taste in an article published in the *Revue des deux mondes*, a forum which assured to his views a world-wide audience, stretching far beyond the circle of physicists.

But in Rennes, as before in Lille and at the Ecole Normale, and later in Bordeaux, philosophy and history of physics were for Duhem but support and complement of his work as a physicist. His productivity as a physicist went on unabated. During his year in Rennes came the publication of the third and final instalment of his studies on 'Dissolutions et mélanges' in the *Travaux et mémoires de la Faculté de Lille*.⁴⁷ It was also from Rennes that he sent to the *Journal de mathématiques*

45. In the July 1894 issue.

46. 1893 (9).

47. 1894 (1).

pures et appliquées in Paris, the third and final part of his commentaries on the principles of thermodynamics,⁴⁸ a work which grew out of his response to the demand of his students in Lille to clarify for them that topic to which no justice was given in the official courses offered there. The *Annales des Facultés scientifiques de Toulouse* received in the same year from Duhem the second part of his study of electrodynamic and electromagnetic actions.⁴⁹ It was during his year in Rennes that the Académie Royale de Belgique offered Duhem its *Mémoires* for seven massive studies on permanent magnetic deformation and hysteresis. He presented the first in person to the Académie on October 13, 1894, a day which became, as will be seen shortly, even more memorable in his life for another, far less pleasant, reason.

Clearly, the many inconveniences and disruptions occasioned by moving into another city and taking a new post did not slow down Duhem's fabulous productivity. The latter usually evokes a study cluttered with notes, books, proofs, and correspondence. In Duhem's case the very opposite was true. His colleague and friend, Jordan, who lodged at 44 Boulevard Sévigné, almost opposite Morin's home and at a five-minutes' walk from Duhem's house where he was a frequent visitor, could not help noting the impeccable order of Duhem's study, a reflection of his orderly, disciplined mind:

Having lived for a whole year, literally side-by-side with him, I do not remember him to have ever given the impression of being overwhelmed by his work or ever being pressed; just as one could have never found his writing desk in disarray although he very often was working on three or four projects. Moreover, he always delivered, well in advance, contributions which he promised in all directions. His life left room for reasonable relaxation, especially for walks. A walk, true, was for him a kind of work. It was his rule to 'walk off' the difficulties, instead of getting enveloped in them. But once his ideas were formed, his facility for putting them in writing was prodigious. He composed in his head and, having sat down at his desk, he filled entire pages with his beautiful, regular and readable writing, without corrections, without stopping except for the time necessary to fetch a book needed for a quotation.⁵⁰

Small was the number of those who like Jordan had the good fortune of seeing, at close range, Duhem at work in his study at home. The eyes of many mathematicians and physicists all over France, and far beyond, were struck by Duhem's publications in leading periodicals. The rapidity with which he produced lengthy

48. 1894 (2).

49. 1894 (4).

50. Jordan, 'Duhem,' p. 164. There is a slight exaggeration in what concerns the complete lack of corrections in Duhem's compositions. The copies which he kept of very important letters are often their first phrasings and show, as does, for instance, his long letter to Liard to be quoted in the next Chapter, extensive alterations. In the manuscripts still extant of much of the last three volumes of the *Système du monde* corrections are few and far between. Jordan must have had them in mind in making the additional remark: 'Duhem leaves behind a certain number of completed manuscripts, ready for printing.' Still another remark of Jordan, 'Duhem leaves behind no notes whatever,' refers to drafts, and is not contradicted by the long manuscript on capillarity, mentioned in note 23 to Ch. 3.

and incisive papers, many of them heavily mathematical, and also rich in references to the latest in experimental data, on a wide variety of topics, could not fail to make an impact, which of course varied according to the circumstances. Thus the confidential report which the rector of the University of Rennes sent to Paris on June 12, 1894, on Duhem was clear enough on several points to give uneasiness to authorities there. For one, the rector noted that the high level of scholarship represented by Duhem was wasted in Rennes where 'we had only two candidates so far for licence and where Duhem does not seem to have a student worthy of him.' If this had not already put the authorities in Paris on the spot, they must have felt even less pleased with the rector's categorical statement: 'I hear some saying that Duhem would be in his proper place only in a chair at the Collège de France.'⁵¹ Most importantly, authorities in Paris basing their attitude toward Duhem on his allegedly difficult personality and looking for further confirmation along that line could but feel uneasy on reading the categorical statement of Sirodot, professor of zoology and dean of the science faculty since 1869: 'I have not heard anything unfavorable concerning his character. His relations with his colleagues are very correct; . . . a distinguished mind, and a firm person.' Curiously, the report also contained the remark: 'He denies having the desire to be given a post in Paris.'⁵² It seems indeed that some authorities in Paris were inviting some evidence against Duhem.

If Duhem ever spoke in this vein to the dean it was possibly because he sensed in the inquiry a trap. Rumors about Duhem's imminent transfer to Paris could be heard time and again. In sending to Duhem greetings for the year 1894, Moy, dean of the faculty of letters in Lille, expressed his surprise that Duhem was still in Rennes: 'It was rumored here that you have been called to Paris. Nobody would be happier than I and all your friends here.' As to Duhem's friends in Paris, they certainly would have been most happy to have him there, but they were powerless in face of Berthelot's opposition. Witness is Painlevé's long letter of January 11, 1894, to Duhem which echoed some passages of a letter written by Duhem to Painlevé in mid-December following Duhem's visit in Paris:

I perfectly understand the extent of your frustration in Rennes . . . but time as well as merit are on your side. You will triumph in the end. I assure you that you are absolutely wrong in assuming perfect indifference on Tannery's part, or a malicious indifference on Darboux's part, toward you. On the Sunday of your departure, Tannery spoke of you to me in the warmest words and told me more or less this: 'For the moment in physics the experimentalists dominate the Sorbonne exclusively and in a very narrow sense at that. It will not always be so and the theoreticians will, one day, make them exit from their exclusivism. And this is an idea which I am going to let enter in Bouty's head.' He [Tannery] added that a few days earlier Darboux had spoken to him of his intention to make you the recipient of the Prix Poncelet next year. He hopes to succeed with the help of Sarrau and others but he is afraid of [encountering] difficulties because of Berthelot. I tell you this under the seal of absolute secrecy because Darboux expressly told Tannery not to speak of it to anyone, let alone to you. He would be furious of any

51. Dossier Duhem, p. 107.

52. *Ibid.*, p. 106.

indiscretion. But I am reporting this to you without scruple, uncertain as the success may be, because it is important above all that you should not believe yourself abandoned in that necropolis of Rennes. I have spoken to Tannery of your absolute wish to return to Paris at the end of the [academic] year but he admitted seeing for the moment nothing [available] that would suit you. You will see him anyhow when you next come to Paris.

Duhem's visit in a week to Paris obviously convinced him that he hoped in vain for a quick transfer there. Knowing the obstacles on his road there, he expected to stay in Rennes for years. He suspected no transfer as he spent his vacation with his mother and daughter at Saint-Briac-sur-Mer, a town on the Channel, a few miles west of St. Malo. On October 10 he left them for a few days to present the first of his seven memoirs before the Académie Royale in Bruxelles. On October 13, as he appeared before the Académie, the Ministry of Public Instruction mailed him a notice about his transfer to Bordeaux. The news left him dumbstruck. While the University of Bordeaux had much more to offer than Rennes, the transfer could easily appear a move dictated to the Ministry of Public Instruction more by the sheer necessity to fill a chair vacated there by Pionchon's sudden resignation than by a genuine appreciation of Duhem's excellence. Indeed, the notice of transfer left him with the title of a mere maître de conférences although he was to take the place of a professor.

Utterly dismayed, Duhem wrote to his good friend Jules Tannery in the Ecole Normale, telling him of his reluctance to accept the transfer.⁵³ Disturbed by this new evidence of lack of good will toward Duhem on the part of authorities in Paris, Tannery went directly to Liard, director of higher education at the Ministry of Public Instruction. The visit was a success, though only in appearance. 'Tell your friend, Duhem,' Liard said to Tannery, who immediately sent a telegram to Duhem, 'that he must accept, that he must understand that Bordeaux is the road to Paris.'⁵⁴ The telegram, coming as it did from Tannery, a trusted friend, dissipated all doubts in Duhem's mind. Otherwise he might have for a moment thought, while traveling to Bordeaux, of a famous dispute between two perplexed travelers nearing the port of that town. Their dispute turned around the problem of whether men, because of their free will, can, unlike hawks, change their habit of preying on others.⁵⁵ Duhem did not suspect that, whereas he went to Bordeaux of his own free will, he would remain the prey of a resentful ill will unable to change thoroughly.

53. *Un savant français*, p. 97.

54. *Ibid.*, p. 98.

55. The dispute in question is that between Candide and Martin. See ch. xxi in Voltaire's *Candide or Optimism*, tr. J. Butt (Baltimore: Penguin Books, 1947), p. 96.

5 BORDEAUX: A ROAD TO PARIS?

From home to university

The failure for the second time in a year of the Ministry of Public Instruction to defray in advance the cost of his moving to another city,¹ should have given Duhem second thoughts about Tannery's telegram, but he was under no small illusion. As he supervised the movers carrying his furniture into his new residence in Bordeaux, he ordered them to uncrate only the essentials such as beds, chairs, kitchenware, writing desk, and books. Items that made life decorative and comfortable were left uncattered for months,² the time he needed to realize that his transfer to Bordeaux could mean a long stay, if not permanent exile there. Arriving in Bordeaux with his mind riveted on the idea of soon moving to Paris, he hardly reminisced on his flight, twenty-five years earlier, from Chateaudun to Bordeaux. Nor did he find, in such a state of mind, much time to think of a fact of which any teacher in his early thirties could be justly proud. The University of Bordeaux was eager to welcome a savant of Duhem's stature. The *Rapport général de l'Université de Bordeaux* for the academic year 1893-94 was not printed yet when Bordeaux learned of Duhem's appointment there. To the lines recording the resignation of Pionchon as professor of physics the following line was added in obvious delight about his replacement: 'Mr. Duhem comes to us with an established reputation, in full force and vigor.'³

As in Rennes, in Bordeaux Duhem lived at about fifteen minutes' walk from the University. Always fond of walking, Duhem must have found added pleasure in going to the University along streets lined mostly with two-storey houses, many of them with exquisite wrought-iron balconies, a sight which is one of Bordeaux's charms. Although construction of such balconies was in its greatest vogue during Louis XV and Louis XVI, the golden age of Bordeaux, they continued to be a chief

1. The Ministry acted only on October 30, 1894, almost three weeks after notice was sent to Duhem about his transfer. See Dossier Duhem, p. 176.

2. *Un savant français*, p. 99.

3. *Rapport 1893-94*, p. 15.

décor in the nineteenth-century additions to the city. The Rue de la Teste, where Duhem took up residence, was only a few hundred yards within the administrative limits drawn in 1865 for the city. Not much further to the south beckoned slopes of vineyards, some of which, such as the vineyard Haut Brion, survived to this day the pressure of urbanization. About 2 kms to the southwest was the village of Talence, now a suburb and the site, since 1959, of the sprawling modern university of Bordeaux. The Rue de la Teste, named after a town near the Atlantic, was and still is a quiet residential street. Bending at about 45 degrees at its midpoint, the Rue de la Teste connects two thoroughfares, Rue St. Genès and Rue de Pessac, both leading toward the center of the city and both with a new tramway line, which could be useful in heavy rain even for an avid hiker like Duhem. Near the point where the Rue de la Teste meets the Rue St. Genès lived another faculty member, Dr. Sigalas, charged at that time with physics courses at the Faculty of Medicine, and later dean at that Faculty. On the opposite side, facing almost west and rather close to the Rue de Pessac, was the two-storey house, Nr. 18, which Duhem rented for the next twenty-two years.⁴ In going to the university Duhem first went in the northeast direction along the Rue de Pessac, which took him to the final section of the Rue St. Genès, a section now called Rue Castedoat. He was then only two short blocks away from St. Eulalie, his parish church, which in turn marked the beginning of the Rue St. Eulalie (now Rue Louis Lane). From there he could see a long block away the imposing edifice of the Faculté des Sciences et des Lettres, at the sharp bending of the Cours des Fosses, one of Bordeaux' great historic streets.⁵ The front of the Faculté faced the section of the Cours called Fosse des Tanneurs, soon to be renamed Cours Pasteur, whereas its left side bordered on the Fosse des Carmes, soon to be rechristened Cours Victor Hugo.

Facing the main entrance his eyes must have been attracted to its chief décor: three huge bas-reliefs over the three main doors. The one on the left showed a dozen Greek sages, the one in the center was a cliché apotheosis of France with 'Marianne' in the center. Of the dozen figures on the right only two could be easily identified, the first and the last. The first was Moses holding the tablets of the ten commandments, the last was a figure in ecclesiastical robes looking away from the rest with a distinctly sour face, a symbol, perhaps, of the abolition of the

4. The house, built in the early 1870s, was between 1877 and 1893 in the possession of David Benedict Delpuget, Consul of Monaco. Duhem rented the house from the new owner, Pierre Lucien Loup, a merchant. Communication from the present owners, Mr et Mme André Jarreau.

5. Concerning the city of Bordeaux and its university during the half century preceding World War I, the two major sources of information are C. Jullian, *Histoire de Bordeaux depuis les origines jusqu'en 1895* (Bordeaux: Feret et Fils, 1895), 804 pp, and *Bordeaux au XIX^e siècle*, sous la direction de L. Desgraves et G. Dupeux (Bordeaux: Fédération Historique du Sud-Ouest, 1969), 580 pp. Valuable details can also be gathered from J. A. Brutails, *Guide illustré dans Bordeaux et les environs* (Bordeaux: G. Gounouilh, 1910) and *Bordeaux métropole du Sud-Ouest* (Bordeaux: Imprimerie Gounouilh), a volume published for the occasion of the 47th meeting of the Association Française pour l'Avancement des Sciences, held in Bordeaux in the summer of 1923.

faculty of theology at the university in 1885. Presumably, the other figures between these two stood for the Judeo-Christian tradition, possibly for the prophets and the apostles. If Christ himself was represented it was not at all evident. The covert symbolism of all this reflected the 'official' ideology of which Renan was a chief spokesman and in which the Catholic Church with her almost 2000 years of history and cultural presence was reduced to the role of an outcast. Duhem could not be unaware of the failure of an ideology which wanted to retain religion (and Christ) only at the exclusion of the Church. None other than a most applauded advocate of that policy, Victor Hugo, mused aloud in 1881: 'Among the progress that our age boasts of, one thing, oh Jesus, in secret terrifies me. It is the echo of Thy voice gradually getting weaker.'

Entering the building Duhem was reminded by a black marble plaque of the joint decision of the municipality and government, a decision made in the presence of Jules Ferry, minister of public instruction, on August 5, 1880, to construct a new edifice for the Faculté des Lettres et des Sciences, an enterprise which took six years and cost over two million francs. The same plaque also recalled the dedication of the building on January 17, 1886, in the presence of Jules Grévy, president of the Republic. The real décor of the main entrance hall was an exquisitely carved early baroque monument, the tomb of Montaigne, a chief glory of Bordeaux and of its ancient University founded in 1441. It was there, in the Collège de Guyenne, that Montaigne began his formal studies at the age of six in 1539. Passing by Montaigne's tomb Duhem could hardly help thinking that the scepticism which Montaigne celebrated in his *Essais* with a brilliant pen was the chief target of an even greater master of French style and thought, Blaise Pascal. In his *Pensées*, so familiar to Duhem, an unsparring indictment of Montaigne begins with the words: 'The failings of Montaigne are great.'

Among the first to be visited by Duhem was George Brunel, the noted mathematician. Brunel, as Duhem himself was to recall six years later in writing Brunel's obituary, greeted him with a smiling face, warm handshake and the words: 'Do you recognize me?'⁶ Of course he did. He had first met Brunel shortly after his entrance at the Ecole Normale in October 1882. Brunel, by then an 'archicube' or 'old' graduate, had then just finished his year at the Ecole as agrégé préparateur and was about to take up a two-years' post at the Ecole des Sciences in Algiers. From there Brunel went straight to Bordeaux, first as professor of pure mathematics, a chair transformed in 1886 into a chair of infinitesimal calculus. The presence of Brunel, a member of the University Council since 1892, dean of the science faculty since the Fall of 1896, and acting rector for two months in 1898, augured well for the new maître de conférences. Duhem found in Brunel a man after his own heart: an individual of utter honesty, a penetrating mind, unstintingly devoted to duty, and possessed of a wide-ranging intellectual interest. With almost a decade behind him in the academic life, Duhem knew that persons like Brunel were the minority among academics too, especially at a time of heavy-

6. See 1902 (21), p. 1.

handed politicizing of the academe. Such were certainly the times in late-19th-century France. Duhem himself was to remark in that obituary of Brunel that the decree of 1896, which ordered the unification of various Faculties into a single University in Bordeaux as well as in other cities, was more of a political power play than a move motivated by a unitary vision of learning.⁷ Any genuine unification of the various branches of higher learning could, he noted, only be the work of professors whose horizons extended well beyond their specialties. This was no idle criticism on Duhem's part. In Bordeaux, and perhaps in France, Duhem was the first scientist to offer courses which attracted for over a decade large audiences from students and professors of various faculties. In this latter respect Duhem gained much inspiration from Brunel, who turned the Société des sciences physiques et naturelles, founded in 1854 by professors of the science faculty in Bordeaux, into an organ of vibrant intellectual exchange.

A chair and a department

Duhem had, of course, to pay his respects to G. Rayet, professor of astronomy and dean of the science faculty. While Rayet held Duhem in high esteem, he would not speak to him at this point of a problem posed by the vacant chair of physics. A problem it was and Rayet wished it did not exist. When two months later the problem had to be met head-on, he turned to Louis Liard, who as director of the bureau of higher education in the Ministry of Public Instruction carried out the reorganization of French universities between 1884 and 1896. As a former professor of philosophy (1874-1880) at the Faculté des Lettres of Bordeaux, Liard had retained close contacts there and could be counted on for special help. The crux of the problem was a diligent, though not at all distinguished physicist, Morisot, fifty-eight and already for 20 years at Bordeaux as maître de conférences. Respect for a senior colleague clashed with esteem for a young savant with unquestionable superiority of whom Rayet wrote on December 4 to Liard: 'From the Rue d'Ulm to the Ministry in Paris and to the banks of the Garonne there are many of us who think that Duhem, already over thirty, has the right, on account of his many and original publications, to become the occupant of the chair.' Rayet thought the problem could be solved only through the transformation of the actual chair into one for experimental physics with Morisot as its occupant and through the simultaneous creation of a new chair for theoretical physics. 'You would appoint Duhem to the new chair,' Rayet suggested to Liard, 'and everybody would applaud.'⁸

Liard was all too eager to take up the suggestion as a specious cover-up for his having exiled Duhem to Bordeaux. He may even have found at first thought a further cover-up in the unanimous wish, stated on November 27, of the Conseil d'Université of Bordeaux on behalf of the new chair.⁹ Uneasy second thoughts may have occurred to Liard as he reflected on the arguments set forth by that

7. *Ibid.*, p. 19.

8. Dossier Duhem, pp. 174-75.

9. The transcript of the deliberations was placed in the dossier, to be quoted as Dossier Duhem (Bordeaux), kept on Duhem by the University of Bordeaux.

Conseil. The Conseil called attention to the preponderance of experimental physics in France and the simultaneous neglect of the tradition of such theorists as Ampère, Fourier, Poisson, and Lamé. 'Abroad Helmholtz, Maxwell, Thomson, Tait, and Gibbs represent an area of research which was launched originally in our country but which is today represented in France only in Paris, through the courses at the Sorbonne of Boussinesq, Poincaré . . . The circumstances now permit the organization of similar courses at the University of Bordeaux since it has as chargé de cours, Mr Duhem, one of the young and brilliant representatives of the school of Poisson.' If Duhem was so brilliant that he could singlehandedly create in Bordeaux a school of theoretical physics on a par with the one represented by Helmholtz in Germany, by Thomson (Lord Kelvin) in Great Britain, and Gibbs in the United States, then the question must have occurred to Liard why no place could be found for Duhem in Paris, where the Bordeaux faculty could name only two theoretical physicists? Neither Liard nor for a long time any of his successors looked for a first-rate school of theoretical physics to be developed in the provinces.

The creation of the new chair and Duhem's appointment to it as a lowest ranking or fourth-class professor with an annual salary of 6000 francs, was decreed on March 11, 1895. Duhem's mixed feelings can easily be guessed. Couat, Duhem's first rector in Bordeaux, could only be embarrassed in his private moments. After all, as in Lille, in Bordeaux too, he had to witness in Duhem a brilliant professor and an outstanding savant. At the end of Duhem's first year in Bordeaux he sent the following confidential report to Paris on Duhem: 'I have known for a long time Mr Duhem and I am happy to record the success of his debut in Bordeaux.' The phrase was a comment on dean Brunet's confidential statement: 'Mr Duhem's teaching is the greatest success among candidates for licence and agrégation. He is an excellent professor and excellent colleague. Mr Duhem devoted himself with great zeal to the reorganization of the physics laboratory.' Duhem's comportment as a colleague was described as 'perfect.'¹⁰

In itself, an appointment to Bordeaux, let alone to a chair there, could be seen as a distinct honor. Unlike Rennes, still a very provincial town, Bordeaux had witnessed its population rise between 1865 and 1896 from 150,000 to 250,000, a significant level at which it stayed until the end of World War I. Commerce and business also reached, around 1895, a temporary peak, corresponding to transactions equalling in value almost a thousand million francs. A sign of the bursting atmosphere in Bordeaux was the tramway and omnibus system, consisting of 250 cars just imported from England. The Bordelais could pride themselves on a considerably better water-supply system than the one available to the inhabitants of Paris and London. Another pride of the city was the iron railroad bridge over the Garonne, a feat of no less an engineer than Eiffel. The seaport of Bordeaux was in a stage of rapid expansion, with new dockyards and drydocks built near the city's center and with new shipping lines linking it to North and South America.

10. Dossier Duhem, pp. 104–05.

The city which housed over forty consulates was making great advances culturally as well. Learned societies and public conferences were rapidly increasing in number. In early August 1895, Bordeaux hosted for the second time in twenty years the big annual meeting of French scientists in which Duhem participated by reading a paper on electromagnetic waves and theory.¹¹ A few years before that, a Museum of Natural History was added to a redesigned Jardin Public including a new botanical garden to which Duhem often took his daughter for a leisurely walk. The much larger and forest-like Parc Bordelais also must have seen them from time to time. Unlike Rennes, Bordeaux had several excellent libraries, among them the University Library with nearly a quarter of a million volumes, an impressive quantity a century or so ago.¹² The University itself was in rapid expansion. The number of chairs in its Faculté des Lettres increased between 1880 and 1895 from 11 to 20, and only slightly less, from 10 to 16, was the increase of chairs in the Faculté des Sciences during the same period. Nevertheless, the leading historian of the city at that time, Camille Jullian, himself a professor at the University, had to admit: 'Bordeaux today can boast of no truly great names comparable to Montaigne or Montesquieu. If it ever possesses such bright glories they will, let us be certain on this point, go on shining in Paris. But things were no different under Louis XIV and Louis XVIII. What can be asserted is that even if Bordeaux possesses no scholar with extraordinary renown, the army of ordinary workers has never been more numerous and better provided with means, zeal, and intelligence.'¹³ Duhem had just arrived on the scene when these lines were written by Jullian who graduated from the Ecole Normale in 1880 as a student of Fustel de Coulanges. Even if Jullian had an eye for the extraordinary in Duhem, he would have been wrong in thinking of Duhem as someone to shine one day in Paris.

Not everything was as bright as Jullian suggested and certainly not so in the newly-built Faculté des Sciences. All physics and chemistry laboratories were located in the basement, an arrangement which could only lead to considerable discomfort. The number of students, these very ordinary workers, had never been more numerous, but the means at their disposal were all too often well below standard, a circumstance which could not be unknown to Jullian. He himself was to read about this in the *Rapport du Conseil universitaire* for 1895-96. Although the 110 students assigned in that year to laboratory work in the general physics course were divided into three shifts, only a part of each shift could be accom-

11. A summary of the paper appeared in *Association Française pour l'Avancement des Sciences . . . Compte rendu de la 24^{me} Session. Première Partie. Documents Officiels. – Procès-Verbaux* (Paris: Au Secrétariat de l'Association, 1895), p. 219. The Congress was held between August 4 and 9. Duhem read his paper on August 6. Only eight foreign scientists participated (p. 132). One of the participants from Lille was Arthur Duhem, a manufacturer (p. XLV). Duhem's paper was not printed in the massive *Seconde Partie (Notes et Mémoires)* published in 1896 in Bordeaux.

12. It may be worth recalling that there were only fifty thousand volumes at that time in the Library of the University of Lille.

13. *Histoire de Bordeaux*, p. 773.

modated in a room of 11 by 6 meters. 'There is no hallway in the Faculty which we have not utilized one way or another,'¹⁴ stated the Report. From the hygienic viewpoint the arrangement was often beyond endurance, causing as it did frequent preliminary symptoms of asphyxiation. In winter, experiments on static electricity were vitiated by the necessity to stoke small stoves; in summer there was not enough light as the windows had to be shaded from early morning to keep out the blazing sun. In addition, there was the problem of compulsory science courses for students of the humanities and law most of whom, as the Report stated, came wholly unprepared.¹⁵ 'Among ten of such students there is hardly one who understands the language we speak and even fewer who can answer our questions,' reported dean Brunel a year later.¹⁶

By then, or 1897, Duhem was at the peak of his efforts to turn the department of physics in Bordeaux into a first-class place of research. Aiming at excellence through assiduous work came naturally to Duhem even if he had not hoped that ultimately his scholarship would carry him to a chair in Paris. He had thrown himself into teaching and writing with an energy and singlemindedness typical of him. By present-day standards his teaching assignment could appear a sinecure but quite a normal workload at that time. His schedule during his first year anticipated in essence his schedule during the next two decades. In 1894-95 he held on Monday afternoons at five a seminar (*conférence*) for the most advanced students preparing for *agrégation*. On Tuesday and Wednesday afternoons at 2:30 it was the students preparing for *licence* who were instructed by him in optics.¹⁷ The 'normal' or general introductory course in physics was taken care of by one of the *maîtres de conférences*. Gossart (an associate professor since 1896), who also gave a course in industrial electricity. In addition to Gossart, there was also Morisot, an experimentalist who gave a course in electricity and acoustics. Students who merely worked for 'certificat' or general degree were in the charge of Caubet, who was also the 'chef des travaux' or chief of laboratories, though not of the laboratory reserved for Duhem where, as will be seen, Caubet received generous support for his research. An ardent Protestant, Caubet was later to occupy a room adjoining the office of Duhem with whom he often discussed questions of theology. Whenever possible, the door connecting their rooms was left open, a telling evidence of a cordial relationship.¹⁸ The two posts of assistants attached to the chair of physics

14. *Rapport 1895-96*, p. 117. It should not be difficult to guess Duhem's feelings as he read about the same time the lengthy and illustrated account in the *RGScPA* (15 juin 1895, pp. 475-93) of the new buildings of the Faculté des Sciences of Lille, of which several were almost as large as the entire main building of the University of Bordeaux in which a half of two floors housed the physics department.

15. *Ibid.*, p. 121.

16. *Rapport 1896-97*, p. 67.

17. Concerning these details, information may be gathered either in the *Programmes des enseignement* and the *Annuaire des Facultés de Bordeaux*, or in the *Livret-Guide* (student guidebook), all published annually. Tellingly, not even the University of Bordeaux library has a complete set of any of these series.

18. *Un savant français*, p. 140.

were in 1894 held by Chevallier and Turpain, the latter a future doctoral student of Duhem. Morisot suddenly died just before the start of the academic year 1896-97, an outcome, as will be seen shortly, of some consequence for Duhem.

As in Rennes and Lille, the teaching of mechanics was reserved for a special chair which in Bordeaux was also the chair of theoretical astronomy. Attached to it first as maître de conférences and from 1895 as its occupant was Hadamard who received in 1892 the Grand Prix de l'Académie des Sciences and achieved world fame among mathematicians in 1896 through his solution of a fundamental problem in number theory, the law of the distribution of prime numbers. For his own excellence as a mathematician Hadamard gave generous credit to his conversations with Duhem during those two years in Bordeaux: 'Duhem was my educator in mathematics and physics. He opened to me new paths in thermodynamics and shared his insights with me. Those were beautiful, unforgettable years but circumstances separated us when I was nominated to Paris.'¹⁹ Another part of teaching physics devolved to the chair of physical astronomy, filled then by Rayet who was also in charge of the Observatory of Bordeaux constructed in 1878 at Floirac, a locality about 2 miles west from the center of Bordeaux, off the right bank of the Garonne. Picart, a maître de conférences attached to Rayet's chair, was to become the Observatory's future director. As a dean of the Faculté des Sciences during Duhem's last eight years in Bordeaux, he showed much appreciation for Duhem's scholarship.

As was the case in Rennes (and in other provincial universities), in Bordeaux too the great majority of the student body, which stayed slightly above 2000 during the two decades preceding World War I, belonged to the faculties of law and medicine. The total number of students in the science faculty was about one eighth of the total. It rose from 125 in 1891-92 to 187 in 1894-95 and to 299 in 1896-97. This was a peak for a while. During 1897-98 the number dropped to 246 and rose only to 326 as late as 1912-13. These figures included all those who studied any of the sciences: mathematics, astronomy, chemistry, zoology (biology), and botany, in addition to physics. Moreover, the number of those studying physics for no special degree had always been at least twice as high as the number of those who worked for licence and agrégation, that is, the group mainly in Duhem's charge. That group was never larger than two dozen and at one point much less than a dozen.

Fortunately for Duhem, he was able to secure, in the Fall of 1896, following the sudden death of Morisot, the transfer from Caen, of Lucien Marchis, his former student in Lille, to Bordeaux as maître de conférences, although he did not have yet his doctorate. Rayet fully recommended the move to Liard in Paris. By concurring, Liard perhaps wanted to compensate Duhem for his transfer to Bordeaux. Part of Duhem's strategy was his urging, unknown to Rayet, another candidate, a former colleague from the Ecole Normale, to withdraw, a move hardly to Rayet's pleasure. With Marchis' collaboration, Duhem organized a program in theoretical physics which remained in force for the next two decades. The program consisted

19. See *Archeion* 19 (1937):124.

of two series of lectures. The first series was not geared to any specific set of examinations, but mostly involved those preparing for agrégation. The courses of the first series, as Duhem described years later in the student guidebook (*Livret-guide*) an already long-standing practice, 'combine with those of Mr Marchis in such a way as to cover in two years the entire program of physics.' As to the second series, the same guidebook contained a detail which pertained more specifically to Duhem himself: 'The lectures of the second series are the ones which without doubt offer the best prospect to attract foreign students. Each year, they bear on a different topic. The topic is chosen from among such questions of theoretical physics that are currently in the center of interest, and, as much as possible, from among such topics which are the subject matter of the professor's own research. These topics are studied in a detailed manner and in depth.'²⁰

The courses of the first series covered thermodynamics, physical chemistry, hydrodynamics, physical optics, elasticity, acoustics, and electrodynamics. In the second series Duhem lectured on permanent modifications and hysteresis (1897-98), general thermodynamics or energetics (1898-99), Maxwell's theories and Hertz's experiments (1899-1900), viscosity and principles of hydrodynamics (1900-01), on finite deformations of rigid bodies (1901-02), and on stability and small movements (1902-03). These courses, and even more so the ones within the same program during the subsequent years, closely reflected the main topics of Duhem's publications which made an impressive list in the annual *Rapport* issued by the University Council. Marchis' courses in the second series were all in applied physics, especially on various motors. He began offering these courses after he had successfully defended his doctor's thesis under Duhem's mentorship in 1898. He was not the only one to do so.

A string of doctorates and their perspective

First came E. Monnet, chemistry teacher at the Institut Catholique in Lille and a close friend of Duhem ever since the two had met there. Monnet defended his main thesis, 'On the complete calorimetric study of a salt,' on April 8, 1897, Thursday afternoon at 3, as the *Rapport du Conseil de l'Université* specified details in obvious evidence of the importance of the event in the history of the University of Bordeaux. Monnet's secondary thesis was a 'physico-chemical study of the neutralisation of acids through the addition of bases.' The *Rapport*, whose section on the activity of the science faculty was written by Brunel, stated also that 'Monnet showed through a felicitously chosen case, how delicate was the determination of the various constants which are required by the complete study of a single one, a study which he had pursued over several years through patient and hard work. Monnet showed that he was not only an excellent experimentalist; he had proved in his second thesis that in the study of the works of others he possessed valuable qualities of assimilation, that he knew how to appreciate and

20. *Livret-Guide 1906-07*, p. 73.

how to criticize when necessary.’²¹ In these remarks one could easily recognize several important traits of Duhem’s own mental physiognomy. Duhem himself may very well have provided these lines at Brunel’s request.

Duhem’s next doctoral candidate, H. Pélabon, also came from Lille, where he held the post of head of the chemistry laboratories at the (State) University. Pélabon’s affiliation with a State University may have been a reason for Gosselet, a former colleague of Duhem in Lille, to try to persuade Pélabon to seek his doctorate in Paris instead. This may have been part of a broader resistance which, as will be seen, Duhem encountered in his efforts to secure physicists from Paris as members of the jury examining his doctoral candidates. The defense of the thesis of Pélabon, who remained loyal to Duhem, took place on February 17, 1898, again at 3, Thursday afternoon. The *Rapport* did not contain a detail, namely, that at Duhem’s insistence the examining jury donned its academic robes in recognition of the importance of the event.²² The main thesis of Pélabon, who also received the highest mark, that is, ‘very honorable,’ was on the dissociation of selenohydrogenic acid. His secondary thesis was on thermoelectric phenomena as applied to temperature measurements. In his main thesis Pélabon clarified the previously unexplained effect of hydrogen on selenium, an effect that had already been observed by Ditte. In the *Rapport* it was noted with obvious satisfaction that no sooner had Pélabon received his doctor’s degree from Bordeaux than the Ministry of Public Instruction gave him the rank of maître de conférences.²³

Far more significant than the account in the *Rapport* was the commentary which Duhem himself offered on Pélabon’s doctorate to the public of Bordeaux in the pages of the *Revue philomathique de Bordeaux et du Sud-Ouest*.²⁴ He began with a description of the occasion in the main amphitheater of the University. Presiding was Couat, the rector, assisting him were Brunel and Nabias, respective deans of the faculties of science and medicine. Assisting Duhem, as members of the examining jury, were Gossart, whose lectures on industrial electricity, as Duhem recalled, ‘had been applauded by the Bordelais public,’ and Vizès, professor of chemistry, ‘whose courses of high exactitude are much appreciated by many of our young students.’²⁵ Duhem then noted that had it not been for the insistence of Brunel, who knew how to overcome the extreme modesty of B. Elie, a world-renowned mathematician in Abbeville and Brunel’s former teacher there in the local college, Bordeaux would not have been in 1892 the place of the elderly Elie’s doctorate. If there was now in sight a trend of doctorates in Bordeaux it was clearly the work of Duhem, who in his brief speech delivered at Pélabon’s doctorate had set forth the reasons for having tried to establish such a trend. First, he asked, was not that trend to devolve to the detriment of the candidates who

21. *Rapport 1896-97*, p. 66. Monnet’s thesis, ‘Sur l’étude calorimétrique complète d’un sel,’ was published in *MSScPhNB* 3 (1898):41-139.

22. *Un savant français*, p. 114.

23. *Rapport 1897-98*, pp. 99-100.

24. 1898 (12).

25. *Ibid.*, p. 244.

would, on occasion, be disparagingly referred to as 'doctors from the provinces'? Second, was the trend aimed at setting up a rivalry with the Sorbonne? If there was any rivalry, Duhem argued, it was part of a life which involved struggle and selection, even on the intellectual level. Those who almost a century later cast the progress of scientific ideas in terms of Darwinian theory may not look altogether original in view of the following statement of Duhem who, of course, was not an evolutionist to the point of pre-empting evolution of its meaning by turning Darwinism into metaphysics:

What is true of all living beings, is also true of scientific doctrines: It is through struggle that selection is made among them; it is the conflict which fragments and sweeps away the false ideas; it is the struggle which forces the right ideas to make more precise and more valid the proofs which they claim to themselves; it is the struggle which forces the fruitful ideas to deliver all their products.

Now this struggle of ideas is impossible if science is entirely in one single locality; when this absolute centralisation is in effect one finds before long in each branch of knowledge only one teacher, and the disciples of that teacher. The teacher, no longer exposed to being contradicted, and long since accustomed to seeing his best ideas received as products of a genius, hardly has any concern to protect himself from an exaggerated confidence in his own judgment, confidence which delivers him defenseless against the habit of making errors. The disciples, receiving their master's teachings as oracles instead of improving them with free discussions through a contact with opposite doctrines, yield to the nonchalant habit of repeating a lesson already learned which ends in no longer being comprehended.

Precisely because we feel how dangerous it would be to let French science reach that point, we desire to see our universities vigorously armed for engaging in a contest with one another. We wish that a doctrine proclaimed in Lyon may see an opposite doctrine rise in Toulouse or Nancy, that a doctrine proclaimed in Paris might develop in Lille or in Bordeaux. We wish that in France each man of science may find at every moment these two essential conditions for scientific work: the freedom which permits him to put forward all his ideas, and the opposition which obliges him to produce only mature ideas.²⁶

In the rest of the essay Duhem put Pélabon's work in the perspective of a turning point which, in his view, science reached at that time. The hallowed program, in full force only since the 19th century, which aimed at an explanation of the transformations both physical and chemical, by calculating the trajectories of each atom and molecule, could not be carried to a successful completion. A more modest though very fruitful alternative suggested itself through thermodynamics. The latter offered means of investigation of cases such as the one which formed the subject of Pélabon's thesis. Duhem drew a graphic picture of the question Pélabon aimed at answering: why is it that when two test tubes, one filled with selenium and hydrogen, the other with selenic hydrogen, are heated gradually to a much higher temperature, the combination between these two substances will not be the same in the two tubes although in both there will be an equilibrium? The answer, Duhem noted, lay in the fact that 'to use the expression of modern

26. *Ibid.*, p. 246.

diplomacy, there is a buffer region instead of a sharp line of demarcation between the states of dissociation and recombination.’²⁷ This corresponded to the case of the so-called false equilibrium. As revealed in the action of hydrogen on selenium, this false equilibrium illustrated in turn the all-important point that the former program was applicable only to a situation which was but a limiting case of a much wider range of phenomena.²⁸

Toward the end of the academic year 1897-98, which had already witnessed Pélabon’s doctorate, came Marchis’ doctorate on June 30, before a jury for which Duhem tried in vain to obtain as members Ditte and Brillouin from Paris. The latter, as will be seen, found no merit at all in the thesis. Duhem once more regaled the public of Bordeaux with penetrating insight into the subject of the thesis and of its broader significance.²⁹ What was, he asked, the use of twenty thousand measurements digested into 450 pages³⁰ concerning the permanent modification of the zero point of thermometers? Have not the best instrument makers offered to the public and to the laboratories thermometers in which the zero point changed imperceptibly, whatever the deformation of the glass tube? Was it reasonable to contrive special conditions in which a thermometer, when placed in melting ice, signals not 0° but 32°, that is, almost body temperature? Did not Marchis (and Duhem) ignore Buffon’s precept: A fly must not occupy in a naturalist’s mind a greater place than it does in Nature herself? But, Duhem countered, had Pasteur followed this rather utilitarian precept he would have given but cursory attention to any and all bacilli. Small could appear the significance of the slight alteration in the length of a wire after it had been made to expand and to contract again. But this slight difference was one of the many cases of irreversible processes with which the old thermodynamics could not cope. To study these small effects a new thermodynamics was needed, but this implied the need of magnifying small effects as done, for example, in Marchis’ experiments with thermometers.

Similarly, apparently negligible effects are often portentous of great lessons, so Duhem argued his point which, as he added, was all too often illustrated in the history of science. The slighting of such effects may satisfy wishful hopes for simplicity but will become self-defeating in the long run. This dramatic development was portrayed by Duhem to the Bordelais public in a way which makes many recent accounts of the conflict of scientific dogmas appear as feeble echos:

When around some principles, which appear evident, the human mind has succeeded in grouping in a system a certain number of facts, it naïvely takes this system for the adequate and definitive representation of the world and from then on its faith will stubbornly resist being contradicted and belied by experimental evidence. If facts

27. *Ibid.*, p. 250.

28. Pélabon’s thesis, ‘Sur la dissociation de l’acide sélénhydrique,’ was also published in *MSScPhNB* 3 (1898):141-276.

29. See 1898 (13).

30. Those 450 pages referred to the *printed* form of Marchis’ thesis, ‘Les modifications permanentes du verre et le déplacement du zero des thermomètres,’ *MSScPhNB* 4 (1898): 1-442.

refuse to accommodate themselves to its theory, the mind will refuse to see these facts; it will declare them obscure, poorly known, unimportant. It will discard them from its teaching. When the mind feels its efforts too feeble to stifle the voice of reality, when the facts cry out too loudly to be covered with silence any longer, then it mutilates and tortures them, it resorts to ruses and scheming, it multiplies the vague explanations, the tortuous reasonings, the artificial distinctions, the lame comparisons, it tries to deceive others and even to fool itself. But a day comes when yielding to facts becomes a must. Then a new system rises triumphantly, a system more ample and comprehensive than the old. In this framework easily accommodate themselves both the facts, which the old system succeeded in classifying, and those which its narrowness had rejected. The human mind then embraces with a new fervor the new dogma: it declares it infallible and eternal and, smiling with pity at those who cast their faith with the ideal worshipped yesterday and overthrown today, it celebrates the continually ascending march of science which knows no coming to a halt, always receptive to contrary evidence, and always ready to confess its error. The history of science is but a long series of such apostasies of the human mind.³¹

Between two states of faith, or rather apostasies, there was the transitional state of struggle in which young ideas, already daring but still poorly formulated, dispute the place of doctrines, for many years strong and fruitful but exhausted and sterile today. The old thermodynamics, which rested on the clear notion of reversible phenomena and viewed irreversible phenomena as obscure, was now confronted with a new thermodynamics which took reversible phenomena as ideal limits. But Marchis showed, Duhem continued, through a concrete example that an irreversible phenomenon cannot be explained without conceiving it as being a series of many small permanent modifications imposed on the process by the slight oscillations of temperature. That such an idea and finding had a broad relevance could easily be seen. It certainly promised an ample harvest of new ideas, a prospect most useful for those who, Duhem noted, believed with Pascal that 'we must replenish ourselves with thought and not with space and time which we could not fill.' But was there also some more concrete usefulness on hand? Here Duhem cautioned against utilitarianism in science. Not that he deprecated the inventive spirit. He even presented it as the embodiment of the comprehensive mind, or *esprit de finesse*, which grasps in a flash all the concrete connections. But, he asked, was the inventiveness of an Edison possible without the *esprit géométrique* or incisive mind, operative in an Ampère, a mind capable of deriving many consequences from a single law? This is how Marchis' thesis, so heavy on theoretical interpretation of carefully planned experiments, would be helpful to the inventor, disdainful as he might remain of theoretical investigations.

The investigation of truth, Duhem concluded, 'leads to the discovery of the useful as to its surplus product.'³² Such 'surplus benefits' were certainly noticeable, potentially at least, in Marchis' thesis. It was pointedly noted in the *Rapport* that in the course of his investigations, 'pursued with patience and tenacity,' Marchis obtained 'preliminary results of potentially great significance for the production of steel and various alloys.' The jury therefore recommended support

31. 1898 (13), p. 491.

32. *Ibid.*, p. 523.

for further researches to be carried out by Marchis who 'is now in the position to tackle the issues in question and to extend the results already obtained to an entire series of various compounds.'³³

Marchis' researches were indeed continued and in addition he had embarked on a systematic study of the latest types of motors. Such was the subject between 1899 and 1909 of the special courses he successively offered on gas-driven motors, steam engines, electric motors, automobile engines, aerial navigation, industrial refrigeration, industrial utilization of low-quality gases, application of internal combustion engines to the lifting of heavy loads and to the propulsion of ships, steam turbines, and the dirigibility of balloons and airplanes. Following this last course, given in 1908-09, Marchis was called to the Sorbonne as the first occupant of a newly-established chair on aviation. It was a telling case of the disciple preferred to the master. Marchis knew, of course, all too well, why Paris failed to call his master for whom he had the greatest respect and admiration. Duhem's appreciation of his disciple's talent was equally in evidence when he contributed an introductory essay on the impossibility of perpetual motion machines to Marchis' treatise on thermodynamics published in 1904.³⁴

That a physicist like Marchis completely given to the industrial application of thermodynamics flourished so well in Duhem's vicinity should reveal something of Duhem's wide horizons. Duhem was a theoretician with deep roots in experimentation, otherwise the thesis guided by him would not have been so heavy on the experimental side. Strongly experimental was indeed the main thesis of A. Turpain, preparator in the physics department of Bordeaux, who investigated Hertzian waves.³⁵ About the time when Turpain defended his thesis on June 26, 1899, an assistant in the department of botany in Bordeaux defended his doctoral thesis in Paris.³⁶ Clearly it was an uphill fight for Duhem to engage the University of Bordeaux on a program of intellectual self-respect. For a while Duhem seemed to make headway. In 1899-1900 he guided two doctoral theses to successful completion. One was by E. Lenoble, assistant professor at the Institut Catholique in Lille, who studied permanent deformation of metal wires³⁷ and defended his thesis

33. *Rapport 1897-98*, p. 100.

34. 1904 (18).

35. 'Recherches expérimentales sur les oscillations électriques,' *MSScPhNB* 5 (1899):97-248. In the *Rapport 1898-99* (pp. 100-01). Brunel recalled his surprise when years earlier (1886 or so) the Post Office employee (Turpain) handling his telegram asked him about the date of exams for licence in physics. In view of Turpain's accomplishment and of the promise of the Ministry to provide Turpain with further funds to carry on with his research, Brunel conjured up the day when Turpain would be as famous in France as Marconi in Italy. The prognostication was rather overdrawn. Albert Turpain (born in 1867) produced as professor of physics at the University of Poitiers (1901-1937) textbooks, long and short monographs on the theory and technology of telephones, telegraphs, and radio. He also did experimental work on storms and atmospheric electricity. Given to sudden flare-ups of temperament, he once threatened to take the life of Duhem, who, of course, did not take the matter seriously.

36. *Rapport 1898-99*, p. 100.

37. 'Contribution à l'étude des déformations permanentes des fils métalliques,' *MSScPhNB* 5 (1899):261-383.

on July 5, 1900. The other was a study of Gibbs' and Duhem's work on the equilibrium of chemical systems. Its author, Paul Saurel, twenty-seven when he arrived in Bordeaux in the Fall of 1898, was a Cornell graduate and had already served there for four years as instructor in mathematics before he transferred in 1896 in the same capacity to the City College of New York. That Saurel, who spoke and wrote French fluently,³⁸ did not go to the Sorbonne but to Bordeaux, was a proof of the spreading of Duhem's renown in the United States and especially at Cornell, which housed the editorial offices of the *Journal for Physical Chemistry*.³⁹ Saurel found in Duhem not only a brilliant teacher and mentor but also a trusted friend. In the Spring of 1899 Saurel could reassure his sister that his work with Duhem would not prevent him from joining her in Paris where she was to arrive from the States in a few weeks: 'I can always take a week or ten days off without serious injury to the work, for Duhem would certainly be willing to lend me his lecture notes which are very complete.'⁴⁰

A great first ignored

Duhem put in perspective for the Bordelaise public Saurel's doctorate, which took place on June 20, 1900, in an essay in the September issue of the *Revue philomathique*.⁴¹ There, in a periodical of very limited circulation even in Bordeaux, let alone elsewhere, the essay, though all too important by its very topic for Bordeaux, remained effectively buried. On its journalistic merits alone the essay would have deserved a place in any of the great Bordeaux dailies, and especially in the *Bordeaux illustré*, a weekly devoted to the latest in literature, art, learning, and fashions. Fashions, of patently political kind, demanded however that a great first for Bordeaux should remain largely ignored even in Bordeaux. Once more excellence and merit lacked the approval of crusading pundits, always eager to mix learning and politics.

38. Saurel's grandfather, a teacher of mathematics in Pau (Pyrénées), emigrated to the United States in the 1840s. I owe this information to Saurel's son, Mr. Paul Saurel, attorney in New York, who kindly put at my disposal documents relating to his father's stay in Bordeaux and connection with Duhem. Saurel died in Paris in early 1932 after serving with great distinction for the previous thirteen years as the head of the department of mathematics in City College. The French background was carefully cultivated in the Saurel family and especially strengthened when Saurel, during his two years in Bordeaux became betrothed to Gabrielle François. They were married in June 1901 at the Church St. Vincent de Paul (116 West 24th Street, New York) which was the church for French-speaking Catholics.

39. Chiefly responsible for this was the fact that J. E. Trevor, one of the co-founders of the *Journal*, obtained his doctorate in Leipzig in 1892 as a student of Ostwald.

40. Letter of April 27, 1899, of Paul Saurel to his sister, Miss Louise Saurel. Ten days later Saurel wrote to his sister: 'In all likelihood I could even manage to be free a week beforehand — Duhem would let me have the missing lecture in manuscript.' Duhem's solicitude for Saurel extended, as the same letter shows, also to alerting him to the custom which required guests in restaurants in Bordeaux to tip their hats also to the cashier. It may be noted here that a dinner cost 3 francs in the Grand Café Restaurant de la Rotonde, one of the best restaurants in Bordeaux at that time (see *Guide de touriste et du commerçant à Bordeaux* [Bordeaux: Feret et Fils, Avril 1899], p. 45).

41. 1900 (10).

Duhem first reminded his readers of two brief notices in the Bordeaux newspapers concerning Saurel's and Lenoble's doctorates. The former was referred to as 'docteur de l'Université de Bordeaux (mention *sciences*),' the latter as 'docteur ès sciences.' This slight difference could appear a mere 'chinoiserie,' or ceremoniousness; actually, Duhem argued, it could mean such a parting with long-established patterns as would, for instance, be the lifting of China's isolation by causing the huge wall around her to tumble. To justify such an image about the prospective end of the isolation of French Universities, and especially of those outside Paris, Duhem portrayed to his readers the American scene, still made up of only thirty-two states and of vast territories still to be civilized.⁴² It was the scene of huge masses of humanity from diverse races and nations pouring into wide-open lands to be moulded into a single nation, a process which Duhem described as the most unique event of contemporary history. In that process a basic role was to be played by grim competition which, like other struggles, called for the survival of the fittest in the form of a coherent society. No less basic a role was being played by the schools in that process of unifying so many heterogeneous groups. Faced with the pressing demands of providing the know-how for the conquest of still receding frontiers and still unsettled urban areas, American colleges and universities could not pay enough attention to the cultivation of learning for learning's sake, an indispensable precondition, Duhem argued, for the training of their own elite of teachers. Younger American faculty had therefore to migrate to the universities of Europe, especially to those of Germany.

To be sure, Germany with the throbbing energies of her newly-found unity appeared particularly attractive. But the great number of young American college professors at German universities demanded a better explanation. The latter had as much to do with the freedom with which German universities could accommodate foreign students as with the rigidity of highly centralized French educational policy. While a capable American college graduate could earn his doctor's degree in Germany in two or three years, in France he had to spend six to ten years and face up to cumbersome examinations in subjects such as French composition, history, literature, Darwinian theory,⁴³ and sundry others, which had little if anything to do with his field of doctoral research. More importantly, far-sighted Americans did not find the clustering of young American faculty in German universities an unmitigated blessing. Duhem referred in this respect to a study by James Pierpont, professor of mathematics at Yale and a laureate of the University of Göttingen, who had just urged, in the pages of the *Bulletin of the American*

42. *Ibid.*, p. 396. Here Duhem gave generous credit to his conversations with Saurel about conditions in the United States, but also mentioned Paul Bourget's *Outre-Mer* in which vivid descriptions were given about the influx into New York City of vast numbers of immigrants.

43. Duhem was all too aware of the ideological rather than scientific reasons behind this emphasis on Darwinian theory on the part of officials of the Ministry of Public Instruction. He was wont to ask candidates about Darwinism, and before they had time to answer he listed the non sequiturs of the theory and gave them a good mark (P. Humbert, *Pierre Duhem* [Paris: Bloud & Gay, n.d.], pp. 15-16).

Mathematical Society, his younger compatriots to profit by the French school of mathematics, in full flourishing at the Sorbonne, the Collège de France, the Ecole Polytechnique and the Ecole Normale.⁴⁴ Even more telling must have appeared to the educated French public the alarm which had just been sounded before a full gathering of the Sorbonne by a visiting American professor according to whom

Young American scholars who visit in Germany in increasing numbers already influence American public opinion. It begins to consider Berlin the scientific Mecca of the world . . . There is, in certain circles in the United States, plain evidence of a cult of Germany; there is for German thought an enthusiasm in which a sympathy for the political aspiration of Germany allies itself unconsciously with the high regard justly accorded to German education. Both are among the causes which produce sympathies and antipathies among nations. Americans studying in Europe are the ones who will shape the thinking of the upcoming American generations. The sympathies of the American nation will be guided by these students.⁴⁵

Only thirty or so Americans worked for their doctors' degrees in Paris, whereas there were two hundred of them in Berlin. Such a lopsided proportion could but appear ominous if taken together with the fact that while the universities of Göttingen, Leipzig, and Heidelberg boasted of scores of Americans, the universities of Toulouse, Lyon, and Bordeaux, to say nothing of lesser French universities, hardly ever saw any of them.

The long-range effect of this shocking disparity could easily be guessed. Since all students, even the most independent-minded of them, imbue the spirit of their teachers, the great American cauldron, so portentous for mankind's future, would be fashioning its intellectual elite mainly along German ways of thinking. Not that the proclivities of the German mind were to be slighted. Duhem was in fact willing to see in Haeckel's pantheistic proclivities not only a negative characteristic of the German mind, but also a stimulus to scientific theorizing. No less was he ready to acknowledge the contribution of that concreteness with which a Darwin, so typical of the English way of thinking, elaborated the theory of evolution.⁴⁶ The respective coloring which the English and the Germans contributed to scientific and cultural discourse made, however, all the more indispensable as their complement the contribution of the French mind, bent on clarity and rigor:

Fond above all of exactness, order and clarity, born enemy of all which is obscure or incoherent, adventurous or excessive, the French mind seems to have for its mission

44. 'Mathematical Instruction in France,' *Bulletin of the American Mathematical Society* 6 (1899-1900):225-49. Pierpont gave a detailed account of mathematical instruction in France on the intermediate and higher level and especially in the *grandes écoles*, a task in which he was greatly helped by Painlevé. 'It is a question in my mind,' Pierpont wrote, 'whether it is wise for us to imitate so freely German methods, and be so largely dominated by the German way of looking at things. America is not a New Germany' (p. 225).

45. The sole identification given by Duhem of the professor was his name, Furber. Very likely Duhem quoted a newspaper report.

46. 1900 (10), p. 392. Duhem noted in the same breath that in Germany the theory of evolution was colored through the efforts of Haeckel with pantheism which Duhem took for a penchant of the German mind.

to organize science by investing each idea with its proper form and assigning its right place. In England as well as in Germany it is a byword that a doctrine has not taken its definitive form until it has been pondered in a French way. There it is readily proclaimed that the French have to a supreme degree the art of fusing together separate studies and producing from them that work of logic which is called the classic treatise.

Classic spirit! This form, in which Plato and Aristotle, Euclid and Archimedes have first immersed their ideas, invariably imposes itself as the perfectly beautiful mode, as the eternally true type of human reasoning. It must not be astonishing at all that the Greeks, being the creators of that spirit and ravished by their product as was Pygmalion by his statue, could recognize in it a memory or vision of an ideal world superior to ours. It is the great intellectual honor of France to have been in modern times the depository of this spirit. It is enough to recall the chaotic state of those branches of science which France has neglected for so long, in order to convince oneself of this truth: after a short while human knowledge can quickly become a Babel if France fails to maintain the rule of the classical spirit. That rule had been gravely compromised by the draconic regulations which kept foreigners at a distance from our doctorates.⁴⁷

Changes in those draconic rules were borne out of the necessities of academic life, a process of which Duhem was an eyewitness in Lille. The university there had from neighboring Belgium many brilliant students, any one of whom, if eager to obtain a doctorate, had to desert France, Lille, and his favorite professors. Similar was the situation in Nancy, which had a large number of students from neighboring Germany. Partly under pressure from these universities, the Ministry of Public Instruction had, on July 21, 1897, obtained from the government a decree which allowed provincial French universities to submit their own plans for doctoral programs. These programs secured the title of doctor but could in no way claim any of the privileges connected with the doctorat d'Etat. Such was a miser's generosity and hardly effective in the long run, but for the time being French provincial universities could dream of bright horizons. Duhem and Brunel had a lion's share in working out for Bordeaux, in the face of some opposition and lack of enthusiasm, such a program which was approved by Paris on March 16, 1900, only a few days before Saurel submitted his thesis to the faculty.

Duhem had high hopes. He told the public of Bordeaux about the prospect of further Americans coming to Bordeaux, about the official presence of Colonel Tourgee, the American consul in Bordeaux, at Saurel's doctorate, about the intellectual ties that connected the work of Gibbs, the greatest American physicist, to the work done in the chair of theoretical physics in Bordeaux. He also conjured up the vistas of Bordeaux' intellectual radiance toward South America, connected with Bordeaux by new shipping lines, and especially toward that

noble and chivalrous nation which, beyond the Pyrénées, stifles, in silent dignity, the painful cries of her recent setbacks. The hour is perhaps near when her very misfortunes will oblige her to move out of her three-century-long isolation and mingle in the intellectual movement of the European nations, in order to give her genius the eminent place which belongs to it. Who fails to see the role which our faculties in Bordeaux could play in that scientific rejuvenation of old Spain and the help which in that respect could be provided by granting here this new doctor's diploma?⁴⁸

47. *Ibid.*, p. 393.

48. *Ibid.*, pp. 397-98.

As Duhem directed his final thoughts to his own France, his poetic talent came to the fore. His bent on logic and clarity never oppressed the artist in him:

At this moment when France opened wide to students coming from everywhere the doors of her Faculties, hardly penetrable until recently, she also changed the mint of her coins. On the metal she imposed the figure of a woman who is sowing the good seed. Cannot we see in this coincidence a symbol and a prophecy? Will not this *doctorat d'université* support that great sower of ideas, our dear country, as she throws with lavish hands on all furrows of the intellectual world the fertile seeds of French doctrine?⁴⁹

Such a spirited and penetrating analysis of what lurked behind that apparently trivial difference between two kinds of doctoral titles could only be lost once it saw print in the pages of a provincial periodical of very limited circulation. The real loser was Paris, all too often usurping France herself. The miserly generosity of the decree of 1897 may have helped bring foreign doctoral students to Lille, Nancy, and Toulouse, all close to France's frontiers. Bordeaux soon became a barren ground as far as doctorates were concerned. For a long time, Saurel's doctorate was the last such title earned there by a foreign student. As to the French, they kept looking to Paris for the regular, long-established title of *docteur d'Etat*. In the spring of 1901 Duhem had to witness the very end of a promising start. The doctorates of H. Chevallier⁵⁰ and F. Caubet,⁵¹ two younger members of the physics department in Bordeaux, were the last within the foreseeable future which he was asked to guide to a successful completion. In that year, 1900-01, he and Marchis had to give their advanced courses to a single student.

Prodigious productivity and a recognition

Had Duhem been only a brilliant, almost spellbinding teacher, whose phrases flowed with astonishing precision, clarity, and ease, his talents would have amply deserved a large audience, and in Paris, the center of French intellectual life, at that. Duhem was also a physicist whose productivity seems to have been inexhaustible. Had he done nothing more in Bordeaux than guide eight doctoral theses to successful completion, he would have more than merited promotion. He was kept until 1904 at the lowest or 4th rank with a not at all generous salary of 6000 francs.⁵² Elected a member of the Conseil de la Faculté, at the end of his first year in Bordeaux, he served assiduously in spite of his dislike of petty politics which all too

49. *Ibid.*, p. 398. It was pointedly noted in the *Rapport 1899-1900* by the dean that 'it was the first time that the Faculty conferred the degree of doctor of the University of Bordeaux' (p. 104).

50. Chevallier's thesis, 'Sur les variations permanentes de résistance électrique des fils d'alliage platine-argent soumis à des variations de température,' was defended on April 25, 1901, and covered almost a hundred pages in *MSScPhNB* 1 (1901):385-460. It also appeared separately as a monograph (Paris: Gauthier-Villars, 1901).

51. Caubet's thesis, 'Liquéfaction des mélanges gazeux,' defended on June 20, 1901, and published by Gauthier-Villars (Paris, 1901, 170 pp), proved its importance by its being immediately translated into German in *ZPhCh* 40 (1902):256-367.

52. The impression given in *Un savant français* (p. 132) that Duhem's salary stayed until his death on that level is misleading.

often set the tone of academic councils. While Brunel was on the Conseil, Duhem saw hope that principles would as a rule prevail over personalities. To be sure, principles could at times be seen as trivial matters. Certainly trivial had to appear those 35 centimes which Brunel once found misplaced in the University budget. Duhem was obviously present at the meeting of the Conseil when Brunel was 'congratulated' by some over his 'find'. The mind of Duhem, always bent on seeing the ultimate implications of a detail however minute, could but immensely relish Brunel's rejoinder. Had that misplacement of 35 centimes gone unchallenged, it could have been turned into a rule which, when applied throughout the budget, would lead to an annual decrease of 7500 francs in revenues for the University. The congratulations were repeated, but this time 'the irony had vanished,' as Duhem was to recall.⁵³

After Brunel's death, Duhem expressed his own feelings by recalling Brunel's words to Elie: 'Ideas are perhaps easier to manage than men.'⁵⁴ While in Lille, and still a bachelor, he was not reluctant to spend hours with students over a cup of coffee. Later he came to think that a professor did his best by limiting himself to the professional instruction of his students. He found rather naive the efforts of intellectuals who wanted 'to go to the people.' 'If they only knew,' he used to remark to friends, 'how difficult it is to reach the students!'⁵⁵ Duhem was completely at home in smaller gatherings of scientists (he viewed big congresses as sheer wastes of time) engaged in informal discussions. Such were the meetings, especially under the guidance of Brunel, of the Société des sciences physiques et naturelles de Bordeaux. To what extent Duhem enjoyed the biweekly meetings of the Société can be gathered from his obituary of Brunel. There he specifically listed three meetings which Brunel turned into exciting conversations on such arcane topics as the rise of various algebraic systems under the successive generalization of complex quantities, the history of functional calculus, and Babbage's calculating machines. It was at a meeting of the Société that Brunel called attention to a little known, more than half-a-century-old essay of Henri Sainte-Claire Deville, whose importance was quickly recognized. The reprinting of the essay in the *Mémoires* of the Société was voted and Duhem was asked to write an introductory essay to it.⁵⁶ Duhem's active role in the Société can also be gathered from the fact that he secured publication in its *Mémoires* (published by Gauthier-Villars in Paris) a place for the eight doctoral dissertations for which he acted as mentor, although none of them was shorter than a good hundred pages and several of them were twice as long or even longer. He often served as a referee for manuscripts submitted for publication in the *Mémoires*, and involved his own doctoral

53. 1902 (21), p. 17.

54. Ibid.

55. Jordan, 'Duhem,' p. 171.

56. 1899 (6).

students in its sessions. Their short contributions often saw print in the *Procès-Verbaux* of the Société.⁵⁷

Duhem's own contributions to the *Mémoires* and *Procès-Verbaux* of the Société were frequent and at times book-length. They were but a small part of his publications during his first seven years in Bordeaux. His 207-page-long memoir on the: thermodynamical theory of viscosity, friction, and of false chemical equilibria, which he finished on March 2, 1896,⁵⁸ should look smallish in comparison with the work which he started immediately in its wake, the four volumes of his treatise on chemical mechanics (1897-99).⁵⁹ Three years later there followed his almost five-hundred-page textbook on chemistry and thermodynamics which was immediately translated into English.⁶⁰ In addition, he published a series of memoirs or essays to be quickly published as books on such disparate topics as Maxwell's electromagnetic theory (1900-01),⁶¹ and the notion of chemical mixture (1900-01).⁶² Among his serial contributions not gathered into single books were his essays on permanent deformation and thermodynamics which appeared in German in the *Zeitschrift für Physikalische Chemie*,⁶³ whose founder and editor, Wilhelm Ostwald, himself translated the first installments. The *Journal de mathématiques pures et appliquées* received from him in 1897 two articles on fluid mechanics,⁶⁴ while the Académie Royale de Belgique was the beneficiary of his great memoirs on permanent deformation and hysteresis. Indeed, when after the first three memoirs, published in 1896,⁶⁵ Duhem did not send in quick order the further installments to follow, the Académie sent him word about the esteem in which his memoirs were held.⁶⁶ The only problem was their length, a point which Duhem ignored by making the fourth and fifth memoirs even longer than the first three.⁶⁷ In comparison with these often massive productions, his five articles between

57. In the volume 1896-97 Marchis (p. 137); in the volume 1897-98 Lenoble (p. 74). Monnet (p. 200), Pélabon (p. 205), Turpain (pp. 27, 55, 117, 171, 216, 267, 270); in the volume 1898-99 Caubet (p. 60), Chevallier (p. 64), Pélabon (p. 32), Turpain (p. 103); in the volume 1899-1900 Caubet (pp. 7, 63, 78), Chevallier (pp. 52, 64), Lenoble (p. 51), Marchis (p. 14), Turpain (pp. 2, 8, 59, 64), Wintrebert (p. 79); in the volume 1900-01 Chevallier (p. 3), Wintrebert (pp. 8, 23, 89, 100, 107); in the volume 1901-02 Chevallier (p. 41), Wintrebert (pp. 9, 31, 34); in the volume 1902-03 Baudeuf (p. 61), Chevallier (pp. 2, 58); in the volume 1903-04 Wintrebert (p. 131). While the Abbé L. Wintrebert obtained his doctorate in chemistry, the topic of his dissertation, 'Recherches sur quelques sels complexes de l'osmium hexavalent' (*AChPh* 28 [1903]:15-144), was suggested by Duhem whose continued interest too was much appreciated by Wintrebert (*ibid.*, p. 21).

58. 1896 (11).

59. 1897 (1), 1898 (1), 1899 (1).

60. 1902 (1) and 1903 (1).

61. 1900 (13), 1901 (20, 21), 1902 (3).

62. 1900 (1) and 1902 (2).

63. 1897 (2, 3, 4), 1899 (2, 3, 4), 1900 (4).

64. 1897 (6, 7).

65. 1896 (6, 7, 8).

66. Letter of April 30, 1897, by Charles Lagrange, followed by three more letters in the same year, one of them accompanied by a letter of Marchal, perpetual secretary.

67. 1898 (4, 5).

1897 and 1901 in the *Journal of Physical Chemistry*, then published by Cornell University, might appear minute,⁶⁸ but they certainly witnessed the eager welcome of his writings abroad.

In his own country Duhem's writings did not always find the proper outlet. Efforts to block their appearance were not missing. A telling case was the sudden cooling, in early 1896, of the editorial board of the *Revue des Deux Mondes* toward Duhem who was eagerly solicited in late October 1893 to make contributions.⁶⁹ Duhem's paper in the *Bulletin des sciences mathématiques*⁷⁰ struck Radieu, editor of the *Revue*, by its 'luminous' character, worthy of a first-rate popularizer of science. The appearance in 1895 of three articles by Duhem on thermodynamics was a great success and the editor-in-chief, Brunetière, himself sent words of appreciation to Duhem.⁷¹ That the publication in three parts implied changes in the galleys was no high price for Brunetière in return for Duhem's contributions which were supposed to continue on the same subject. Brunetière realized too late that the subject was very touchy for the scientific establishment. Obviously, pressure was exerted on the *Revue* to abstain from giving further opportunities for Duhem to present his views and acumen to a worldwide audience. Strange delays in the publication of further installments ended with a letter of August 5, 1896, from Radieu to Duhem: 'I am charged to tell you that we would rather renounce being a party to this publication and return the manuscript to you to do with as you wish.'

That a series of articles on thermodynamics provoked such a sudden change of heart suggests Berthelot's manoeuvring behind the scenes. He was not however all powerful in every respect. In the Académie des Sciences considerations of merit often prevailed when opportunity arose. Such an opportunity was provided by the government's decree of June 24, 1899, which created four new posts for correspondents to the Académie in the various sections of exact and natural sciences. It was through that provision that Gibbs and Boltzmann became, on May 21 and May 28, 1900, respectively, corresponding members of the Académie in the section of mechanics in which such membership was raised from six to ten. That the third of the four new members was Duhem showed that for once the French scientific establishment knew how to match foreign greatness with homegrown excellence. Duhem could confidently expect his own election. Darboux, his former mentor in the Ecole Normale, who channeled his first communications to the Académie fifteen years earlier, had just succeeded (May 24) Joseph Bertrand in the post of perpetual secretary of the division of exact sciences of the Académie. Duhem was elected on July 30. Of the 38 votes cast he received 36, the remaining

68. 1897 (13), 1898 (12), 1899 (12), 1900 (8), 1901 (24).

69. See letter of October 28 of Radieu to Duhem.

70. The reference was quite possibly an error. Items 1887 (16) and 1890 (2) were not for the general public. Very likely Radieu referred to one of Duhem's articles in *Revue des questions scientifiques*.

71. Letter of April 1, 1895.

two went to two other candidates.⁷² Two days later, on stationery marked with the printed lines, Université de Bordeaux, Faculté des Sciences, Laboratoire de physique théorique, Duhem expressed his appreciation to the perpetual secretary in a letter classic for its brevity:

By nominating me to the post of corresponding member in the section of mechanics, the Académie des Sciences conferred on me a great honor which touches me profoundly. I beg you to accept the expression of my deep gratitude and convey it to the Académie.

Letters of congratulations poured in and almost invariably contained a reference to the belatedness of official recognition. J. E. Trevor, professor at Cornell and editor of *Journal of Physical Chemistry*, wrote: 'I was greatly pleased to learn of this mark of official recognition which has taken so long to come.' Good old Professor Morin in Rennes was blunt: 'It is rather the Académie des Sciences that ought to be congratulated for having understood the impossibility of any further delay and for having given evidence, through a rare unanimity, of its regret of not having done earlier what it has just done today.' The reason for the failure of the Académie to act much earlier was subtly conveyed in the congratulatory note of Gernez who referred to the 'absolute independence' of Duhem's ideas as the sole cause of the honor bestowed on him.

The timing of the honor could not of course have been more inappropriate for official celebration at the University of Bordeaux, which had just closed its doors for the great summer vacations. But this was hardly an excuse for the niggardly handling of the news about Duhem in the *Rapport* for 1899-1900 when written up in October 1900: 'Mr. Duhem was named correspondent of the Académie des Sciences and received thereby the highest approval of his remarkable studies.'⁷³ The report, all too brief for such an event, was not even listed first among the few honors that fell in that year on various members of the Faculty. That the first item, a promotion of a professor to the rank of officer of the Légion d'honneur, smacked of politics was revealing enough of the priority of non-academic considerations within the academy. Duhem was partly compensated for this by the beautiful vase which on November 8 was presented to him by Marchis on behalf of 35 former students of Duhem. In the vase were 35 letters. Marchis who secured one even from Saurel, already back in the States, wrote in the name of all: 'The Académie did not want to separate your election from that of Gibbs, serving thereby evidence that you have not merely continued the work of the American savant but equalled him and even advanced beyond him.'

Life at home

Behind such an advance there lay a disciplined effort, hardly ever broken by relaxation, that kept Duhem working from early morning till evening and through much of the entire year. In the mornings he gave himself to writing as was his custom in

72. CR 131 (1900):325.

73. *Rapport 1899-1900*, p. 11.

Lille. Most of his afternoons were spent with his students, in lecturing and in the laboratory. But after returning home for dinner, he gave himself entirely to his mother and daughter. How the latter remembered those evenings from a distance of almost forty years deserves to be quoted in full, even if her reminiscences were not the only information in this respect:

Nothing was more lively in the house in Rue de la Teste than the meals and the evenings. In the evenings Pierre Duhem used to read to his mother whose eyes were in poor condition. That was a real treat, because he used to read with a genuine skill which came from both a deeply poetic and artistic sense, able to do justice to the entire value included in the harmony of words, and from an extraordinary talent for imitating. On hearing him, one saw. When he read a play, the actors talked and moved, each with his peculiar character, as if made present by the intonation of his voice.⁷⁴

Hélène Duhem is also the only, and once more a gifted source as to what Duhem's mother meant to her son and her granddaughter:

She was the very soul of the house. Her face was a bit severe, with a look which at first intimidated and kept at a distance. (Woe to the one who deserved a reprimand; her dark eyes could be vanquishing!) But, if one knew how to merit it, the same look softened and sparkled with the most serene goodness, as a smile ran across her gentle lips. She had the strength to keep her setbacks and sorrows in the secret of her heart and to recover, for that little one, the happiness which suits children. Her conversation was charming and lively. She joined a refined politeness to a natural disposition, to the good manners of old times. Very active and a complete mistress of the house, she watched with unceasing care over the good order of its interior, the well-being of her beloved ones, and she did so with the skill of the [Bible's] 'strong woman' concerning many a task requiring skill and effort, as once the custom had been. She also found time to instruct her granddaughter, assuming the ungrateful task of making her learn to read and write, and, to the end of her life, she would oversee her studies. Her solicitude, which handled all the cares, left her son with the quiet needed for meditation and work. As much as was possible for an unprofessional, she took interest in his projects responding from the depth of her heart to all his hopes and disappointments.

Pierre Duhem was most communicative. He kept his mother abreast of his ideas, work, and projects. He loved to discuss with her topics, religious, political and literary, which at that time created passionate interest everywhere. By listening to the two the little girl learned most.⁷⁵

The picture of the widowed Duhem's household in the Rue de la Teste would not, however, be complete without a priceless detail, unfortunately the only one of its kind left for posterity. There were days when Duhem worked at home in the afternoon with his little daughter around. Indeed, mother and daughter were much around because as Duhem was writing at his large desk in his study, his mother was knitting in a chair nearby, and his daughter doing her homework at the end of the desk reserved for her. As Hélène recalled, she often longed to jump into her daddy's arms as he interrupted his work to walk to the fireplace and

74. *Un savant français*, pp. 187-88.

75. *Ibid.*, pp. 186-87. Duhem's objectives concerning Hélène's education will be discussed in the next Chapter.

stand with his back to it with a distant look. But she was not allowed to disturb his train of thought. 'Be quiet, Papa is in search of a theorem,' came the warning from the grandmother.⁷⁶ That her words were beyond appeal was all too clear to little Hélène. Although she was lovingly called 'ma commandante' by her father,⁷⁷ the latter took his mother's wishes for a command. Such filial respect on the part of a man in his thirties and forties struck many an outsider, including some ecclesiastics fond of preaching the fourth commandment. As one of these reminisced:

Toward his mother, I can say that I don't recall having seen anyone more obedient and deferent than he. Already forty, widowed and father of a family, he did not at all consider himself as emancipated. He remained a little child, docile and affectionate. In his projects of excursions he took into account the wishes, even at times exaggerated concerns, of maternal tenderness. One day he was asked about this with some surprise. 'Ah,' he replied, 'the fourth commandment of God does not say that an old mother is no longer a mother . . . Moreover, one has a mother only once. If I stopped obeying, it would appear to me that I had lost my mother.' All this was said naturally, with no affectation whatever.⁷⁸

Avid hiker

At times Duhem's evenings took a form of relaxation as he paged through his albums of sketches, so many memories of the best scenes he saw during his summer vacations. As will be seen later from a letter which Duhem wrote a few years before his death, part of his summer vacation, mainly the months of August and September, was devoted to writing essays and reviews that were constantly solicited from him. Although Cabrespine was considerably closer to Bordeaux than to Rennes, let alone to Lille, Duhem went there for the time being only during the last weeks of vacation. There he was joined by his sister and they spent some of their time in remodeling the garden by planting rows of box-trees.⁷⁹ The Atlantic around the Ouessant saw him less and less. A reason for this may have been Jordan, no sailor at all but a particularly close friend since the year they had spent together in Rennes. During Duhem's first six years in Bordeaux, Jordan was his companion almost every year on a hike which lasted about two weeks and took them mostly to the Cévennes.

The procedure was always the same and very typical of Duhem. Once he reached by train the area he wanted to explore on foot, he followed a route which was not so much planned as improvised according to what caught his eye. His theory of travel was much closer to the one popularized by Rodolphe Töpffer in his *Voyages en zigzag*⁸⁰ than the one advocated in the *Guides Bleus* and *Baedekers*. The method perfectly suited meditative souls who wanted to commune with

76. *Ibid.*, p. 103.

77. In his letter of Dec 1, 1902, to Saurel, Duhem mentioned that he was writing at the bedside of 'le commandant who was down with fever.' Nine years later Duhem mentioned, again in a letter to Saurel (April 3, 1911), that the 'little commandant is already almost twenty.'

78. A reminiscence of the Abbé Bernies, 'Pierre Duhem,' *Revue des Jeunes* 15 (1917):519.

79. *Un savant français*, p. 102. Töpffer (1799-1846) was a painter in Geneva.

80. *Ibid.*, p. 109.

nature and with each other. 'I count,' Jordan reminisced years later, 'among the best memories of my life the few excursions which I had the good fortune to make with him, backpacking and in short stages.'⁸¹ In 1896 they explored the magnificent slopes of Aigoual, from the peak of which one can catch in good weather a glimpse of the Alps and the Pyrénées. They went next year to explore the border region between Lozère and Ardèche. In 1898 they hiked in Lozère, in 1902 in the Eastern Pyrénées, south of Carcassone. Duhem was not for the first time in the Gorges du Tarn when Jordan accompanied him there in 1906. Duhem was familiar with the wilderness of Montpellier-le-Vieux, an area opened up to the public only in the 1880s. The huge and ragged stone formations and their strong contrast of light greatly appealed to Duhem. The evidence of this is an album of some thirty exquisite drawings in ink.⁸² In 1900 Duhem and Jordan explored the region north of Montpellier where they could admire the magnificent silhouette of the southernmost ranges of the Cévennes as the sun was setting beyond St. Hippolyte-du-Fort. Farther to the northeast was a ragged valley whose description by Duhem is a fine example of his powers as an observer and a writer:

After traversing the dry calcareous plains of Larzac, with its protruding stones, with its rocky labyrinths resembling cities in ruins, the traveler turns his steps toward the plains bathed by the Mediterranean. The route he has to follow is traced by huge ravines. They are the remains of ancient torrents or of drained rivers which grow and sink ever deeper into the chalky plateau. These ravines soon unite into a single gorge. High sharp walls covered with dangerous streaks of sliding rock enclose the bed where once a beautiful river rolled its deep and impetuous waters. Today, this riverbed is a chaos of worn and broken blocks. No spring wets the rocky walls, no drop of water moistens the gravel. Between the piles of stone no greenery shoots forth. *Vissec* (dry Vis) is the name which the Cévenoles have given to this river of aridity and death.

The hiker who treads uneasily among the holes and fallen rocks hears from time to time a muted noise similar to the rumbling of distant thunder. As he goes on he hears that rumbling increase and explode finally into a formidable din, the roaring of *Foux*.

There gapes in the calcareous soil a dark cavern widely split like an enormous muzzle. With no letup this muzzle disgorges into a whirlpool, full of the transparency of crystals and of boiling white foam, huge masses of water which the fissures of the plateau have collected from afar and gathered into a subterranean lake.⁸³

What Duhem saw with eyes to which no detail was lost, he also saw with his mind's eyes. The foregoing scenery served him, as will be seen later, as a graphic symbol of a crucial phase in the history of science. Tortuous as was that history, its sharp turns were the result of gradual transformation, witnessed by every hole, rock, and turn in that valley. That the sudden and gigantic had no appeal to him was the reverse side of his love for the simple and unpretentious. Jordan could in no way persuade him to visit the Alps which for Duhem smacked of 'tourism' and

81. Jordan, 'Duhem,' p. 169.

82. Given as token of gratitude by Hélène Duhem in the late 1940s to the family of Norbert Dufourcq.

83. The first four paragraphs of the conclusion of the second volume of *Les origines de la statique*.

vogue. He wanted to see and not to be seen, as Jordan remarked.⁸⁴ Duhem wanted above all to commune with the scenery, hardly compatible with the exertions of serious mountain climbing. He preferred to move along without obeying any fixed itinerary or schedule. Whenever he found a special view, he stopped and made a sketch in pencil, which later at home he developed and retouched in India ink. What he wanted was to record the chief impression given by a scene rather than to keep an exact image of it. He preferred pencil and drawing pad to cameras. According to Jordan, Duhem spoke in a half serious way of making one day an illustrated survey of rocks and houses of the entire French countryside.⁸⁵

The relaxing mood of these excursions brought out time and again the impish boy in him, ever ready for a joke. There was, of course, always something amusing about the big stick reinforced by iron which he carried faithfully along. Originally it belonged to his great-uncle Timothée Fabre who received it from a poor peasant. A single token of gratitude for some favor, it was fashioned from a chestnut branch.⁸⁶ The stick, rather different from the kind used by most hikers, added to the strange impression which Duhem, dusty and informal traveler that he was, could readily create. He was invariably amused. He laughed when he was denied lodging by the suspicious owner of a hostel which he reached too late in the evening. Once, when he was asked about his identity by a woman who was left by her husband to guard a railroad crossing, he replied, 'Good woman, don't tell anybody, I am Carnot's assassin.' It must have been the summer of 1894. On another occasion, while wandering in the Pyrenées, possibly in 1902, when the Abbé Pautonnier, future director of Stanislas, was his companion, he ventured onto Spanish soil to obtain a better view of the scenery he wanted to sketch. On his way back he was stopped by two Spanish border guards whose suspicion was aroused by Duhem's sketchbook. Not knowing what to do with him they decided to consult with the officer in charge who happened to be taking his siesta. While they worked on waking him up, Duhem escaped to the French side of the border. From his safety he poked fun with vivid laughter and lively gestures at his would-be-captors who were all the more unfortunate as the officer held them responsible for the interruption of his sleep.⁸⁷

A chair and its political prize

Less fun perhaps was the tone of the excursion which he made in lower Brittany

84. Jordan, 'Duhem,' p. 169. Jordan adds that Duhem derived a greater pleasure from seeing scenery for the second time than for the first time, because in the second viewing he was already prepared to choose the best things to contemplate.

85. *Ibid.*, p. 168.

86. See Jordan, 'Duhem,' p. 158.

87. For these details, relating to the summers of 1894 and 1902, see *Un savant français*, pp. 111-12. Duhem could poke fun at French officialdom as well. As a professor he received from the Ministry of Public Instruction every year a questionnaire which contained the entry: 'What benefices do you enjoy outside the University?' 'A magnificent beard,' replied Duhem on one occasion, most likely during his early years in Bordeaux (P. Humbert, *Pierre Duhem*, p. 15).

in the company of the renowned geologist, Charles Barrois, a former colleague of his in Lille, who was elected a member of the Académie des Sciences in 1905. Whoever was Duhem's companion on such trips was also his confidant. In addition to a variety of topics, mostly intellectual and scientific, there also came the turn of vital subjects relating to country, church, and education. It is difficult to imagine that conversation would not have turned ultimately to the thorny topic of Duhem's career and academic future. Some of his friends might have heard from him details of the conversation which Duhem most likely had with Liard who came to Bordeaux in late January 1897 to grace with his presence the inauguration of the new statutes which turned the 'Académie de Bordeaux' into the 'Université de Bordeaux.' Liard insisted on being seated with the Faculty, many of whom were his former colleagues in Bordeaux, a gesture which created an atmosphere of informality for such a great occasion and was long remembered.⁸⁸ Duhem might have found the occasion not only opportune, but also urgent. A course for physical chemistry, recently set up at the Sorbonne and assigned to G. Robin whose publications were insignificant in comparison with those of Duhem, was before long to be enlarged into a program befitting a chair. Though never pushing his cause, Duhem was always ready to make discreet moves, one of them being his turning to Denys Cochin, deputy from Paris,⁸⁹ who wrote to him: 'I have kept saying for a long time to Mr. Liard that you would be the most worthy occupant of that new chair [for physical chemistry].' Now in speaking to Liard, perhaps on the pretext of thanking him for Marchis' appointment, he must have felt that Liard was after all the representative of a Paris where Berthelot ruled supreme. He knew, for instance, from Painlevé's letter of Dec. 1894, that earlier that year the prestigious Prix Poncelet would have been awarded to him had some of his best supporters in Paris not been apprehensive of Berthelot's reaction: 'Jules Tannery, responsible for many decisions concerning the Ecole Normale, would no more have Berthelot against him than Darboux, who expects to succeed J. Bertrand as perpetual secretary at the Académie des Sciences. If he [Darboux] could have given you the Prix Poncelet without compromising himself, he would have been delighted to do so, but he preferred not to compromise himself.' Last but not least there was Duhem's criticism of Berthelot's principle of maximum work, especially in the *Introduction à la mécanique chimique*, the work very likely referred to by Painlevé in the same letter as the 'anti-Berthelot bomb.'

Even if Duhem had a pleasant chat with Liard, his prospects did not improve. He saw 'the paws of Berthelot,' to recall a phrase from Painlevé's letter, when Gustave Bizos, the new rector, attacked him rudely at the very first meeting of the Conseil d'université in the Fall of 1898. The provocation, which Duhem felt

88. As shown by the glowing obituary of Liard in the *Rapport 1916-17*, p. 14.

89. Cochin's letter, undated, was most likely written around 1898. Shortly afterwards his usefulness as an intermediary would have largely diminished because, as a deputy from the liberal-conservative constituency of the 8th Arrondissement, he staunchly opposed the anti-Church laws of Waldeck-Rousseau, to say nothing of their radical implementation during the cabinet of Combes.

to have been done on higher instruction, was indeed all the more unexpected as at the end of the previous academic year he had been named by the Ministry 'officier de l'Instruction publique,'⁹⁰ an obvious recognition of highly meritorious service. Duhem, a member of the Conseil, resigned his post on the spot. Indignation over the rector's action was so strong in the Conseil that its members decided to put their sentiment on official record at the next meeting, November 22, 1898. Following the reading of the minutes of the previous meeting, Professor Arnozan asked for the floor:

Professor Duhem, who resigned during the previous meeting, has for long co-operated in our work. He has maintained with all his colleagues the best rapport. The Conseil d'Université has him in high esteem and has often adopted the propositions submitted by him. It seems to me that we cannot let him leave without conveying to him the expression of our sympathies. Therefore, I ask the Rector to submit to vote the following resolution: The Conseil d'Université of Bordeaux expresses its regrets that Mr. Duhem, who rendered so many services to the University, has tendered his resignation. Adopted. The Secretary of the Conseil.⁹¹

Duhem, so it seemed, was to be sidelined, on higher orders from Paris. The tactic was in strange contrast to the growing reputation of Duhem abroad where it was asked more and more why he was not teaching in Paris. On May 19, 1900, he was elected foreign associate of the Société hollandaise des sciences de Haarlem and on June 7 was given an honorary doctor's degree by the Jagellonian University of Cracow celebrating its 500th anniversary.⁹² Neither of these honors was of course comparable to Duhem's election as a corresponding member of the Académie in Paris, but signal as that honor was, it fell short of a chair in Paris. To anyone in the know, it could easily appear as a panacea.

One signal act that fitted that category was the invitation which Duhem received in a letter written on February 29, 1900, by Lucien Poincaré, a former fellow Normalien and a future successor to Liard, but now the secretary of the committee organizing the International Congress of Physics to be held in Paris in August that year. Poincaré asked Duhem to give there a report on the thermodynamic theory of permanent deformation, leaving however aside basic topics of thermodynamics, topics to be set forth by physicists from abroad! The next day Duhem wrote directly to Cornu, president of the committee, a reply in which he declined the

90. *Rapport 1897-98*, p. 98.

91. Archives, Université de Bordeaux.

92. On that occasion, the Jagellonian University conferred thirteen honorary degrees within its theology faculty, fifteen within its faculty of law, twelve within the faculty of medicine, and thirty-one within the faculty of philosophy which included all the humanities and the sciences. Among the half-a-dozen foreign physicists who received honorary degrees were Simon Newcomb, Roland Eotveos, Joseph Thomson, and William Ramsay. Information provided by Jan Pirozynski, Deputy Director of the Jagellonian Library. The degrees were conferred in the name of the Emperor, Francis Joseph. Duhem's nomination owed much to Ladislav Natanson (1864-1937), a physicist who served in 1906-07 as dean of the Faculty of Philosophy and in 1922-23 as rector of the University. Natanson, a specialist in thermodynamics, published widely in English and in German as well as in Polish.

invitation. He pointedly noted that neither time nor taste allowed him to send in a report in which he was not to touch 'on general questions of thermodynamics and chemical phenomena – reserved for reports written by foreigners.' The actual letter did not include the last paragraph in the draft: 'I must congratulate the commission for reserving to foreigners the reports on the foundations of thermodynamics and on chemical mechanics [physical chemistry]. The rights of French science will be well safeguarded.' The chief target of this irony, fully justified for all its bluntness, were French physicists in Paris unwilling to recognize Duhem's true merits. Poincaré himself, most likely on instruction from Cornu, tried to save face in another letter nine days later. While pleading his inexperience, and declaring himself open to Duhem's suggestions, he clearly was not allowed to change anything essential concerning the report to be presented by Duhem.

Duhem's presence in the Congress⁹³ gave him plenty of opportunity to meet there with the physicists of the *grandes écoles* and members of the Académie des sciences and higher officials of the Ministry of Public Instruction. He obviously brought up the future of the courses in physical chemistry at the Sorbonne. Who would succeed Robin, not only in giving them but also from a chair to be soon established on a full-fledged and permanent basis? He most likely met at the Congress Jean Perrin, whom he had warmly congratulated when given the assignment in Paris 1898 to continue the course inaugurated by Robin and who replied on May 1898: 'I was deeply touched by your congratulations whose value I know all too well . . . I hope to have the honor of meeting you when you come to Paris – and I wish you to come – because I know very well that I would derive great benefit from talking with you about topics which are familiar to you and to which I have to address myself.' Duhem, of course, must have thought it strange that the same Perrin, who informed him in that letter of his immediate plans of going to see Ostwald in Leipzig and Van't Hoff in Berlin, found no time for traveling only as far as Bordeaux. (Perrin could not risk his chances of advancement by consulting with Duhem.) Thus as the year 1900-01 went by Duhem must have felt the growing need to make a direct and official step, his letter of July 3, 1901, to Liard:

Monsieur le Directeur,

When you have honored me with an appointment in Bordeaux, I hesitated to accept: 'Mr. Duhem must understand,' you said at that time to Mr. Tannery, 'that Bordeaux is the road to Paris.' On that road I have so far made a journey of seven years. Until now I have never complained about its length and I have done nothing to shorten it. Twice I was solicited by various persons to present my candidacy, namely, when the death of Tisserand and then the death of J. Bertrand led respectively to a vacancy of the chair of physical mechanics at the Sorbonne and of the chair of mathematical physics at the Collège de France. I did not want to follow the advice and gladly gave way to my seniors, Koenigs and Brillouin. Nor did I want, in spite of the unquestionable superiority of my qualifications over these two candidates, to ask for the chair

93. Duhem is listed as a participant (member) in *Travaux du Congrès International de physique, réuni à Paris en 1900 sous les auspices de la Société Française de Physique*, rassemblés et publiés par Ch.-Ed. Guillaume et L. Poincaré, *Tome IV. Procès-Verbaux. – Annexes. – Liste des membres* (Paris: Gauthier-Villars, 1901), p. 140. One of Duhem's doctoral students, A. Turpain, gave a paper there on Hertzian waves. See *ibid.*, pp. 109-116.

of physical chemistry occupied by Robin. I understood that certain polemics, which it was my duty to carry on and without which French instruction would not have perhaps entered the true avenue of chemical mechanics, made my nomination difficult [to that chair]. But today, I believe, without presumption, that I am allowed to take the view that my turn has come and I am now asking you to think of me when a post, for which I am qualified, is vacant.

I will not set myself up as a judge concerning my achievements in teaching. Allow me to recall merely the fact that in the space of five years, eight doctoral theses, born of that teaching, have been defended in Bordeaux by Messrs. Monnet, Pélabon, Marchis, Turpain, Saurel, Lenoble, Chevallier, and Caubet. Mr. Saurel came from New York to follow my courses. Nor shall I myself evaluate my scientific publications. In the single year of 1900 the Jagellonian University of Cracow, by conferring on me an honorary doctor's degree on the occasion of its fifth centenary, the Société hollandaise des Sciences de Haarlem, by awarding to me the title of foreign associate, finally the Académie des Sciences, by naming me a correspondent in the section of mechanics, rendered to my scientific work a recognition which you no doubt would judge sufficient.

What helped me to expect until now that you yourself would open a chair for me in the capital, was my strong desire to make myself useful at the University of Bordeaux and to its Faculty of Sciences. In the University Council I have supported a large number of initiatives and had the joy of contributing to the success of several of them, until the day when the unexpected and unjust rudeness of Mr. Bizos forced me to leave the Council. As member of the Faculty I have never ceased to multiply courses of all sorts well beyond my professional duty, to propagate a large number of doctrines which have never before been put into the curriculum, and to stimulate the zeal of our young assistants. Today, I am obliged to register painfully that my efforts would be henceforth in vain and that the Faculty of Sciences in Bordeaux is entering into an irremediable decadence.

Even the student population is rapidly disappearing. This year Mr. Marchis and myself had to give all our courses for licence before a single student and we do not know if the next academic year will not find us before empty benches.

If at least in the absence of candidates for licence and agrégation we would still have the possibility to press our laboratory chiefs towards the doctorate! But those whose brains, void of ideas, could never germinate a thesis, think only to stop the impulse which is given by some of us.

Yesterday, some of our laboratory chiefs – doctors and charged with giving complementary courses – asked to be granted the title 'chargé d'un cours complémentaire' which, without increasing their salary, would have permitted them to enter at least officially into the teaching body of the Faculty. At their head was Mr. Caubet, whose physics courses are one of the mainstays which prevented the P.C.N. [survey courses in physics, chemistry and natural sciences] from collapsing. Mr. Caubet has recently defended a thesis of great importance and his defense of it was exceptionally brilliant. The Faculty Council, in spite of the efforts of some of us, did not even want to examine the qualifications of these gentlemen, and decided that there should be no attempt at introducing new members into the Faculty Assembly.

This vote, dictated by selfish electoral considerations, has made to overflow my disgust which the actual state of the Faculty of Sciences in Bordeaux provokes in me. That situation made me decide to turn to you and ask you to provide me with a theater where my activity may produce some useful effect before that activity is killed by discouragement.⁹⁴

94. For the printed text, see *Un savant français*, pp. 119-24. Duhem's emphasis on 'his turn' was part of a social understanding which forms the material for chapter 22, 'Gerontocracy,' in T. Zeldin's *France 1848-1945* (Oxford: University Press, 1973-77). Tellingly, the next chapter there is entitled, 'Hypocrisy.'

Such was not a letter that could be answered with ease. Liard must have felt all the more uneasy, as by mid-1901 the creation for Durkheim of a chair of sociology in the Collège de France was in the making. Durkheim, a former Normalien and Duhem's senior by only four years, was to advance shortly to Paris from Bordeaux. Liard, who could not assure Duhem of the same advancement, took the easy way out by derailing an essentially academic matter to the field of politics. He obviously had no courage to face the heart of the matter — politics, though not its ordinary kind which had nothing to do with the question of scientific truth. The political views of Duhem were not of course of help in 1900. Nor was his frankness about them an advantage. Trapped in an idealized view of his beloved France, he came to dislike any trend that seemed to be in conflict with it, either by intent or practice. As to the French Revolution, he often spoke of Taine's famed analysis of it as being his own view. He conspicuously failed to see that the selfishness, which Taine took for a specific mark of French youth in the closing decades of the 19th century and for which Taine blamed the Revolution, could easily be said about the youth of almost any decade, provided one readily overlooked evidence to the contrary.⁹⁵ Yet, sympathize as he did with the cause of the Duc de Chambord, he had no use for aristocratic mannerisms. He saw little merit in universal suffrage, yet he viewed the university system threatened when an open discussion of all matters of common interest was curtailed. Though an avowed opponent of socialism, he gave touching evidence of his concern for the poor and underprivileged. He admired the unselfishness of such stalwarts of Christian socialism as Marc Sangnier and Goyau, but was also convinced that the ideology of *Sillon* and of other publications of the movement was contradictory. He used to tease young Sillonists selling copies of *Le réveil démocratique* at church doors with the remark, 'Why don't you sell 'Le sommeil démocratique'? Then I would immediately buy a copy.' Yet, he was generous with his time and advice when they came to him for solutions to this or that 'scientific objection to Catholic dogma' as they prepared a popular debate or lecture.⁹⁶ Devout Catholic as he was, he was wont to dismiss Leo XIII's policy of rapprochement toward the Third Republic with the remark: 'When even the rats leave the ship, Catholics board it.'⁹⁷ His private comments about the strict measures imposed by Pius X on Catholic intellectuals may not have been any more flattering.

A small speech as a big crime

Duhem's summary indictment of the Third Republic can only be explained in

95. See *Un savant français*, pp. 129-30 and H. Taine, *Les Origines de la France contemporaine*, Vols. 5-6, *Le régime moderne*, Tome II (Paris: Hachette, 1894), pp. 294-97. Taine's grand conclusion, which could but please Duhem, was that for the past fifteen years, that is, since the Republican takeover in France around 1880, the youth's behavior amounted to the declaration that *égalité, liberté, fraternité* should be taken for sheer rhetoric. For a massive portrayal of such and similar symptoms, see K. W. Swart, *The Sense of Decadence in Nineteenth-Century France* (The Hague: Martinus Nijhoff, 1964).

96. *Un savant français*, p. 127. Duhem's parish, St. Eulalie, had many Sillonists.

97. *Ibid.*, pp. 140, and Jordan, 'Duhem,' p. 162.

the light of his idealization of the past and it is in that light that his sympathy for the right-wing Action Française and his anti-Dreyfus stance ought to be seen. His modest though quick contribution to the appeal of Drumond's *Libre parole* for legal funds on behalf of Colonel Henry's widow, who wanted to prosecute a chief Dreyfusard, should seem less reprehensible than the opposition over years of many left-wing politicians to the re-opening of the Dreyfus case. What Duhem wanted above all was to vindicate the honor of the French Army which for him meant the honor of France. A moving summary of his vision of France, in which Army and traditional Christian culture were thoroughly fused, is the speech, a mere thousand words, which he delivered on June 25, 1899, as president of the annual banquet of the alumni of the School and Institute Sainte Marie in Bordeaux, an establishment run by the same Marianist fathers who educated him in the Collège Stanislas:

My dear Camarades,

You will allow me to address you with this word because, even though we did not study in the same benches, we have been formed by the same teachers and it is to this common education, a firm assurance of common sentiments, that I owe the honor of presiding over your festive reunion.

Indeed, the influence of the great moulders of men who have distinguished the Society of Mary made its impact on all of us; although in different places, that influence has implanted in all of us the same principles capable of maintaining forever the harmony of our thoughts and the unity of our efforts. At this hour when the winds from the four corners of the world blow divisiveness and hatred, it is appropriate to point out clearly the ties which unite us into a closely knit alliance.

We admire, we love, we serve the same things and these things are the ones which are symbolized by the blazon of our Collège Stanislas.

You are familiar with that blazon: one half of it is occupied by a book, the other half by a knight armed from top to toe; joining the two is the emblem of France.

The book stands for all the truth, beauty, and goodness produced by the thought of all peoples and centuries, but especially for the products of the minds of the Greeks and Romans – educators of our national genius and especially of the French way of thinking, which is the clearest, most precise and most logical, and at the same time, the most humane way of thinking in the modern world. This is what our teachers have in the first place taught us to savor. Their efforts have not been sterile. From the moment they have given a Sainte-Claire Deville to the world of science to the day they explained *Cid* to the future author of *Cyrano de Bergerac*, they have launched a good number among us into those peaceful conquests of the intellectual world which increased France by making larger the possessions of mankind.

Beside the book there is the knight well set on his charger, his sword drawn. What was seen in him by the ardor of our eighteen-year-old ones, was not the brain of a France with clear ideas but the strongly beating heart and the boiling blood of France, the Army.

The Army! I cannot pronounce this word without seeing again at my side absorbed in silent study camarades and friends who prepared by severe efforts for the honor of carrying the sword: A Berger, who in Tonkin would unite his blood with that of Négrier; a Duchâtelet, who would enter Tananarive on the side of Duchêne; a De Planhol, who exhausted by fever would collapse on the burning sand to die there as died the valiant knights at Tunis in the time of Saint Louis.

When these, on their first leave from St. Cyr, walked across the courtyards of the Collège Stanislas, proud of the brand new cassowary plumes which clapped on their

shakos, there were in those courtyards others, their juniors, who vowed to imitate and outdo them. Among them were Gourand, who was to lay firm hold on the unconquerable Samary, and Barattier, loyal aide of Marchand in that expedition which could make jealous the ten thousands of Xenophon if jealousy were not the lot of the living.

Between the book and the knight is the emblem of France as if to vivify by the same breath, as if to fuse in one single idea and in the same love every field of science, every beauty of literature, all bravery of the Army. How well placed were, in the center of our blazon those three white lilies against an azure field, symbol of an education in which everything tended to make us know and love France in each of her soil's regions, the France of Clovis and of Charlemagne as well as the France of Saint Louis and Joan of Arc, the France of Henri IV and of Louis XIV as well as the France of Napoleon, the France victorious at Valmy and Iena as well as the France murderous at Saint-Privat and at Patay.

To know and to love one's country is something but not all. It is necessary to serve it and to contribute effectively to its prosperity and glory. Our teachers knew this and sought to make us men capable of accomplishing this task without fail.

They wanted us, first of all, to be men of initiative. To have initiative is not merely to propose a target for one's activity. Initiative consists above all in keeping one's will firm in the teeth of adversities, temptations, and discouragements along the way one has chosen. Initiative consists in obeying for a whole life the order which one has imposed on oneself. Therefore, in order to learn how to use our will, our teachers taught us to obey; they bent us along the lines of discipline – without which the will becomes caprice – strict, exact, specific discipline, but a discipline accepted loyally and gladly, because it was right, steady, free of surprises and sudden moves, especially because those who imposed it upon us have assumed a stricter yoke and preached by example.

In the life of a man of initiatives there are grave hours, hours when he has to choose between happiness and mission, hours when he has to sacrifice himself. Our teachers foresaw those hours and inspired in us the spirit of sacrifice. Spirit of sacrifice! What a sense these words had assumed when they fell from the lips of the Abbé de Lagarde as he let a lightning flash from under his eyelids, already half closed for the grave, when he stiffened for a moment his body bent much too soon and ravaged by the unspeakable pains of cancer!

Cult of science and letters, patriotism, spirit of discipline and of initiative, spirit of sacrifice – to let these sentiments germinate and grow in us our teachers relied on the help of the One who reinforced the heart of man. In every truth, and beauty, they showed us the reflection of eternal Truth and of a supreme Beauty. In the annals of the history of France – of her intellectual history as well as in her military history – they taught us to perceive the gestures – conscious and unconscious – of God's soldiers. To bend our excesses under the yoke of discipline, they taught us that all authority comes from God; to kindle in us the spirit of sacrifice, they constantly set before us the image of the Crucified God. To give France 'Frenchmen without fear,' they exerted themselves to give the Church 'Christians without blame.'

My dear comrades, I hope to have faithfully traced the characteristic features of the education we have received. If we have come together today, it is to assert that we are proud of having received that education, to acknowledge that the experience of life has made us understand its price increasingly every day, and to thank those to whom we are indebted for it. It is on this note of gratitude that I want to end. I raise my glass in honor of our teachers, priests and brothers of the Société de Marie, and in order to make our homage more concrete, I propose two toasts: one in honor of the one whom I saw in the days of my childhood directing my seniors at Stanislas and whom I see today preside with so much vitality over the frolics of the children of Sainte Marie, to our dear Mr. Héral; – the other to the one who directs so actively Sainte Marie, our Ștanislas of the Southwest, to my fellow student, the Abbé Bernard.

This speech, published in *Le Nouvelliste*, a conservative Bordeaux daily,⁹⁸ is important not only as a mirror of Duhem's inner sentiments but also as an incident on which Duhem's chief antagonists in Bordeaux eagerly seized to present him to authorities in Paris as an active enemy of the Republic. In the land of a Revolution which enshrined free speech, innocent rhetoric was now a crime. The chief of Duhem antagonists was none other than Georges Bizos, Couat's successor as rector. Although poles apart from Duhem on the ideological spectrum, Couat always did his best to keep in focus Duhem's undeniable merits. Only two months before his sudden death on July 21, 1898, Couat sent to Paris this confidential report:

Duhem's scientific valor is too well known that I should recall it once more. Well known is also the independence, perhaps slightly extreme, of his character. I would rather insist on his complete devotion to his students and on the outstanding service which he renders thereby to the Faculty of Sciences by preparing for the schools useful physicians and scientists.⁹⁹

The dean, although noting Duhem's 'fearlessness to speak his mind,' attested Duhem's 'irreproachable conduct.'¹⁰⁰ Clearly, whatever his ideology, Duhem qualified as a first-rate civil servant in the Republic. This way of looking at him presupposed an elementary measure of fairness. In its absence he appeared a dangerous threat to rabid Republicans, such as Bizos. His first confidential report on Duhem spoke for itself. Bizos took an emphatic exception to the dean's description of Duhem 'as an integer character; rather combative.'¹⁰¹ Brunel, though a friend of Duhem, was not blind to his shortcomings, one of which was Duhem's unsuitability for administrative posts, which Brunel flatly noted. But, according to Bizos, Brunel was

rather indulgent in his appreciation of a man who is violence itself. I think that whatever Duhem's scientific merits, a University which employs him has in him a continual and dangerous source of discord. Very convinced of his superiority Duhem acts and speaks indiscriminately, not sparing either his superiors, whom he treats as enemies, nor the most illustrious masters of French science among whom he counts himself on every occasion, nor those among his colleagues who resist his dominating attitude, nor especially those students who do not belong to the Catholic and antirepublican coterie of the Ozanam circles. Imbued to the most extreme fanaticism with clerical ideas, Mr. Duhem is above all an ultramontane militant of the most violent kind.¹⁰²

No wonder that Bizos began to fulminate on reading Duhem's speech in the *Nouvelliste*. Bizos, who must have felt defeated in November 1898 when the Conseil d'Université went on record in support of Duhem, now saw his opportunity.

98. Mercredi, 28 juin, 1899, p. 3, cols. 4-5.

99. Dossier Duhem, p. 94.

100. *Ibid.*, p. 92.

101. *Ibid.*, p. 83. The dean added that Duhem was 'ready to devote himself at any moment to his students.'

102. *Ibid.*, p. 86.

He drafted a letter, in which he denounced to the Ministry of Public Instruction Duhem's speech as a flagrant breach of professional duties and a prime example of a violently antirepublican clericalism, and asked Duhem to state his case. In his reply to Bizos' charge Duhem insisted that an alumni association was a private affair which he, professor or not, was free to attend as a citizen.¹⁰³ Bizos had different ideas about the kind of 'liberté, égalité, fraternité' to which a State employee of the Republic was entitled. Nor could he be unaware of the potential usefulness of his action for some in the Ministry who lent their obedient support to the campaign which Berthelot waged from behind the scene against Duhem. Bizos wanted to deserve well of the Republic as he wrote:

Monsieur le Ministre,

Mr. Duhem, professor at the Science Faculty, sends you along the official channel the copy of *Nouvelliste* which contains the printed text of the speech he delivered while presiding over the [reunion of the] Association of the Alumni of the School and Institute of Sainte Marie. He believes that in delivering the speech he did not exceed his rights, but that what he did is in conformity with his devotion to the University. He states this opinion of his in the letter here attached which contains a copy of the page in question of the *Nouvelliste*.

In my opinion Mr. Duhem is strangely mistaken and in addressing to you this letter he gives you a new example of his state of mind.

1. Though it is true that the Collège Stanislas in Paris is an institution attached to the University system, the schools run in the provinces by the Marianists are everywhere the rival of our lycées and of our colleges. They are maintained by all the forces of the political and clerical reaction. In Bordeaux the school of the Marianists is for us more threatening than the Collège of the Jesuits. The sectarian clientele of the Jesuits never would come to us. The clientele of the Marianists would be ours if the Marianists were not there. The hardest blows are delivered against us by the Marianists. Also, it is in our lycées and collèges that the struggle is waged against the close rapport which exists between Mr. Duhem and the Marianists and which now comes so forcefully to light. The entire situation shows one thing, namely, that their students must not have Mr. Duhem for examiner . . .

2. Mr. Duhem admits that it was with his permission that his speech was published in a Bordeaux newspaper. The paper is the *Nouvelliste*, which pours every day floods of intrigues on the Republic, on the Head of State, on the members of the Government, and on those members of the Higher Education who are known to foster liberal ideas. I do not speak of the Rector. He is a main target of that paper. Respectfully . . .¹⁰⁴

Needless to say, as long as Bizos was Rector, he every year described Duhem as a violent person, a firebrand, a threat to the Republic, a militant Catholic, always ready to hurl anathemas at those disagreeing with him. At one point Bizos even questioned the soundness of Duhem's reputation as a scientist of first rank by beginning his report with the question: 'Is he the great scientist which he proclaims himself to be, surrounded by thurifers, for he knows how to have them around and whom he sways by eagerly providing support for them?'¹⁰⁵

That in his confidential reports on Duhem Bizos did not make a reference to

103. *Ibid.*, pp. 167-68.

104. *Ibid.*, pp. 165-66.

105. April 20, 1901; Dossier Duhem p. 78.

the alleged role of Duhem at the funeral of Couat, on July 24, 1898, has its partial explanation in the fact that at that time and for some years after the government was on the side of the Army in the Dreyfus affair. The major reason seems to be the fact that Duhem did not play that prominent role which is assigned to him in that respect in his biography by his daughter. According to that account, Duhem, on hearing Stappfer, dean of the Faculty of Letters deplore in the presence of General Delavigne, commander of the Army Corps in Bordeaux, the Army's attitude toward Dreyfus, Duhem stopped the speaker short with a loud 'enough,' walked to the General, shook his hands and immediately left the cemetery at the head of several faculty members. He led them again next day to the General's headquarters to assure him of their indignation over the dean's remarks.¹⁰⁶ There is no reference to Duhem in the accounts which the Bordeaux newspapers gave of the lavish funeral and of the incident.¹⁰⁷ Merely a group of faculty is mentioned, together with the report that after the funeral services in front of St. Bruno's church facing the cemetery were over, the majority of the Faculty of Letters gathered for an impromptu meeting to disassociate themselves from Stappfer's remarks. Again, there is no reference to Duhem in the reports concerning the march of some Faculty to the General's headquarters.¹⁰⁸ Duhem may have of course been the first to make the cutting remark, 'Half a year of paid vacation for having insulted the Army!'¹⁰⁹ following the news that Stappfer was suspended for six months by the Ministry from his duties as dean.

Making a stand in defense of France's honor as Duhem saw it to be his duty is probably the best explanation of several of his rather harmless actions which had

106. *Un savant français*, p. 131. H  l  ne Duhem mistakenly wrote Delavigne instead of Varaigne.

107. The most detailed account was given in *La Gironde* (Monday, July 25, p. 2), where the generals Varaigne, Lebrun, and Maleper are mentioned. In his speech, reported there in full, Stappfer compared Couat to the great Stoic, Marcus Aurelius, who bravely and quietly faced adversities. It was in that perspective that Stappfer concluded with a reference to Couat's silence about Dreyfus, a silence forced on Couat, the civil servant, but which pained him much.

108. According to *La Gironde*, 'an incident, unnoticed by many, took place when people began to return home. A group of professors decided, following Stappfer's speech, to walk to General Varaigne and express to him their loyalty to the Army. Very kindly General Varaigne answered that he did not find anything in what had taken place that would irritate and concern the Army' (loc. cit.). The account in *Le Patriote* ('a political and literary weekly, absolutely independent' according to its masthead) was rather different: 'This unexpected conclusion [in Stappfer's speech] did not fail to create emotion among those present . . . Very significant protests, although somewhat subdued in deference to the sacred place, were heard. Several professors present decided to express immediately their sympathies and regrets to General Varaigne' (Saturday, July 30, 1898, p. 1). The *La Gironde*, which gave verbatim the statement of the Faculty of Letters that Stappfer spoke only on his own behalf, reported to have learned that other Faculties too delegated some of their members to go to the Army Headquarters to express their sympathy (loc. cit.). In the Monday, July 25, issue of *La Petite Gironde* (p. 2, col. 4) it was reported with obvious satisfaction that no speeches were given in La Rochelle where Couat's body was laid to rest.

109. *Un savant français*, p. 131. Stappfer's suspension came immediately. On Saturday, July 30, *Le Patriote* commented: 'This decision will cause more satisfaction than surprise.'

the appearance of an extremist political stance. The animated tone with which he discussed matters dear to him and events which stirred public passions everywhere in France could further create the impression that he was deeply engaged in politics. Such a tone characterized Duhem's conversations with his mother at dinner and was vividly remembered by his young daughter,¹¹⁰ though she could hardly understand much of what had been discussed. Madame Duhem, it is well to recall, was an ardent royalist and fond of going back in thought to the *ancien régime*. In the shaping of Duhem's political views some role may have been played by his deep respect and deference toward his mother. But beneath the apparent extremism of his 'political' actions there lay an almost childlike innocence. This was well put into focus by his friend E. Jordan as he commented on Liard's charges that Duhem's politicking was the cause of his failure to obtain a chair in Paris:

In a sense the charge is absurd, in another it is understandable that one could be taken in by it. No one had a greater horror than Duhem did of the professional occupations of politicians, of electoral campaigns, or of journalism. I would even say . . . that one of his startling characteristics was to have no political opinions. I have seen him follow with sympathy the political start of our fellow Normalien Goyau.¹¹¹ Duhem had good friends in the ranks of Christian democrats. One cannot say, to be sure, that he belonged to it, or to any other party. His statements would have quickly discomfited anyone intent on classifying him. I think he was much too absorbed in his work not to consider as a loss of time the effort necessary to form considered judgments in matters political. When his instincts of patriotism, justice, freedom, and honor were, rightly or wrongly, contravened, a sort of reflex reaction touched off on his part all too lively manifestations and all the more so as vivacity was part of his character. He was fond of journals of polemical tone and was pleased, either in others or in himself, with all forms of resolute stance.¹¹²

To engage in contest with others was a natural necessity for Duhem, a born fighter. With him a reference to the Darwinian struggle for life was no mere rhetoric, but an acknowledgment of a reality which he saw predominant not only in the biological realm, but also in the realm of ideas. Just as he loved to battle the waves and winds around the Ouessants, so he relished banterings and disputes. The prospect of running short of opponents would have disheartened him. He wanted for everyone in the academe the same freedom of speech which he demanded for himself. In that very fundamental sense he was a liberal and a democrat, and far more so than those professedly liberal democrats of the French academic world who lent their ready assistance, especially in the years of the Combes cabinet (1902-05), to a radical Gleichschaltung of the faculties of French lycées and universities, to say nothing of the suppression of over thirteen thousand Catholic elementary schools and of the exile into which tens of thousands of religious, men and women, were forced. A story, which Duhem loved to recall to his friends,

110. *Un savant français*, pp. 130-01.

111. The Christian social concerns of Georges Goyau (1869-1939) were carried far and wide mainly through his analyses of the history of the Church in modern times, of which the nine volumes of his *Allemagne religieuse* (1898-1913) were the first major installment.

112. Jordan, 'Duhem,' p. 162.

best illustrates how far he was, in spite of all his ‘royalism,’ from the thinking characteristic of the *ancien régime* and of any of its latter-day wishful restorers. Or as Jordan reminisced about his friend:

I have heard him recount that in a university, I don’t remember which, a circular imposed, in the days of ‘good morality’ [the early years of MacMahon’s presidency, 1873-80] on all the professors the duty to assist in academic robes and in a body at the Corpus Christi procession. Some of them, freethinkers, were shocked, but too timid to protest. One of their colleagues, well-known for his Catholic convictions, saved the situation by volunteering to write a letter of refusal in the hope that while public knowledge of his own convictions would protect him, he would effectively serve as a lightning rod on behalf of the others. Duhem, very much a Catholic, greatly admired this attitude and I am convinced that he would have done similarly if occasion arose. Also, he never resented even on the part of his best friends if they thought otherwise than he did on questions which impassioned him most. Finally, having always most unselfish sentiments, he did not have the slightest difficulty in espousing, when circumstances demanded, ‘the sacred cause.’¹¹³

In a clash for a sacred cause

Science was for Duhem such a sacred cause, hardly a crime if Galileo, Darwin, Freud and many others deserve perennial accolades for their devotion, in the teeth of much opposition, to the cause of science as they saw it. In fact, so sacred was that cause to Duhem – who, it is well to recall, chose physics as his life career after having been seized as a youth by an ideal view of it – that he never recoiled from taking great personal risks for that cause. On the part of those who, whatever their prominent standing in the academic world, were no match for his arguments, nothing was more natural and convenient than to brand Duhem’s campaign as the ‘politicking’ of an upstart. The campaign could be expected to dissipate itself before too long if denied a proper sounding board. Such seemed to be a fair expectation in connection with the most pointed salvo of that campaign, Duhem’s thirty-page-long critical essay on the two massive volumes of Berthelot’s *Thermo-chimie*, published in 1897.¹¹⁴ Not that the *Revue des questions scientifiques*, which carried Duhem’s essay,¹¹⁵ was in itself a negligible organ. But since it was a Catholic organ, it could be hoped that few would take notice outside its mostly Catholic readership. The motto, ‘Catholica non leguntur,’ was a guideline of intellectual respectability in Renan’s France and in Spencer’s England no less than in Harnack’s Germany. Of course, the motto often meant not so much a studied ignorance as a systematic scorn, expressed mainly through silence which, however, was not easily applicable to matters strictly scientific and especially when voiced with an already international repute. Brief and approving accounts of Duhem’s essay appeared abroad, as will be seen, in leading scientific periodicals. Berthelot therefore could not ignore the review whose devastating force he must have fully

113. *Ibid.*, pp. 162-63.

114. *Thermo-chimie. Données et lois numériques* – Tome I. *Les lois numériques*. – Tome II. *Les données expérimentales* (Paris: Gauthiers-Villars et fils, 1897).

115. 1897 (5).

perceived. Otherwise, he would have tried three years later, in 1900, to throw a roadblock against Duhem's election as a corresponding member of the Académie. He was tactfully absent on the day of balloting.¹¹⁶ A few years later, when Duhem was considered for promotion in professorial ranking, Berthelot voted for him and remarked: 'Here only Duhem's scientific merits ought to be considered.'¹¹⁷

In spite of having grown aware of Duhem's scientific triumph over him, Berthelot could not bring himself to acknowledge this to the extent of letting him obtain a chair in Paris. At stake was the renown of the theoretical interpretation which Berthelot gave to his vast and most valuable experimental researches. It was all too human of Berthelot to protect that interpretation from Duhem's devastating criticism which, if delivered from a chair in Paris, would have forced Berthelot into the open. Herein lies the clue to the slighting which affected Duhem for thirty years, from his first doctoral dissertation to his very death, that is, his whole academic career. Without a careful look at it a presentation of Duhem's life would not appear that poignant drama which it actually was. The slighting was nowhere more evident than in a lengthy statement which Berthelot made on the principle of maximum work and entropy in the June 18, 1894, session of the Académie des Sciences¹¹⁸ and in Berthelot's refusal to dignify Duhem to as much as a word of reply when three years later Duhem took up the dispute between them in a formal way. Duhem's long delay in calling for a major clash suggests in itself that a personal triumph was not his aim. Rather, the publication in 1897 by Berthelot of his massive *Thermochimie* convinced Duhem that the cause of science, a cause sacred to him, called for a clash.

That Berthelot was not equipped to join a clash set up by Duhem with a consummate command of theory as well as experiments was a foregone conclusion. Berthelot's statement was a sequence of reasonings which shows a prominent man of science withdrawing behind the facade of equivocation where he traps himself in the pathetic stance of a scientific blunder. Berthelot did his best to conceal his emotions which clearly blinded him to the obvious. He spoke condescendingly of those who are lost in the 'formulae of mathematical physics' and who wanted 'for good reasons or bad, to force the endless varieties of chemical phenomena into the absolute framework of a mathematical formula.'¹¹⁹ Such a remark could only be aimed at Duhem. Among the very few in France who dared to criticize Berthelot's work, only Duhem did so in an open and sustained manner and with the latest and best weapons of mathematical physics. In defending once more his formulation of the maximum work principle as being not only independent of that of Thomsen's publications, but also far superior to them, Berthelot should have made a reference to Duhem's *Introduction à la mé-*

116. *Un savant français*, p. 148.

117. *Ibid.*, pp. 148-49. For further details, see Ch. 6.

118. 'Le principe du travail maximum et l'entropie,' *CR* 118 (1897):1378-92.

119. *Ibid.*, p. 1383. Three pages later Berthelot identified the formula as $\int dQ/T$, the well known expression for the increase of entropy. His chief objection against its universal validity was that at absolute zero temperature it would imply infinite entropy which he considered meaningless from the viewpoint of physicists or chemists. An extraordinary objection indeed!

canique chimique in which a very strong case had been made to the contrary in both respects.¹²⁰

Equally vulnerable should seem the effort by which Berthelot tried to make it appear that his opponent, whom he reduced to a nameless entity, had largely misunderstood the issue at stake. By 1894 the quality and quantity of Duhem's work could readily discredit such a tactic in the eyes of anyone modestly familiar with that work. But Berthelot could still count on the loyalty of his 'princiate' to lend a tacit support to two claims, both pivotal in Berthelot's argumentation. According to one, there was a strict distinction between chemical and physical processes, a distinction through which Berthelot hoped to ward off the ominous specter of a thermodynamics based on the principle of entropy. His other claim was no less a scientific blunder. The unsparing tools of the psychoanalysis and sociology of science would only help understand how in 1894 it could be claimed from the chair of a perpetual secretary of the Académie des Sciences, and without provoking so much as a murmur of dissent, that 'the principle of entropy cannot be rigorously defined in the actual state of our knowledge except in a purely mathematical sense,' and that 'in the physico-chemical sense, which is often the case when one applies the definitions of pure thermodynamics to the real mechanisms of physical phenomena, the entropy is an obscure notion and an unknown quantity, inaccessible to experiments in the greatest number of cases, and whose definition casts very little light on the prevision and interpretation of the preponderance of chemical phenomena.'¹²¹

Berthelot was then forced to make a pathetic appraisal of his whole work in chemistry as he could not deny that entropy played an obvious and essential role in all cases of chemical dissociation. Nor could he deny the fact, except by passing it over in silence, that Duhem had already established himself, through half a dozen memoirs published during his years in Lille, as a leading authority on this topic and certainly as the foremost authority in France. The only shield Berthelot could now find was lame rhetoric: the cases of dissociation, he declared, 'escape the grip of the primitive formulation of the principle of maximum work.' Actually, all those cases contradicted that principle and made it appear a very primitive error indeed. This was unwittingly intimated by Berthelot's further remark: In the process of dissociation there is 'a fundamental aspect of the problem, developed, since my first researches on chemical analysis, through the work of Gibbs and Helmholtz on non-utilizable energy. An entire realm of new and essential notions arose from it.'¹²² This emergence of essentially new ideas is, Berthelot declared,

not a reason as some pretend in a facile manner to deny the importance and even the existence of previous laws verified by the observation of facts. These laws are in no way destroyed, but are merely modified in a part of their interpretation and remain indispensable for a general understanding of the phenomena . . . The discoveries of science form a continuous chain. The facts and positive relations established today in thermochemistry cannot be overthrown, although susceptible to further development

120. 1893 (1). See especially ch. 4, 'Le principe du travail maximum.'

121. 'Le principe du travail maximum et l'entropie,' p. 1385.

122. *Ibid.*, p. 1392.

by the introduction of new concepts and facts; such was the conclusion [in 1879] of my *Essai de mécanique chimique fondée sur la thermochimie*. Everyone should only wish a similar progress and applaud it.¹²³

Such was a hollow call for applause born out of a shallow view of scientific progress. As a pioneer in publishing Lavoisier's laboratory notebooks, Berthelot himself argued that instead of perfecting the chemistry of caloric, Lavoisier's chemistry had discredited it once and for all. To imply the contrary, namely, that no essentially wrong notions have ever been proposed in the course of history, was to advocate an utterly naive notion of the continuity of scientific progress. Such naiveté, as will be seen, was explicitly combatted by Duhem for all his advocacy of genuine continuity. At any rate, Berthelot was soon to provide a monumental intimation that nothing of the principle of maximum work could be salvaged. The intimation consisted in the two massive volumes of Berthelot's *Thermo-chimie* and in the ambiguously muffled applause which greeted its publication.¹²⁴ Duhem was the only one daring enough to spell out the bare truth in all its details.

Duhem first noted that the *Thermo-chimie* was in a sense a second edition of the *Essai* with one big difference, however. In the former, all data were interpreted in terms of the maximum work principle, whereas the principle was not mentioned in the latter, a work of over 1600 pages, except for its first chapter. In fact, apart from that first chapter, the work contained only a vast series of data with no theoretical interpretation. What Berthelot presents us, Duhem wrote, 'is not the edifice, enlarged and transformed, which his former work was. He had completely disassembled the edifice. He kept only the materials which, although he reshaped them and increased their number, he did not put together. It seems that the fragility of the first construction evoked in him an insurmountable diffidence with respect to any new effort to assemble the data of thermochemistry.'¹²⁵

The first construct was meant to be a fortress for its architect so that he might dominate from it the whole realm of chemistry. In a sense, and in France at least, Berthelot had success, a story, which thanks to Duhem's courage, was now put in print in its salient aspects. In essence, Berthelot's influence was powerful enough to stifle a flourishing work on the process of dissociation, a work initiated by Sainte-Claire Deville at the Ecole Normale and continued there by Debray, Troost, Hautefeuille, Isambert, Gernez, and Ditte. In the course of that work it was found that the distinction established by Thomsen and Berthelot between exothermic and endothermic reactions, a distinction on which the principle of maximum work rested, was contradicted by an increasingly large number of observations. An important generalization of these findings was in 1876 proposed by Moutier who, though not of the Ecole Normale, had a liberal access to the laboratories there. According to that generalization, of two inverse reactions that is exothermic which

123. Ibid.

124. Otherwise, M. P. Crosland, an admirer of Berthelot, would have hardly fallen in the trap of unwittingly damning with faint praise, which is carried by his sole remark about the *Thermo-chimie*, namely, that it suggests 'Berthelot's continuing interest' in the subject. See his article, 'Berthelot' in *Dictionary of Scientific Biography*, 2:69.

125. 1897 (5), p. 362.

takes place at high temperature, whereas the contrary process at low temperature is endothermic. 'Moutier died ignored and his name would have never been uttered by those who wrote on chemical static if the disciple, whom he formed and to whom he had carefully communicated the very depth of his thinking, had not seized every opportunity to proclaim his master's titles for fame.'¹²⁶

Yet the correctness of the new thermodynamics could forcefully be intimidated by its rediscovery and further development abroad by no lesser figures than Horstmann, Gibbs, Helmholtz, and Van't Hoff, whose major attainments were now recited by Duhem. As to France, Duhem was alone in trying to keep alive the torch almost extinguished by the silent treatment imposed on it by Berthelot. But, Duhem recalled, with reference to the reception accorded to his *Le potential thermodynamique*, 'nothing was missing in that reception to discourage a beginner.' It then became clear to Duhem that since Berthelot's thermochemistry enjoyed an unquestionable authority in France and no work, unless inspired by it, was to be given a hearing, 'the first task of anyone who wanted the new thermochemistry to triumph, was to make room for it by just dismantling from top to bottom the principle of maximum work.'¹²⁷ Such was the aim of his small book, *Introduction à la mécanique chimique*, published in 1893. Duhem summed up the major points made there together with the devastating remark that 'in order to escape the grip of experimental evidence the third principle of Berthelot's thermochemistry has taken on a variety of forms; but in order not to be strangled by the ironclad logic of Deville, it was forced to vanish in a ridiculous tautology.'¹²⁸

Duhem then surveyed the main points of Berthelot's long statement, obviously prompted by his *Introduction*. His conclusion minced no words: 'Such are the ramparts of [Berthelot's] thermochemistry. In each of them a wide breach is gaping.'¹²⁹ Berthelot's reasons for a sharp distinction between chemical and physical processes were nothing short of being futile and self-defeating. Were not, Duhem asked, allotropic, isomeric, and polymeric transformations becoming in Berthelot's hands 'so many jacks of all trades which move from physics to chemistry and back at a mere handwaving?'¹³⁰ Duhem illustrated the point with a concrete example (sulfuric ozone), and concluded that Berthelot's defence of the principle of maximum work flew in the face of elementary logic. 'A physicist who had best studied that part of Berthelot's work,' Duhem recalled, 'told me once that with such reasoning one can prove anything one wants to.'¹³¹

126. *Ibid.*, p. 365.

127. *Ibid.*, p. 368. In disputing Berthelot, Duhem almost invariably referred to Berthelot's reasonings as set forth in the introduction and first chapter of *Thermochimie*.

128. *Ibid.*, p. 370. There Duhem also spoke of the 'incontestable priority' of Thomsen over Berthelot.

129. *Ibid.*, p. 371.

130. *Ibid.*, p. 374.

131. *Ibid.*, p. 376. This physicist may have been Moutier himself, whose inability to advance in spite of a long list of excellent publications could hardly be an accident.

No different was the case with Berthelot's proviso that his arguments considered only the transformations at constant temperature, 'a point often poorly grasped by some.' Duhem now felt entitled as if attacked directly and at a most pivotal point (his prowess in logic seemed to be at stake), to address his words to Berthelot himself:

Excuse me, Mr. Marcelin Berthelot, I have perfectly understood you. I have understood that you did not count the calorific energy among external energies except in a way of defense. I have understood that such an escape hatch, of which you have availed yourself in a desperate cause to avoid the grip of facts discovered by Deville, you would also wish to close right away, because you are too perspicacious not to have seen that the principle of maximum work itself would thus entirely disappear through that opening. But what I have also equally understood was that in such a way logic was not given its due. In order to explain the phenomena of dissociation, one is entitled, according to you, to take the words 'external energy' in the sense of 'absorption of heat.' If these words can take on such a meaning *in this particular case*, your mere wish cannot prevent one from taking them in the same sense *in general*.¹³²

It was easy for Duhem to marshal experimental evidences which made short shrift of Berthelot's proviso. One of them was Pélabon's work on selenohydric acid. Its summary by Duhem came to a close with the words: 'It seems to me that the most rigorous logic could not ask for a more convincing example.' Duhem now gave a glimpse of the logic of Berthelot's possible rejoinder:

I know that Mr. Berthelot has a mind more subtle than does the most rigorous logician. My objection will not embarrass him for a moment. He will affirm – I do not know on what grounds – that liquid selenium is absolutely incapable of combining with hydrogen; that it is first reduced to vapor, a modification which, without embarrassing the principle of maximum work, can absorb as much heat as it wants to, since it is purely physical. Once vaporised, the selenium combines with hydrogen by releasing heat which once more will save the principle of maximum work.¹³³

Why then, Duhem asked, did Berthelot find so much difficulty in admitting that an endothermic combination could take place directly at a sufficiently high temperature, since he did not at any time try to deny the dissociation which at high temperature is undergone by exothermic compounds? Why does he abandon the latter to thermodynamics, while he refuses to do the same with the former? After all, has he not abandoned to thermodynamics many other phenomena, such as allotropic, isomeric, polymeric modifications, then the phenomena of dissolution, and finally the dissociation of exothermic compounds? 'Is Mr. Berthelot afraid that by depriving his thermochemistry of the phenomena of the synthesis of endothermic bodies, he would transform the principle of maximum work into a king without a kingdom?' But, Duhem warned, Berthelot had apparently no such fear, if indeed one was to take seriously the concluding phrase of the first chapter of his *Thermochimie*, a phrase which, if it was not a plain miscomprehension of the entropy function, was indeed a revealing phrase. Duhem asked: 'Should one

132. *Ibid.*

133. *Ibid.*, p. 382.

see in it an admission of defeat, an act of submission to the triumph of thermodynamics? Should one see in it a final pretence of the vanquished, a last bulletin about an unlikely victory aimed at hiding the pains of a rout?’¹³⁴

The rout seemed indeed complete as judged by the almost total absence of references to the principle of maximum work over one and a half thousand pages, the remainder of the book. It was a vast arsenal of experimental data and an important preliminary toward a genuine thermochemistry. Some of its salient results could be likened to the location of the principal peaks on a vast continent. Unfortunately, Berthelot’s thermochemistry provided no means of connecting those peaks, that is, of tracing the continuity of a vast terrain separating them. This complete survey and the establishment of many more data could only be done through a thermodynamics systematically eschewed by Berthelot. To illustrate this contrast Duhem referred to Monnet’s thesis on saline dissolutions: ‘On the work of Berthelot we would write the words, ‘how experimental thermochemistry has been treated until now.’ On Monnet’s memoir, the words, ‘How it should be treated in the future’.’ Monnet’s thesis demanded thousands of measurements, two or three years of fierce work, a prospect which could discourage certain thermochemists. Have they not read, Duhem asked, Berthelot’s own reference to the determination ‘of a great number of physical and chemical parameters which are necessary to make possible the carrying out of an exact calculation of entropy?’¹³⁵

Since they certainly read it, they were the just target of Duhem’s broadside: ‘It seems that this mass of experimental research demanded by the new chemical mechanics is for many the real reason which forces them to reject without any further examination this doctrine whose foundations they do not dare to contrast. These fools, who prefer to let error lull their indolence rather than to contribute, after a hard effort, to the triumph of truth! They will not prevent the truth from triumphing, but they will force it to triumph against them.’ In order to vanquish them Duhem had to challenge their leader Berthelot, as David once confronted Goliath. Berthelot certainly looked a giant, but a saddened one, if one carefully read the Preface to his *Thermochimie*, possibly the last major feat of a career not only very long, but in all appearances an uninterrupted chain of triumphs. In France, Berthelot was not only the recipient of the highest scientific distinctions, he was also given a most powerful influence over all branches of education, he was called to important political posts. In Europe he was the recipient of all decorations, a member of all Academies: ‘He became,’ Duhem continued in his portrayal of Berthelot, ‘the official representative of modern science. If the majesty of that divinity was offended by someone impious, it is Berthelot who excommunicates the one guilty of sacrilege; it is he who receives the oaths of loyalty of the faithful; it is he who presides over the sacred banquets where the propitiatory victims are exterminated.’¹³⁶ Yet an unmistakable touch of sadness could be heard from the Préface. It was the same tone which one could also detect in the July 15, 1897,

134. *Ibid.*, pp. 383-84.

135. *Ibid.*, p. 388.

136. *Ibid.*, p. 389.

issue of the *Revue de Paris* which carried, with an introduction by Berthelot, the first instalment of the life-long correspondence between him and Renan, the respective leaders in the sciences and letters, of the crusade on behalf of a religion whose absolute god was man himself. In that introduction Berthelot spoke of 'the radical impossibility of attaining an absolute end point.'¹³⁷

What this admission implied was the bankruptcy of scientism which expected science not only to deliver a paradise on earth, but also to replace ultimate philosophical and quasi-religious presuppositions.¹³⁸ Devoted to the religion of scientism from the very start of his scientific career, his first signal successes – the synthesis of acetylene, of formic acid, and of alcohol – seemed to promise to Berthelot the eventual conquest of a goal far more philosophical than scientific, namely, the production of life in a test tube. It was this philosophical dream which, so Duhem argued, became Berthelot's 'evil *génie*.' It blinded him to the organic chemistry of Dumas, Wurtz, and Kékulé, to the point of stopping it at the doors of French higher education. It also blinded him to Claude Bernard's gradual parting with his erstwhile hope of reducing life to physics and chemistry. But he had to see how the admiration of many a philosopher was turning toward 'that lucid mind and man of honor, Louis Pasteur, whose researches had for their foundation the radical impossibility of extracting life from a chemical compound.'¹³⁹

Thus Berthelot was forced to shift ground with that marvellous agility which, in his own words, 'allowed him to transpose his thinking almost simultaneously from one order of notions into another.' His new chosen field was thermochemistry, most appropriate for his indefatigable activity and prodigious talent as an experimenter. But once more he became the victim of that 'evil *génie*.' At a time when Sainte-Claire Deville started his work on dissociations, which called for the new science of thermodynamics, he espoused the misleading ideas of Thomsen and set himself in opposition to that new organic chemistry which called at the same time 'for a theoretician and experimenter, who had to be a mathematician, physicist, and chemist in one.' Berthelot was no match for such multiple demands. Thus his 'evil *génie*' pushed him 'to attach himself to a discredited doctrine, to defend it against all new ideas, to devote to that sterile and thankless enterprise all his ingenuity, all his time, all his labor, all the time and labor of his numerous and active collaborators, whom it was his rare fortune to encounter. Today, he is too perceptive not to recognize that thermodynamics has created, without him and in spite of him, the chemical static to which he dreamed to fasten his name.'¹⁴⁰

137. *Ibid.*, p. 390.

138. A memorable presentation of science by Berthelot in exactly that sense was his speech, 'En l'An 2000,' delivered at the banquet of the *Chambre syndicale des produits chimiques* on April 5, 1894. The onset of that age of absolute plenty, 'the realization of the dream of socialism,' when even the richly laden dinner tables would be replaced by capsules of nutritional pills, depended, according to Berthelot, on the success 'of discovering a spiritual chemistry which changes the moral nature of man as profoundly as our chemistry transforms the material nature.' (M. Berthelot, *Science et morale* [Paris: Calmann-Lévy, 1909], pp. 510-11).

139. 1897 (5), pp. 390-91.

140. *Ibid.*, p. 392. Those three qualifications were certainly united in Duhem.

Duhem had advice for Berthelot: 'Let him listen to the murmur which issues from the crowds of French chemists and physicists whom a superstitious fear still prevents from raising their voices. These murmurs carry to him a commentary formulated long ago to his recently uttered words professing 'dislike of betrayals, deceptions, and desertions.' The commentary, with no religious overtones in itself, had been long in *The Imitation of Christ*, a book which Duhem always kept within reach in the drawer of his desk. The passage which Duhem quoted with reference to chapter and verse could only cut Berthelot to the quick: 'Tell me, where are now the great students and famous scholars whom you have known? When alive, they flourished greatly in their learning, but now, others have succeeded to their posts and promotions, and I cannot tell whether their successors give them a thought. In their lifetime they were considered great in the world, now, little is spoken of them.'¹⁴¹

Had Duhem been a slightly better Christian than the very good Christian he was, he would have spared Berthelot a message which, because of its provenance, could only be distasteful to him. But Duhem was at least a Christian who never tried to appear a half-hearted one, acceptable to the secular establishment insofar as it was secular, and much less did he try to hide his Christianity, as was the case at that time with not a few French Catholic scholars holding posts in the *grandes écoles*.¹⁴² Duhem was certainly Christian in that having stated what he felt was his duty, he let matters rest. It was enough for him to see the essential points of his essay carried to all corners of the scientific world in the pages of the *Zeitschrift für physikalische Chemie* in which Ostwald wrote: 'With sharpness, nay with fury, is held high to the representative of the older viewpoint its refutation through more recent advances, and the impression becomes rather tragic through the recognition that the attack was necessary and irresistible.'¹⁴³ From America came in the pages of the *Journal of Physical Chemistry*, Bancroft's staccato summary of each section of the essay and his full endorsement of it all: 'That is a terrible arraignment and the sad part of it is that it is true.'¹⁴⁴

That Duhem succeeded in driving the point home even in his own France became very clear on November 24, 1901, a day which saw the French political and academic elite gather under the great aula of the Sorbonne to celebrate the 50th anniversary of the start of Berthelot's scientific career. The Third Republic did not witness a more glittering fête given in honor of a scientist. But those familiar with Berthelot's writings and scientific objectives could not help noticing an in-

141. *Ibid.* Book I, ch. 3, par. 5.

142. In speaking of his student years at the Sorbonne, E. Gilson recalled the surprise with which he learned that J. Lachelier and V. Delbos, both professors there, were Catholics. See Gilson's autobiographical *The Philosopher and Theology*, tr. Cecile Gilson (New York: Random House, 1962), p. 35. A similar surprise about Delbos on the part of Jacques Maritain, also a student of philosophy at that time at the Sorbonne, was recorded by his wife, Raissa, in her autobiographical *We Have Been Friends Together. Memoirs*, tr. J. Kernan (New York: Longmans, Green & Co., 1942), p. 69.

143. *ZPhCh* 28 (1899):178-79.

144. *JPhCh* 2 (1898):395.

visible dark shaft piercing through the glow of festivity. As Berthelot and the several thousand select guests heard speech after speech celebrate his achievements as a chemist, not one reference could be heard to Berthelot's favorite idea, the principle of maximum work, although such words as *thermochimie* and chemical affinity often fell from the speakers' lips. Particularly telling was the silence about that principle in by far the longest speech of the day, a detailed and in places very technical survey by H. Moissan, member of the Académie des Sciences, a future Nobel-laureate, and professor of chemistry at the Sorbonne, of Berthelot's feats in that field.¹⁴⁵ The silence was an all too loud evidence of the tacit admission by the scientific community that the young Normalien was right when the Sorbonne judged him wrong in 1885.

Duhem, of course, could hardly succeed in another respect. It mattered not that the vast preponderance of his armory consisted of arguments rooted in that positive scientific research whose objectivity was above any dispute. It mattered not that he himself was of that anti-atomist camp to which Berthelot belonged and, for that matter, all those who held in France at that time the leading chairs in physics and chemistry. Such incisive atomists as the Curies, Perrin, and Langevin were still few and relatively young to have a voice in academic promotions. It mattered not that Duhem was ready to resort to that, in his view, selfish move, of writing a letter to Liard, a chief representative of a hostile establishment, requesting for himself a chair in Paris on the basis of his unquestionable feats. He was still to learn what should have been all too clear to him that, especially around 1900, means other than the powerful wedge of objectivity — a wedge constituted by his staggeringly numerous and valuable publications — were needed to open the road for an advancement befitting him. While he never abandoned all hope in the efficacy of that wedge, he did not seem to be able to accept that science, in more than one sense, was no less human an enterprise than advancing on any road, be it the one from the University of Bordeaux to any of the *grandes écoles* in Paris.

145. The text of all speeches, together with the text of congratulatory messages from everywhere in the scientific world, is contained in the sumptuously printed volume, *Cinquanteenaire scientifique de M. Berthelot. 24 novembre 1901* (Paris: Gauthier-Villars, 1902); for Moissan's speech, see pp. 26-36.

6. BORDEAUX: JOURNEY'S END

A companionable solitary

In the first year of the twentieth century, when Liard was formally reminded by Duhem that Bordeaux was meant to be for him a road to Paris, other roads too must have taken on for him a dispiriting outlook. For one, his access to physics students narrowed ominously. He gave, mostly before empty chairs, his special courses in advanced physics (on elasticity in 1901-02 and on stability in small displacements in 1902-03).¹ Such was a waste of talent the shocking measure of which was amply revealed when the next year he gave the first of his courses open to all the educated public of Bordeaux, which immediately sensed the genius he was. The course was on the aim and structure of physical theory which, once in print, immediately proved itself a classic. The impression made by the course can be sensed from the rector's reference to it in the *Rapport 1903-04*: 'The Faculties of Science and Letters offered this year seventeen public courses which drew people of all conditions . . . I will mention only one, because it represented a happy innovation. In about twenty lectures . . . Duhem appealed not only to physicists but to philosophers as well. His course brought together students of both Faculties, professors of secondary and higher education, and interested outsiders. Let me add that these lectures, published in the *Revue de philosophie*, will soon appear as a book.'² Not for the last time Duhem treated his University and the educated public of Bordeaux to a series of lectures ready to be printed which, in view of the perfection of his oral delivery, must have been a first class treat. That such a lecturer and thinker had practically no students in his real field, theoretical

1. Duhem's complaint to Liard about this state of affairs, mentioned in the preceding Chapter, is fully attested by the data in the *Rapports* for those years: The number of students who took the exam in physics for certificat d'études supérieures was 1 in July 1901, 2 in July 1902, and 4 in July 1903. Five years later in the confidential report about Duhem it had to be admitted that this 'incomparable professor has unfortunately no sufficiently large audience.' Dossier Duhem, p. 42.

2. *Rapport 1903-04*, p. 13.

physics, could not fail to be the cause of the kind of puzzlement which readily turns into suspecting sinister causes behind patent anomalies.

Privation of proper outlets for Duhem's talents as a physicist was paralleled in respect to University affairs. Following Brunel's death Duhem took the view that 'political' factors made increasingly futile any fight for openness and fair-play. His increasing isolation³ was all the more conspicuous as his renown kept growing. His reputation as a lecturer was matched by the invariably vast list of publications in the annual *Rapports*. Those *Rapports* also brought to the notice of all Faculty in Bordeaux and the officials in the Ministry of Public Instruction in Paris that Duhem's renown, however slighted in his own country, kept spreading abroad. On April 9, 1901, his lecture, 'Sur quelques extensions récentes de la statique et la dynamique,' opened a three-day celebration of the silver jubilee of the Société scientifique de Bruxelles in which he had, since the previous year, been among the handful of its honorary members.⁴ On December 15, 1902, Duhem became foreign associate of the Academy Royal of Belgium, an honor that came on the heels of his having been elected honorary member of the Société scientifique de Bruxelles. On April 14, 1905, he was elected member of the Polish Academy of Sciences in Cracow. That the latter honor could come to him only after an exchange of letters between the ambassador of Austria-Hungary to France and the Foreign Office in Paris must have amused Duhem to no end. The detachment with which he considered this and subsequent honors transpires from his letter of October 25, 1909, to the secretary of his University who asked him for a list of such honors: 'Would you please file this list with a view to my future obituary notice.'⁵

It would, of course, be mistaken to picture Duhem as one who suddenly shunned fighting for any and all causes. One cause for which he fought related to his laboratory boy facing dismissal. When Duhem found that his appeals to dean and rector were of no avail, he took the night train to Paris only to run into his sister at the Gare d'Austerlitz. Marie Duhem first thought that her brother had come to Paris in order to please their mother by applying for a chair or by pressing his candidacy for some academic honor. 'To please Mama,' Duhem replied, 'by making two hundred visits [in high places] and making as many bows? This is above my strength! No! . . . I am coming on behalf of a 'poor devil,' my laboratory boy, who fell into disfavor with some professors and will lose his livelihood. I am going to ask the Ministry of Public Instruction that he be retained in his job.'⁶ The job

3. In his confidential report sent in May 1904 to the Ministry in Paris the dean added to his acknowledgement of the continued brilliance of Duhem, who is 'in the very first rank through his scientific studies,' the remark: 'He is more and more disinterested in the proceedings of the Faculty.' Dossier Duhem, p. 64.

4. See *Annales de la Société scientifique de Bruxelles. Vingt cinquième Année, 1900-1901* (Louvain: Secrétariat de la Société scientifique, 1901), p. 218. The next day Mansion spoke of Duhem's lecture as a classic of 'Thomisme élargi' and as the culmination of a quarter-of-a-century philosophical development of the *Revue des questions scientifiques* (ibid).

5. Dossier Duhem (Bordeaux).

6. *Un savant français*, p. 174.

was saved but not the 'poor devil' who soon fell sick. As he agonized on his hospital bed, he had Duhem as his sole visitor. Duhem was also alone in accompanying the body to the cemetery. Bareheaded and praying, Duhem marched behind the coffin to the edge of the common grave, the most crowded solitude.⁷

Duhem imposed a solitude on himself in one very important aspect. His best friends' pleas that he should present himself as a candidate for any vacant chair in Paris fell on deaf ears. Few of these pleas were so much to the point – and could count on a favourable hearing – as the letter of the Abbé Pautonnier, professor at Stanislas, and a very trusted friend indeed. Duhem could be touched by the fact that in Pautonnier's long letter, written on New Year's Day 1902, the mere idea of Duhem's coming to Paris was the only bright detail in a gripping survey of the political and ecclesiastical situation. About the latter, Pautonnier, who was on a visit in Rennes, stronghold of ultraconservative French Catholicism, Duhem was told that 'the Church, being deified down here, cannot reform herself. A revolution must be unleashed by God to implement that reform.' As to Stanislas, its good lay faculty languished under an incompetent Marianist director. As to you, Pautonnier now turned to Duhem,

you must come to Paris. Since there is generated around you a well-calculated silence, you must come to Paris. Come and see Picard who is in full reaction [against that silence] and who could at a given moment be of service to you. Present your candidacy whenever there is a vacancy. You play into your enemies' hands by retiring into your tent. I do not think that you would demean yourself by presenting your candidacy. You would not present yourself as a beggar, but as a man of distinction, conscious of his work and talents . . . Publish more often in the best French periodicals – don't send articles, such as your critique of Maxwell, important as it is, to a *Revue* which is hardly read and which many affect not to read. In brief, a little more diplomacy and politics. Don't get discouraged. In the end they will feel obligated to do you justice. Remember the uneasiness with which they had to do justice to Cauchy. Here, there is against you a market looking for rumors such as 'they say Duhem is a boy of great talent, a boy so loyal, so generous; what a pity that his personality is so bad!' Therefore, abstain from all public actions for a while, except in very grave cases. One is willing to recognize that you are basically right, but it is bad to be right too often . . . But, I repeat, profit of Picard's attitude and try to come back to Paris no matter how. To the Ecole Normale like Brunetière, to the Collège de France, to the Ecole Centrale, or what have you. But come back!⁸

Pautonnier's letter not only suggested the kind of arguments with which Duhem argued against making himself a candidate, but also made clear with a gentle touch that in Duhem's character, splendid like a shining armor, there was a chink, a touch of pride. Duhem had a too vivid awareness of his own integrity. This is why that armor isolated him unnecessarily on too many occasions. Thus he earned the reputation of being a solitary, a recluse, even a misanthrope. So was Duhem described to Albert Dufourcq, a former Normalien and eleven years Duhem's junior,

7. *Ibid.*, p. 175.

8. The Abbé Pautonnier served as director of Stanislas from 1905 until 1920, and was considered its second founder (H. Bordeaux, *Le Collège Stanislas*, [Paris: Gallimard, 1936], pp. 134-44).

who came in 1901 to Bordeaux with an already strong reputation as a Church historian. A devout Catholic, Dufourcq must have heard of Duhem and indeed Duhem was one of those on the Faculty with whom he wished to establish a more than perfunctory rapport. 'Useless,' Dufourcq was told by a colleague. 'Duhem never sees anyone. He will not even return your visit.'⁹ Duhem returned Dufourcq's visit and soon was dining every Saturday at the Dufourcqs until their departure from Bordeaux in 1914. Duhem not only saw the Dufourcq family increase but saw his love for the Dufourcq children fully returned. Once more little children were good judges of genuine affection. They enjoyed being called 'machurés'¹⁰ and indeed kept a warm and vivid memory of their frequent meetings with him.¹¹ Marie (Mimi), the fourth of the six, born in 1910 called him 'Hem,' for a baby an easier form of 'Duhem,' which pleased Duhem enormously. His letter of August 12, 1913, to Marie, his princess, then only three, shows Duhem at his affectionate best. The Feast of the Assumption, which was also Marie's name day, was only three days away and her old friend vacationing in Cabrespine would not miss it:

Princess Mimi,

Since it is you who in the family carry specially that beautiful name of the Virgin Mary, it is to you first that I convey my good wishes on that Feast. And when I have already said that I pray to your patroness in heaven for your happiness, I ask you to offer my good wishes to all who love you – God knows there are some. You begin with Louise, your sweet little sister, and then you go to all the others, from the younger to the older, Norbert, Mathilde, Henriette, Mama, Papa, Grandmother. To all, please say that Hem asks the good Lord and the Virgin Mary to protect them. You embrace on my behalf all those whom I am allowed to embrace and on your own behalf all the others. Then I will give on your sweet rosy cheeks as many kisses as you have given. I don't know whether you will find this very charming but I hope I will not have to complain. Adieux, Princess Mimi, Your old friend, Hem.¹²

The Dufourcqs first resided in Rue Margaux, a small street off Rue St. Catherine, the main shopping street of Bordeaux then as now. Later the Dufourcqs moved to

10. See *Un savant français*, p. 212. Duhem probably learned about the word *machuré* (which the children did not understand) while in Lille, where it meant anyone with blackened face, primarily coalminers, and secondarily also the dark-faced magi in the story of Epiphany. Such was Duhem's gentle teasing of small children apt to soil their hands and faces. For the etymology of the word, see Claude Augé (dir.), *Dictionnaire universel encyclopédique. Tome cinquième*. (Paris: Larousse, n.d.), p. 819.

11. As was all too evident in my meetings, in 1981, with two of Albert Dufourcq's children, Mme Henriette Gallet and Mr Norbert Dufourcq. The former still treasures a beautiful book in white leather binding, a life of Saint Elizabeth of Hungary, which Duhem gave her in 1912 for her first communion. The latter too was, on his first communion, the recipient of a richly illustrated book on the lives of saints, which Duhem inscribed with the words: 'à mon cher petit ami.' On Mr Dufourcq, who generously assisted Duhem's daughter over many years, see also the paragraph marked by note 37 in Ch. 1.

12. This letter is in the possession of Mr Norbert Dufourcq, who kindly consented to its publication. A year earlier for the same feast Duhem sent a similar letter to Mimi, addressing her at this time 'Madame.' In the same letter he speaks of 'Herr Norbert,' then eight years old.

Rue Tivoli, a street adjoining Bordeaux's great public park. Taking the half hour walk to either place from the Rue de la Teste could only please Duhem. Hélène, who often went along, became quickly a favorite 'aunt' with the Dufourcq children. Duhem himself became the favorite uncle, a fact which comes through with touching liveliness in a long letter of Dufourcq who was the fifth – in addition to Récamier, Chevrillon, Fabre, and Marchis – to assist Duhem's daughter in the early 1930s with long letters rich in invaluable reminiscences about her father.

Dufourcq's letter covers his association with Duhem until almost World War I in which Dufourcq earned the Croix de guerre and the Légion d'honneur. The letter,¹³ long on details concerning academic struggles, shows all too clearly that deep in his heart Duhem was anything but a warrior:

He tenderly loved my children. When we talked in the evenings, after dinner, and when the cries of a newborn obliged the mother to go and tend the baby, and at times even to bring it to the study, which the baby loved to traverse on all fours, with what a pleasure Duhem loved to follow the frolics of the tiny creature who sometimes shook off its diapers! . . . Such was a way to come back, and with what hilarity, to the sublunary world! Later, when the troop of these 'morons' had grown up somewhat, what beautiful sketches he would make for them, sketches ornate with amusing details! Child with children, a charming conversationalist with ladies – who could not believe after a visit that he was a well-known scientist – he was everything to everybody. His powerful nature, his marvelous poise adapted without difficulty to the diversity of occasions.

But the same letter makes also very clear that Duhem let his very warm nature transpire only in the circle of trusted friends. Beyond that circle he kept up his guard:

He lived a solitary life. And since I hardly knew his story, first I did not understand his reserve. When Duguit,¹⁴ whose independence and rectitude matched these same characteristics of his, organized meetings where current problems were discussed [by Faculty members], I did not succeed in having him join that group of conversationalists. 'I am so little of society,' he told me, 'that I am not sociable.' Little by little I understood. My own history helped. He himself predicted it to me.

Professors at the same university, but attached to different faculties, we often talked of the various incidents which everyday life brings along. He had been in Bordeaux longer than I. He had been a member of the University Council, a circumstance which put him *au courant* of various affairs. It was easy for him to see clearly. What backgrounds he had unveiled to me, the candid neophyte, I was then! I still remember vividly with what verve he recounted to me the intrigues of the foundation of the chair, let us say of Nubian studies! The intrigues he had to endure, the ostracism he had to encounter, soon became my very lot.

Intransigent integrity

The reason for this was very simple and revealing of the countercrusade waged

13. *Un savant français*, pp. 200-13; for the following quotations see pp. 209-10.

14. Léon Duguit (1859-1928) joined in 1896 the Faculty of Law of the University of Bordeaux where he served as dean from 1919 on.

by the political and intellectual spokesman of the Third Republic.¹⁵ As long as Dufourcq's publications mainly consisted in a critical pruning of the legendary lores of early Christian centuries, he had all the support he wanted. When he turned from the largely technical work of text criticism to writing history, the winds of hostility began to blow. Dufourcq found in Duhem a fearless defender against intrigues and in Duhem's life story, which by then he knew in full, startling similarities with some new turns in his own:

My Potentiel thermodynamique was entitled *L'Avenir du christianisme*.¹⁶ Those who applauded my critique of the [Christian martyrs'] legends deeply resented my essays of synthesis [concerning the history of the Church]. Twice some intermediaries tried to buy my silence. The friendship of Duhem compensated me for the hostilities which multiplied, intensified, and could even become frightening. No one defended me with greater constancy and vigor than Duhem did. Of all the memories, which are too personal for me to mention here, I will recall only one from a letter of Duhem to my wife, dated March 3, 1910, as it will prove in an authentic form [his support of me]. Here are some phrases: 'Madame, when I come across a text which may be useful for your husband in writing the *Avenir du christianisme*, I will hasten to send it to him. Today I would like to offer you two very recent documents. They are only a few hours old . . .' The letter included a visiting card from Mr. X, whom the Ministry of Public Instruction and the *Dépêche de Toulouse* wanted to install in the chair for which I have provided the courses for nine years, and another card, that of Duhem. After his name and titles one reads: 'regrets very much not having been at home when Mr. X came to see him; he would have felt it his duty and pleasure to show the door to his visitor . . .'¹⁷

The visit in question was a perfect situation for Duhem's intransigence. In many another case his intransigence closed the door unnecessarily on his own advancement. Contrary to Duhem's and many others' expectations, the Third Republic weathered its grave crises and, quite unexpectedly, the full vindication of Captain Dreyfus left the government free to democratize the officer corps, a bastion of

15. An informative account of this development, but in which the clash between Church and State is claimed to have been in ultimate analysis a purely political contest, is *Waldeck-Rousseau, Combes and the Church: The Politics of Anticlericalism, 1899-1905* by M. O. Partin (Durham, N.C.: Duke University Press, 1969). The study of the antecedents of Combes' politics, *The French Laic Laws (1879-1889): The First Anti-Clerical Campaign of the Third French Republic* by E. A. Acomb (New York: Columbia University Press, 1941), reveals much more of the ideological roots. The most insightful study of the entire conflict is A. Dansette's *Histoire religieuse de la France contemporaine* (Paris: Flammarion, 1948) of which a two-volume and abbreviated English translation by J. Dingle appeared in 1961 under the title, *Religious History of Modern France* (New York: Herder & Herder); see especially vol. II, subtitled *Under the Third Republic*. The roundabout contribution of that conflict to the rapprochement between Church and State in France in the twentieth century is well treated in the first two chapters of *The Second Ralliement* by Harry W. Paul (Washington D.C.: The Catholic University of America Press, 1967).

16. This work comprised seven volumes in its first edition (1908-1914). The tenth volume of a completely revised second edition, which Dufourcq began to publish in 1924, appeared in 1954, two years after his death. On Dufourcq's life and work, see *Mélanges Albert Dufourcq: Etudes d'histoire religieuse*, préface de Georges Goyau (Paris: Plon, 1933).

17. *Un savant français*, pp. 210-11.

aristocratic families with conservative Catholic convictions. As usual, 'democratization' had political aims which discredited truly democratic ideals. In the circumstances the setting up of a Christian democratic front in France could seem to be doomed to failure. Duhem took in this sense the complete break in 1905 between the Vatican and the Republic. He found the impasse best articulated in *Le dilemme de Marc Sangnier* by Charles Maurras, a copy of which he gave to Dufourcq,¹⁸ a Christian democrat and a Dreyfusard to boot. Not that Duhem expected a political victory by the Action Française. As he put it with obvious resignation: 'Every four years I vote for someone who is not elected.'¹⁹

The remark was made in connection with Liard's charge that Duhem blocked his professional advance with his politicking. He simply had not time for political activity. Had Duhem already been an occupant of a chair in Paris when he became a corresponding member of the Académie, he would still have considered it his duty to live up to his new status by frequent contributions to the weekly sessions of the Académie. A fearless spokesman on behalf of the intellectual and economic independence of anyone holding an academic post, Duhem was no less resolute a reminder of the academic's duty to respond with hard work (in the form of teaching and research) to his status, honors, and remunerations. Accolade for hard work would have been the least to be merited by the eleven papers which Duhem communicated to the Académie between December 24, 1900 and June 5, 1901. Their publication in the *Comptes rendus* could not be unknown to Liard, if he needed at all fresh reminders of the objective merits of Duhem's scholarship and of the unlikelihood of Duhem's politicking. By the end of 1903, Duhem's contributions to the *Comptes rendus* increased by two dozen, an extraordinary pace which he kept up until the end of 1906.

The pace was indeed such as to create problems for the *Comptes rendus*. Duhem's attention was called to this by none other than M. Berthelot, perpetual secretary of the Académie. Berthelot's letter written on February 5, 1903, was courtesy and tact in every respect:

Monsieur le Professeur, Your communications have been referred, as usual, to Mr. Darboux who is in charge of the section of mathematical sciences. Their merit is not doubtful. But it has been noted in the [editorial] office that their frequency has for some time exceeded the limits assigned to the *Comptes rendus* and publications would have to be spaced out over several weeks. It would be regrettable on the other hand, in my view, that publication should encounter other hindrances than the unfortunately narrow limits of our budget, a budget further reduced at the end of last December by financial inadequacies and difficulties, With high regards, M. Berthelot.

The tone of Berthelot's letter had undoubtedly to do with a note which he had just received from Duhem. On the morning of February 3, Duhem read the latest issue of *Moniteur scientifique*, a monthly which, to his consternation, carried a

18. *Ibid.*, p. 127.

19. *Ibid.*, p. 126.

reprint of his long and sweeping critique of Berthelot's *Thermochimie*.²⁰ Duhem immediately dispatched two letters. In the one to Berthelot he wrote:

Five years ago I believed it my duty to criticize some of your ideas. Today, the *Moniteur scientifique* reprinted the article which I wrote at that time. I want you to know that this reprinting was done without my authorization and without a solicitation of my opinion, without even an advance notification. I have seen it only a few hours ago as a *fait accompli*. I want to assure you that if my consent had been requested it would have been refused.²¹

The other letter, a strong protest, was sent to G. Quesneville, director of *Moniteur*. Quesneville, a debator of no small skill, called in turn Duhem's attention to the fact that his critique of Berthelot already belonged to the history of science during the 19th century, as the unsurpassed rebuttal of the principle of maximum work. Further, to settle accounts with Duhem, Quesneville requested from him an acknowledgement (to be printed in the *Moniteur*) of data he had received from Quesneville on various matters. Duhem's letter of protest was duly printed in the *Moniteur*.²² By then even the Minister of Public Instruction was assured by Duhem that he had in no way been a party in Quesneville's action. Not surprisingly, behind the kind of action such as Quesneville's, there lay something very different from unselfish interest in scholarship. As Duhem was informed by Darboux on February 10, Quesneville, 'docteur ès sciences, docteur en médecine,' felt slighted by the promotion of Berthelot's son in the Ecole de pharmacie where Quesneville was professeur agrégé. Such a misuse of scholarship was in Duhem's eyes a breach of that integrity which called for an open confrontation with one's opponents. Duhem, who was not one of those who would stand up to Berthelot only after the latter's death,²³ was not one to engage in personal vendetta either.

Duhem's firm disavowal of Quesneville did not fail to impress Berthelot who by 1903 must have perceived that the intransigence with which Duhem criticized the maximum work principle did not lack that hallmark of integrity which is

20. The critique, 1897 (3), appeared in *Le Moniteur scientifique du Docteur Quesneville. Journal des sciences pures et appliquées*, to quote its masthead in full, as the leading article in its February 1903 issue (Tome XVII, Livraison 734, pp. 81-90). It was introduced with Quesneville's remark that in its issue of September 1902 the *Moniteur* carried an article by the German chemist. Fritzsche, who claimed that the synthesis of alcohol should not be credited to Berthelot but to Faraday and Hennel. Clearly, the reprinting of Duhem's article was part of a campaign against Berthelot on the part of Quesneville, who also created the impression that Duhem's article was refused years earlier in the *Annales de chimie et de physique* of which Berthelot was a director.

21. The importance which Duhem attached to this letter was attested by the fact that he kept a copy of it. Duhem also sent a note to his dean, Bayet, who in turn assured Duhem that if occasion arose he would testify on his behalf.

22. *Le Moniteur scientifique*, March 1903, p. 224.

23. Duhem himself stated this, but for a documentation I can offer only my distinct recollection of having seen it somewhere reported.

restraint.²⁴ Berthelot squarely put himself behind Duhem in the deliberation, which secured in early January 1904 for Duhem the promotion from the lowest, or fourth, to the third rank as a professor with an increase of 2000 francs in his annual salary. Tannery, who was a member of the committee that handled for the Ministry of Public Instruction the list of those recommended for promotion, wrote to Duhem in late 1903:

Although matters of money are among items which you despise and perhaps more than they deserve, I am glad to inform you that for the second time the consultative committee proposes you for promotion, and that you have been put at the top of the list by unanimous vote (except one vote) and that it will be very difficult [for the Ministry] not to approve of the vote which Berthelot sealed with the remark: 'One must recall here only the scientific value of Duhem.' If he had uttered these simple words last year, it would have been better – still I am pleased that he did this year. After the meeting of the committee he took aside Darboux and myself to tell us that he wished you knew that the only vote not cast in your favour was not his and that he had voted for you already last year. Liard, Appel and especially Darboux supported you very vigorously and Bayet seconded their motion. This time I was silent as a carp. All this came rather late, but at long last is accomplished, or at least so I believe. Don't make your triumph too apparent to your rector [Bizos]; it is not worth the effort. Naturally, if I knew that he [Berthelot] did not vote for you, I would not tell you this, but I believe that the vote in question was a mere irregularity. How slow is justice! Of course, it is not you that I congratulate, but the committee, Berthelot included. Perhaps in view of the lack of complete beauty in the vote you regret somewhat this promotion. Don't regret it too much. Your best friends rejoice over it and they are at least relieved on seeing that a rank injustice is not perpetuated.

Just as Duhem did not savor the idea of a personal vendetta against Berthelot, he did not wish to have Bizos humiliated. His intransigence, never vindictive, aimed in personal matters, as will be seen shortly, at rendering justice to the one slighted rather than at bearing down on the guilty. The foremost objective of his intransigence was the vindication of rigor in the reasoning which constructed physical theories. This could not fail to transpire even in the brief summaries regularly published about the meetings of the Académie in *Revue général des sciences pures et appliquées*, a biweekly which Louis Olivier founded in 1890 and which rapidly established itself as the French equivalent of *Nature* and of *Naturwissenschaften*. Concerning contributions on experimental topics, which were in preponderance, their summaries usually stated that their respective authors merely 'communicated,' 'studied,' or 'indicated' this or that point. Duhem's contributions called forth almost invariably for the comment that he 'showed' or 'demonstrated' this or that point.²⁵ These verbs would have been most appropriate in characterizing the tenor of Duhem's discourse in a series of articles which he was invited in 1902 by

24. Duhem's disinterest in engaging in polemics concerning that principle was all too evident in the two pages which he devoted to it in the first volume of his *Traité élémentaire de mécanique chimique*, 1897 (1), in which he stated in conclusion that 'Mr. Thomsen formulated that rule in 1854, but applied it without distinction to all chemical modifications; . . . restricted to sufficiently strong chemical reactions, this rule renders great services to chemical mechanics' (p. 94).

25. See, for instance, the volume for 1901, pp. 194, 243, 289, 343, 446, 496, 548.

Olivier to contribute to the *Revue* on the evolution and meaning of mechanics. The choice of the topic, a most sensitive and hotly debated issue at that time, was indicative of the broad perspectives and perspicacity of Olivier, a biologist trained by Claude Bernard. As to Olivier's choice of Duhem, it was a major evidence of wide respect for the value of consistency in Duhem's reflections on the meaning and method of physics, rigidly intransigent as they would appear at times.

The seven articles saw print in seven consecutive issues between January 30 and April 30, 1903, and amounted, when published together later that year, to a book of 348 pages.²⁶ That an English translation was called for almost seventy years later, attests all too well to the book's lasting value, and also to the rare combination in one person of thorough expertise in theoretical physics, in philosophy, and in scientific history. A Polish translation was completed within a year,²⁷ a German translation followed in 1912.²⁸ As for Duhem's compatriots, they should have hailed it as a feat far superior to Mach's already two-decade-old survey of the history of mechanics which, interestingly enough, appeared in French translation in 1903. Both the values and irremediable shortcomings of Mach's work were set forth in an essay-review by Duhem himself.²⁹

Although, as will be seen, no real discussion developed in the French world of science about Duhem's *Evolution de la mécanique*, it was in strong demand as attested by its republication in 1905.³⁰ No echo followed when in Abel Rey's vast survey of contemporary physicists' views on physical theory a long chapter was devoted to Duhem alone, the only physicist given that distinction.³¹ The only one to react to the sole reaction of Rey was Duhem himself. One wonders whether Duhem would have done so had an earlier form of Rey's analysis of Duhem's scientific philosophy not come to a close with the remark that the scientific philosophy of Duhem was that 'of a believer.' The remark prompted a year later (in 1905) Duhem's famous reply, 'Physique de croyant,' which started with the often quoted statement:

Of course I believe with all my soul in the truths that God has revealed to us and that He has taught us through His Church; I have never concealed my faith, and I hope from the depth of my heart that He, in whom I hold that faith, will keep me from ever being ashamed of it.³²

Duhem's concern was not so much a vindication of his own religious integrity as the integrity of the physical theory he advocated. Again, in his unreserved commitment to the cultivation of that theory, the theory loomed larger in his eyes than whatever could be said about the intransigence with which he cultivated it.

26. 1893 (7-13). All these installments, with the exception of one, were lead-articles.

27. 1903 (15) and 1904 (2).

28. 1912 (1).

29. 1903 (30).

30. 1905 (1).

31. A. Rey, *La théorie de la physique chez les physiciens contemporains*, (Paris: Felix Alcan, 1905), pp. 128-67 (Livre II, ch. iii).

32. Quoted in the English translation, 1954 (3), pp. 273-74.

Intensely as Duhem cultivated the philosophy of physics and its history, he did so only to promote physics itself. The depth of his conviction on this point was part of that intellectual integrity which prompted his words to his friend Jordan: 'I am a physicist. Paris will obtain me only as such, if I ever should return there.'³³

Duhem uttered these words in 1893 when a chair for the history of science was established in the Collège de France and a professor there tried to find out through Jordan whether Duhem was available.³⁴ The appointment at that time of Lafitte, often dubbed the 'positivist pope,'³⁵ was already scandalous enough. The scandal reached enormous proportions when in 1903 not only was Paul Tannery passed over for the second time, but preference was given to G. Wyruboff, insignificant as a crystallographer, a mere nullity as a historian of science,³⁶ but a first-rate believer in the religion of positivism, which many leaders of the Third Republic held to be the only legitimate framework of intellectual and scientific history. Already in 1893 Tannery had incomparably better credentials than Lafitte. In December 1903 his selection should have been imperative. Earlier that year the *Congrès des sciences historiques* meeting in Rome recognized him, in a sense, as the leading historian of science by confiding to him the task of establishing for future congresses a section dealing with the history of science. Equally public knowledge was the fact that Tannery was the first on the list of candidates presented by the professors of the Collège de France, and overwhelmingly so on the list voted by the members of the Académie des Sciences. The intellectual world could perceive an echo of Horace's words, 'parturient montes, nascitur ridiculus mus' (mountains in birthpangs bring forth a ridiculous mouse) when the blatant disregard by the Ministry of Public Instruction of both lists was greeted in the *Figaro* with the remark: 'A historian was needed, but a crystallographer was obtained.'

The indignation of Duhem, who quoted that remark in his obituary of Paul Tannery³⁷ two years later, was as much a testimony of Tannery's greatness as to Duhem's refusal to dwell on some bureaucrats' and academics' sinister manoeuvrings. These could, of course, easily be imagined by Duhem, although he could not know of the revolting rhetoric with which Jougue, in charge of presenting the candidates to the Ministry, pushed the cause of Wyruboff, who in spite of all his politicking was only the second choice of the Collège de France for the

33. Jordan, 'Duhem,' p. 162.

34. *Ibid.*

35. The appointment of Lafitte touched off sharp reactions in the Sénat and prompted acid comments in the dailies. The collection of newspaper clippings relating to the matter in the dossier F¹⁷ 13555 in Archives Nationales (Paris) provides for entertaining reading.

36. An apt phrase of H. W. Paul, 'Scholarship and Ideology: The Chair of the General History of Science at the Collège de France, 1892-1913,' *Isis* 67 (1976):386.

37. 1905 (17), p. 229. As Duhem rightly noted (*ibid.*, p. 228), during Lafitte's tenure the chair served as a commentary to the dogmas of the positivist church.

chair.³⁸ Duhem, however, had a first-hand knowledge of a letter which Paul Tannery wrote to someone who marveled at the peaceful composure with which he had met the bitter disappointment:

You are wrong in accusing Chaumié [Minister of Public Instruction]. He served evidence of an astonishing sagacity in remarking himself what escaped the attention of everybody, and first of all myself, namely, that for the chair of the history of science, as for science itself, one had to pass through the three stages; that after the theological stage, aptly represented by Lafitte, the metaphysical stage, which Wyruboff will represent even better, was indispensable. And Chaumié has given the most admirable example of devotion to scientific truth by risking his reputation as a man of discernment in order to furnish an irrefragable proof of that truth.³⁹

‘Beaumarchais himself would not have disavowed such a script,’ was Duhem’s first remark which fell short of the heart of the matter. More was in fact at issue than Tannery’s fate visibly hastened by the blow which destroyed his prospects of escaping the drudgery of his post as a State superintendent of tobacco manufacturing and of earning his livelihood at long last as a full-time professional historian of science. A few months after Tannery presided in 1904 at the Congrès International d’Histoire des Sciences in Geneva, the first of its kind, ‘the sickness engendered or aggravated by the bitter disappointment felled the most eminent historian of science in France.’ The real issue was, however, in Duhem’s eyes the lack of integrity leading to a tragedy: ‘An injustice produces at times grave though remote consequences. The one who did the injustice will have to answer for the remotest results. Is this principle of ethics kept in mind by those who place in the service of sects and parties the power with which they were entrusted for the sake of the public good?’⁴⁰

Accepting favors or honors from those who in his belief abused the public good was incompatible with Duhem’s notion of integrity. Such an honor would have been the Légion d’honneur bestowed at that time by such an anticlerical stalwart of

38. Duhem could have learned from Jordan, who was among the 39 professors of the Collège de France voting in the session of November 8, 1903, that in the second balloting Tannery obtained absolute majority (with 21 votes against the 19 votes cast for Wyruboff) as first choice for the chair. See also the dossier quoted in note 35 above for the handwritten report of the Collège to the Ministry of Public Instruction.

39. 1905 (17), p. 229.

40. *Ibid.*, p. 230. The cause of Tannery’s death was spoken of in exactly the same sense by G. Milhaud, a historian of science very different in his outlook from that of Duhem, in his *Nouvelles études sur l’histoire de la pensée scientifique* (Paris: Alcan, 1911), p. 20. In a shorter necrology, 1905 (18), Duhem recalled Paul Tannery’s active work and interest in the Société des sciences physiques et naturelles de Bordeaux in whose *Mémoires* Tannery published in 1876 his first study of the history of Greek mathematics. Tannery, a mechanical engineer by training, was employed in the French state industry of tobacco manufacturing and twice spent three years in Bordeaux (1874-77 and 1887-90) prior to his promotion to the directorship of the same industry in Paris. The tone of the letters that Duhem received from Paul Tannery’s widow (and eight years later from Jules Tannery’s widow) reveal not only the warm esteem in which Duhem was held by the Tannerys, but also the moving tactfulness with which Duhem could offer solace to the bereaved.

the Republic as Aristide Briand. Some in Paris obviously felt that Duhem would be disarmed by accepting that honor, which, it should be recalled, lost much of its lustre a few years earlier, when its distribution for money brought about the registration of Jules Grévy from the Presidency of the Republic.⁴¹ Furthermore, it was natural to confer that honor on a professor with rapidly increasing reputation. Duhem's declining the honor with mere words was not apparently convincing to his dean, Padé, who on May 7, 1908, sent him the following letter:

With spring comes the time of listing candidates for honors. Have you reached a more favorable view with respect to the Légion d'honneur? There is none among us who would deserve it so much as you and it is very troubling for me not to present you ahead of all others. It seems as if I failed in my duty. Make my task easier by authorising me to propose your name. I will be very grateful.⁴²

Duhem's reply to the dean's letter, which was to impress him also by its 'tutoyer' style, was prompt and categorical:

I hasten to seize the occasion to repeat to you in writing what I had the honor of conveying to you in words a few months ago. I will be very grateful if you were not to propose me for the Legion d'honneur. In fact, were that distinction offered to me, my principles would force me to decline it. By not proposing me, you would avoid a scandal which I do not wish to produce.

If you would kindly deposit this letter in my dossier, it would prevent anyone from ever giving an inexact interpretation of the fact that you have not presented me for the honor.

I consider myself very honored by your wish which you manifested by recommending me for the decoration and I beg you to believe in my most respectful sentiments.

The principle of integrity which Duhem imposed on himself, made him ready to forego even greater honors.⁴³ He did not therefore use double standards in expecting others, especially his younger relatives, to sacrifice advancement when the same principle was at stake. When his nephew, Maurice Chayet, a law student, informed him with obvious satisfaction, in July 1916 that he had been accepted as a secretary by Léon Bourgeois, President of the Senate and a chief anticlerical,⁴⁴ Duhem replied:

41. By the early 1900s the value of the decoration (instituted by Napoleon) was also reduced by 'inflation,' that is, by the too large number of recipients. Because of this the number of soldiers, dispatched by law to the funeral of every recipient, had to be reduced from eight to one (see R. Burnand, *La vie quotidienne en France de 1870 à 1900* [Paris: Hachette, 1947], p. 161). This was the source of many amusing comments which could not be unfamiliar to Duhem. As to our times, a reporter of the fiercely independent *Le Canard enchaîné* lost his job for wearing the ribbon of the Légion d'honneur. 'But I did not ask for it,' he protested to the Editeur, who replied: 'Well, you shouldn't have done anything to deserve it' (TIME, October 29, 1979, p. 99).

42. The French original of this letter and Duhem's reply to it were printed in *Un savant français*, pp. 133-34.

43. Such as membership in the Académie des Sciences, as will be seen shortly.

44. If Bourgeois is today remembered at all, it is because of his indefatigable work for the establishment of the League of Nations, for which he received the Nobel Peace Prize in 1920.

My dear Maurice! You have told me that you were the secretary of Léon Bourgeois. I did not want to believe you. You confirm the news and add: 'You can imagine how interesting this work is!' No! I do not think that for a young man, who bears the name of honest people and of loyal Catholics, it should be interesting to enter in the service of a Pontiff of Freemasonry whose thinking is false and hollow and whose heart is vicious. As long as you are floundering in that milieu I want to forget that I am your uncle and I would be grateful if you don't speak of me to my friends. When you return to the midst of honest people, the prodigal son you are will again find all my affection.
P. Duhem

Twice bereaved

Such intransigence rarely took an aspect of harshness, and never at home. He let both his mother and daughter share the exciting moments of his exploration of a land, which in early 1904 suddenly emerged on his mental horizon, the land of medieval science. Jordanus Nemorarius, Buridan, Albert of Saxony, and Oresme became familiar figures in the household as Duhem began to carry home medieval manuscripts from Paris and elsewhere which he collected from the University library. They saw him deciphering arcane texts, filling notebook after notebook with passages from them,⁴⁵ and heard him conceive one vast project after another.⁴⁶ His mother must have seen this further outburst of his seemingly inexhaustible energy in the perspective which she tried to impress on him almost twenty years earlier. The perspective was her son's youth and his antagonists' age. Duhem's mother was not to witness that perspective come true. In the spring of 1906 her strength began to fail her. As her granddaughter put it in tender words:

The energies, which good Mme Duhem dispensed so generously for her own beloved ones, suddenly diminished during the last months of her life. All the crosses, which she bore heroically in the silence of perfect Christian resignation, seemed to crush her shoulders. Her personality became overcast, finding serenity only in almost continual prayer and in the acceptance of an approaching death. Her son and daughter shared the last weeks of a life which was being extinguished.⁴⁷

Madame Duhem's death, in the evening of August 26, 1906, came nevertheless with some suddenness, in a few hours, though without agony. She was staying with her daughter in Saint Martin-du-Tertre, the little village which thirty or so

45. He filled over one hundred notebooks (21 × 17 cm) each with about 200 pages, now in the Archives of the Académie des Sciences. The drudgery is charmingly described in *Un savant français*, pp. 192-93.

46. As recalled by his daughter (*Un savant français*, pp. 191-92), who added: 'How overwhelmed was Pierre Duhem on making an unexpected discovery and how, in the evening, he hastened to share it with his daughter!' (*ibid.*, p. 197).

47. *Ibid.*, p. 188. The beautifully printed obituary notice gives the date of death as August 28. Duhem's sister is listed there as Mère Marie Dominique de Jésus, and her address as Abbaye aux Bois, 16 Rue de Sèvres, Paris. Marie Duhem seems to have found hospitality in that 'abbey,' a part of which was left as secular residence for Augustinian nuns to whom it belonged prior to the general dissolution of monasteries in France in 1905. From 1912 on Marie Duhem lived in Belgium as a nun, but returned after World War I to France where she died in the 1940s.

years earlier saw her, and her husband and children enjoy the summer. That Pierre Duhem was away when his mother died made the blow, heavy in itself, even more painful for him. For human solace he turned to one of his best friends, Edouard Jordan. The latter recalled, though with no reference to Madame Duhem's death, that in 1906, after four years of interruption, he and Duhem again spent together part of the summer vacation. Jordan's words, 'in 1906 we could once more pass together a few days in Rozier in the Gorges du Tarn,'⁴⁸ are worth a comment or two. Far off the main roads even today, Rozier and the Gorges du Tarn would hardly have been the choice of Duhem while his mother was visibly ailing. Very likely he went there in the company of his trusted friend after his mother's death, that is, in the early part of September.

Happily for Duhem, he could not suspect that, in a less tragic sense, he would be soon bereaved of his daughter as well. Her recollections about becoming an inseparable companion of her father as he hiked in the hills and valleys around Cabrespine, belong to these years:

The outings were at first proportioned to the little legs but soon the little legs trotted as fast as those of Daddy. It was then, during so many happy years that they explored, up and down the hills, the entire region knowing the smallest paths, visiting the isolated hamlets and the outlying farms, enjoying all the beautiful panoramas which one finds from the peaks to be reached by a tough ascent through thorns and rocks, under the blazing sun, tired and thirsty.⁴⁹

Relishing the beauty of nature opened by such outings shows an affinity between father and daughter in which the former obviously took a quiet though great satisfaction:

But at the top, what a recompense! The joy over a well done effort, over an obstacle conquered, the fresh air giving repose, a feeling of the infinite in the face of the faraway horizon! The ravished eyes of the two hikers discover an admirable panorama which the father explains to the child, indicating to her the peaks, so easy to recognize, of the distant Pyrénées emerging from the haze of the horizon, whereas the Corbières with the hollow of the Alaric burn in the sun, and one is given to the amusing search for the silhouette of the towers of Carcassonne in the plains at the foot of the Montagne Noire.⁵⁰

Such exploits were in a sense more suited for a boy than a girl, but as we are told in the same context:

Pierre Duhem raised his daughter a bit like a son (undoubtedly with a thought of that little Pierre whom he had wished for so much). With him one had to be intrepid, to fear no cold, no heat, no rain, to endure thirst when no springs were found along the route, to ignore precipices, and at times even to kill, without trembling, a viper . . .⁵¹

Through the hikes young Hélène even obtained frequent glimpses of some of her father's trusted friends:

48. Jordan, 'Duhem,' p. 169.

49. *Un savant français*, p. 103.

50. *Ibid.*, p. 104.

51. *Ibid.*

How many times, in the full month of August, immediately after the midday meal, at the hour of the cicadas, did he depart in the company of his daughter, to reach, in two hours' walking, a little village [Pradelles-Cabardès] on the slopes of the Pic de Nore. The curé, the Abbé Bernies, who since died as curé of Limoux and canon of Carcassonne, wished to pursue philosophical studies. Pierre Duhem lent him books and instructed him above all through conversations. He used to find there at the rectory of Pradelles-Cabardès, two professors of the Institut Catholique de Paris, the Père Bulliot and the Père Peillaube. It was there, with them, under the centenarian shadows of a beech tree, that the founding of the *Revue philosophique*, of which the Père Peillaube was the director, was conceived and put into planning.⁵²

Thirty years later, the Abbé Peillaube disclosed that not all the three 'founding fathers' were under that beech tree when the hour of decision came about a plan that had been pondered since the previous winter. Several days of discussion at Pradelles-Cabardès failed to set things in motion until, one early afternoon, all three felt strengthened by the white wine ('Blanquette') of Limoux. One of them, quite possibly Duhem, felt so strong as to climb high in the tree, the two others lying on the grass below. 'If only we were to found it!' exclaimed Duhem, and dangled before the mental eyes of the two others a most attractive bait: 'I have just completed a volume on the notion of mixed [compound] bodies.⁵³ I give you the manuscript.' With that the *Revue* was founded.⁵⁴

While these happy vacations in Cabrespine were to repeat themselves as the years went by, from 1908 on Duhem found himself more and more often alone in his house in Bordeaux during the academic year. In 1908 he took his daughter to Paris and left her in the care of his sister who was to introduce her to friends and relatives and, last but not least, to the capital's cultural riches. The visit, only a month long, was all too long for father as well as daughter, but hardly long enough for Duhem's sister. The next year another visit followed at the request of Marie Duhem who, as one of those many thousands of nuns banished after 1905 from their convents, longed for her niece's companionship. It was then that Héléne became acquainted with the 'Maison et l'oeuvre de St. Agnes' in Thiais, about 25 km south of the centre of Paris. A two-story house with a chapel and a garden, the Maison was founded in 1893 by the Comtesse de la Girennerie, wife of a retired general, to provide young working girls with moral guidance while helping them find suitable employment.⁵⁵ A part of the house served as an atelier where children's dresses were made for an annual charity sale. Héléne first took up residence in 1909 in the Maison as a paying associate to help with the charitable work which included regular visits with needy families of the neighborhood. Soon her pattern of life was established. After spending four months (mid-July to mid-November) in Cabrespine, she closed the house there for the winter and moved

52. *Ibid.*, pp. 104-05.

53. Reference is to 1901 (1) and 1902 (2).

54. 'Trentenaire de la 'Revue de Philosophie', *RP* 31 (1931):11.

55. The house (1 Rue de la Bézonne) had to yield in the early 1970s to urban renewal which changed even the name of the street (communication of Mr. R. Laporte, maire adjoint, Thiais).

directly for about eight months to Thiais where her father visited her during the Easter vacations and around Pentecost – cherished opportunities for both to see one another and the relatives, and to explore together the museums of the capital, especially the Louvre.

Whatever of H el ene’s fondness for the Maison, it may not have been the ideal place for her. It certainly failed to satisfy her brilliant mind. Not that the ‘Cours D esir,’ which she followed as a teenager, was not a progressive program, and certainly it was replete with a Catholic spirit that simply did not exist in the lyc ees for girls, which the Republican government hastily set up in at least the major cities around the turn of the century. The problem Duhem tried to cope with transpires well from the letter he wrote to his mother in 1906, a few months before her death, the time when suddenly even the relatively few remaining Catholic secondary schools in France were closed at least provisionally. ‘This course,’ Duhem wrote, ‘is given by women who in a sense form a religious order, but neither wear a habit, nor [are constrained by] anything which would cause problems. The course is oriented in the direction I hoped for; it has as goal the formation not of schoolteachers, but of cultured women at home in society.’ Under the circumstances the ‘Cours D esir,’ offered by members of a quasi-religious order founded by Adeline D esir (1819-1875),⁵⁶ was probably the best option for Duhem concerning H el ene’s education beyond elementary level. That she was not given an education preparing for university studies may have had to do also with her character and also with her feelings for some religious vocation. She was at times impetuous and not as careful with money as was her mother. Something of such problems transpires from a letter of Duhem to Mlle de la Girennerie, daughter of the Comtesse, who by 1909 was in charge of the Maison. On being informed by his daughter about the annual sale, Duhem wrote:

H el ene tells me that this coming Monday you will have a charity sale and that she will have the honor of being a saleslady. What do you sell? Clothes for little boys? Unfortunately, the little Pierre Duhem, of whom we dreamed ever since we were married, has remained in the ‘nowhere.’ There is, however, an item of which I have a great need and which, I believe, is made with perfection [at your establishment]: a moral outfit for a young Christian woman, large enough to give her all the freedom of her personality, sufficiently tight to refrain the excesses of her temperament, fairly accommodating so that she may judge with understanding the excesses of others, and rigid enough to keep her firm and straight in the path of duty. You know for whom I intend that dress. I beg you to take the measurements. Such dresses are being paid for by gratitude, especially by prayer to God, but God himself has instructed us that care for the daily bread can be joined to prayer. Allow me, therefore, by asking Heaven to pay in supernatural money

56. Mlle D esir’s interest in the sciences is especially worth recalling. Her speech on the role of science in the education of young women, given in the headquarters of the Cercle des Soci et es savantes on December 19, 1865, created such an impression as to invite publication in the *Revue des deux mondes* (see O. Butsch, *Une  ducatrice d’avant-garde, Adeline D esir 1819-1875*, pr eface de Gaston Brillet [Paris: La Colombe, 1956], p. 41).

my non-material purchase, to put into the purse of your cashier my little contribution to the daily bread of the Mutual Assistance.⁵⁷

Duhem had some misgivings about the wisdom of his daughter's decision to tie herself too closely to the group at St. Agnes,⁵⁸ but he kept his feelings to himself, especially the one deriving from the prospect of remaining alone for the rest of his life. He had but on rare occasions the kind of joy which the unexpected visit, in June 1912, of his former student, Paul Saurel, brought with it. Saurel was accompanied not only by his wife, but also by his three children, two girls and a boy, who to Duhem's immense satisfaction spoke fluent and accentless French. He sought relief from his solitude by sending daily a letter to his daughter, who especially recalled the one in which over the dateline stood the words, 'Today it is four months since I have seen my little one.'⁵⁹

Duhem tried to lessen his sense of bereavement by sharing his daughter's big and small concerns. As her daughter's dog 'Boy' was his sole companion on many a day, Duhem readily reacted to news about two dogs in the Maison St. Agnes. He wrote to the treasurer there, a special friend of Héléne:

You have, I am told, two dogs; one, called Tobie, is a good animal; the other, Traites, is a beast who barks at people and rejoices in pressing against them. Tobie eats white paper, Traites prefers blue. I send you something to feed both. To Tobie give this letter to devour; for Traites I send you nine prints bathed in Pompadour color. . . Once Traites swallows them, I hope he will go on digesting in silence and will be no more at your heels.⁶⁰

His longing for the warmth of family was all too evident in a letter to Héléne who took special interest in Gino, the little son of a poor couple in Thiais. Little Gino, who at Duhem's invitation was taken for a summer in Cabrespine to let the country

57. Quoted in 'In Memoriam P. Duhem' (*Cahiers catholiques*, Feb. 10, 1922, pp. 1085-86) by the Abbé L. Garzend, who obviously was connected with the Maison.

58. In the long run Héléne's association with the Maison proved disastrous. Being rather indecisive, Héléne came so much under the influence of the directress, Mlle Girennerie, as to make the Maison the legal authority over all her possessions, including the house in Cabrespine. Sometime in the 1920s Héléne lost her possessions owing to some actions legally, though not morally, unobjectionable on the part of some connected with the Maison. It was through the Dufourcqs and the Abbé Blanc in Cabrespine, who died there in 1936 after serving the parish for 46 years, that the house was recovered for Héléne (communication of Mr. Norbert Dufourcq). Ironically, it was not without Duhem's influence that the Académie Française awarded, in 1913, one of its minor prizes, the Prix Agemoglu, worth 1500 francs, to 'Dame de la Girennerie, Marie Thérèse, directrice de l'Atelier Sainte-Agnès, à Thiais, Seine.' See *Institut de France. Académie Française. Institut 1913-27. Séance publique annuelle du jeudi 27 novembre 1913 présidée par M. René Bazin* (Paris: Firmin-Didot, 1913), p. 55 (section: Fondations destinées aux actes de vertu).

59. *Un savant français*, p. 215. Since Héléne rejoined her father in Cabrespine for several months during the summer, most of those letters were written between November and early June from 1909 until 1916. They will be available for study in 1991, the hundredth anniversary of Héléne's birth.

60. Quoted in Garzend, 'In Memoriam P. Duhem,' pp. 1084-85.

air improve his health, was thrilled by the sound of Duhem's big pocket watch. For Gino, Duhem quickly became 'Monsieur Tic-Tac.' Duhem was no less pleased, as he added to a letter to Hélène:

My dear little Gino. It is very kind of you to think of your old friend, Tic-Tac. He often thinks of your big dark eyes. He thinks that you are trotting around in the house and bring there the happy sunshine of your laughter while it rains outside. He would like to be near you and take you in his big arms. Give him your little hand. He will breathe a kiss on it and say: Gino, eat well and sleep well in order to have big rosy cheeks, Tic-Tac.⁶¹

No wonder that Duhem looked forward to the summer months in Cabrespine where the ancestral home became even legally his own. Aware of her son's preference for exploring various parts of France during the summer vacation, Madame Duhem did not wish to tie him down to the ancestral home in Cabrespine. She willed it to her daughter with the condition that 'this little property, a family citadel, may never leave family hands and never be sold.'⁶² But the care of the house, called l'Oustal des Alègres, soon proved too much of a burden for Marie Duhem. In 1910 the ownership of the house was therefore transferred to Duhem who now began to look after it as a sacred bequest from his mother. While previously Duhem spent in Cabrespine at most the last few weeks of the summer vacation, from now on that little village found him there (his daughter and at times his sister too), all August, September, and much of October.

The people of the village soon became his family. Every Sunday, after mass, the children flocked to his house to enjoy his presence, hardly less pleasant than the chocolate with which he kept regaling them all.⁶³ Time and again, villagers, all too respectful of the mayor and of his second in command, asked the simple professor, whom they fondly called 'Monsieur Pierre,' to handle their affairs. Once matters had to be carried as far as Paris when an old Cabrespinois, a veteran of the Italian war (1867), approached him as one who 'knows the people up there.' At issue was the veteran's pension, the sole revenue of a large family, which was suddenly axed by those 'high up.' Monsieur Pierre's first thought was to write to the Ministry of War but he soon realized the high probability of his letter being caught in the slow wheels of bureaucracy. A few days later a better idea came to him, although it meant an act of humility on his part. He thought of his former colleague and one-time friend, Painlevé, with whom he had had no contact for over a decade and for the likely reason that by the 1910's Painlevé was as successful in the political world as he had been in the world of the academia. The letter was written and the pension was restored in a fortnight, an outcome which remained the talk of the village for months.⁶⁴

61. *Ibid.*, p. 1085.

62. *Un savant français*, p. 216.

63. As I was told by several octogenarian villagers during my visit in Cabrespine. One of them spoke of a huge album, kept in the church, for catechetical instruction, full of drawings by Duhem of biblical stories from the Old and New Testament. 'The heavens were high up, the hell deep below,' was his reminiscence of Duhem's illustration of the fall of Lucifer.

64. *Un savant français*, pp. 175-76.

The people of Cabrespine must have been deeply moved as they learned of Duhem's arranging for the transfer of a young shepherdess⁶⁵ afflicted with tuberculosis to a sanatorium in the famed Le Molleau, a suburb of Arcachon on the Atlantic coast, about 50 km southwest of Bordeaux. More difficult would be to evoke their sentiments as word passed around that 'Monsieur Pierre' was taking the train on many Saturday mornings over several years to visit the young shepherdess. He brought her news of her family, talked to her of the mountains and the sheep, and saw to her needs. The simplicity of the shepherdess proved in the long run no less creative than that of her famous protector. Following her cure, she entered, after World War I, the order of nuns of the 'Doctrine Chrétienne' in Bordeaux, and made her final profession under the name, 'Soeur Saint-Pierre.' The story of the little shepherdess did not end there. One part of the story was her starting, at the order of her superiors, studies for a certificate in nursing. Although prior to her arrival in Le Molleau she had always been in the fields and never inside a school, she successfully completed her training for the certificate to the astonishment of all and especially to her own.⁶⁶

Another part of the story is in a letter which was sent on February 25, 1916, to Duhem by a young woman, a schoolteacher, who, while herself hospitalized in Le Molleau, became good friends with the shepherdess and also a beneficiary of Duhem's weekly visits:

Every day I thank God, that very God to whom you have led me back. Why should I not tell you? Much more than the exhortation of the Mother Superior in the workshop, much more than the arguments of a good priest from Bordeaux, you have made me come back to God. How? Not by your direct words, because the conversation never touched upon the subject of religion, but by your example. I have felt that you yourself accepted nothing without inquiry, that after all you reached much higher in the realm of thought than I did. And often when I am fluctuating – because I shall never have the good fortune of a peaceful faith, safe from all dispute – I think of you, and say to myself: others, who know better and more than I, have believed, therefore why should not I do as they?⁶⁷

By 1916 Duhem's love for the sick and the poor had become legendary around the Rue de la Teste. He would have done more than the ordinary had he spent but the latter part of every Friday afternoon in the hospital around the corner where he went to comfort those sick and elderly whom nobody came to visit. The Franciscan nuns running the hospital followed him on his search for the lonely sick in

65. *Ibid.*, p. 178. The little shepherdess, Marie Louise Gabaude, of Trausse, a village near Cabrespine, was born in 1894 and died in 1970. One of her brothers (Marcellin) became, quite possibly through Duhem's generosity, a priest in the diocese of Carcassonne and served until his death as pastor of Citou and Lespinassière, two villages near Cabrespine. Marie was cared for in the preventorium Armaingaud, which was taken over in 1950 by the Sisters of Charity from the Sisters of the Doctrine chrétienne.

66. *Un savant français*, p. 178. Soeur St. Pierre's last station as registered nurse was at the Clinique St. Seurin, Bordeaux (1950-65) (information obtained through the kind cooperation of Prof. A. Charru, Bordeaux).

67. *Un savant français*, p. 179.

dark mansard apartments and regularly sent to him those in need. At times the needy formed a line at his door but nobody was sent away, not even that poor fellow whose daughter served as a guide, part of his scheme to affect blindness. One day, toward the end of June 1916, he happened to be without his guide near Duhem's house when Duhem suddenly appeared in the street. Forgetful of his scheming, the blind man 'noticed' Duhem with a loud greeting. Duhem, without revealing it, was stunned to see himself taken in for so long a time, and vowed to his daughter to turn the 'blind' man away in the future. A few days later the 'blind' man showed up again, this time with his guide, and rang the doorbell. Duhem opened the door. 'Now Papa,' Duhem's daughter asked, 'have you shown him out?' 'Well, I administered him the reproaches he deserved, but also gave him a small alms which he hoped for. What do you expect? . . . He is after all a poor wretch.'⁶⁸

Relentless work and growing recognition

By 1916 Duhem had, of course, been for some time the pride of Bordeaux and of its university. In a trivial sense the reason for this rested on the fact that Duhem indeed was, as his mother told him many years earlier, much younger than most of his antagonists. Berthelot, as was seen, began to relent in his hostility toward Duhem four years before his death on March 18, 1907. Although some antagonists, like Lippmann and Le Chatelier, remained on the scene, in that year Darboux succeeded in what he had failed two years earlier, namely, to secure unanimous support on behalf of his move to make Duhem the recipient of the much coveted Petit d'Ormy Prize for 1907.⁶⁹ The prize, established in 1895 for excellence in pure and applied mathematics, was worth 10,000 francs or 2000 francs more than Duhem's yearly salary between 1904 and 1910. The commission which chose Duhem had Picard, Jourdan, Darboux, Poincaré, Appell, Painlevé, and Humbert as members. Official declaration of the award came in the public meeting of the Académie, on December 2.⁷⁰

If Duhem had been present at that public session, he could have found satisfaction much more subtle than the Prize itself. In addition to the statements and ceremonies connected with the various prizes, the annual public session was also the occasion for eulogizing members of the Académie who died during the year. Duhem would have mused on finding how prophetic were his words written ten years earlier on the thinning out of the number of French chemists who had respect for Berthelot's favorite theory. In the long eulogy by A. Chaveau there was no reference to the principle of maximum work. Not even the word 'thermochimie' was uttered, to say nothing of the name of Thomsen. The eulogy was no less revealing for its hapless justification of the worship of science as advocated by Berthelot:

68. *Ibid.*, pp. 180-81.

69. See *CR* 144 (1907):476. Darboux spoke of his earlier failure in the confidential congratulatory note which he sent to Duhem on June 29, 1907.

70. See *CR* 145 (1907):1059.

Berthelot has indeed written the famous phrase: the world today is without mystery. But for our great confrère this was only a figure of speech, a picturesque way of rendering homage to science, the object of his cult, the divinity which inhabited his thought. This imagery was rather allowable for a savant who could dissipate much darkness. Clearly, he was able to see the universe with the eyes of the inspired prophet for whom the future and faraway conquests of science appeared in their radiance as truths actually demonstrated.⁷¹

Such defense of a patently misplaced reverence for science proved that in thinking about science all too often little if any role is left to objectivity, and especially to that scrupulous kind with which Duhem had already weighed the merits of physical theory. Public recognition of Duhem, the theoretical physicist, was soon followed by his being acclaimed as a historian of science when the Académie conferred on Duhem the Prix Binoux at its annual meeting on December 20, 1909.⁷² The timing could not have been more appropriate. The year 1909 not only saw the publication of the second volume of Duhem's Leonardo studies, but also the printing in one volume of his studies, from the Greeks to the late 19th century, of the question of absolute and relative movement,⁷³ studies that originally appeared during the two previous years in the *Revue de philosophie*, the periodical which he helped launch almost a decade earlier with a similarly massive contribution. In addition, to mention only the outstanding items, in 1909 Duhem edited with a long introduction a medieval Latin manuscript, which he was able to identify as a genuine part of Roger Bacon's *Opus tertium*.⁷⁴ For any of these works the Prix Binoux would have been well merited. Their publication within a single year was all the more a superior feat as during the previous year Duhem gave in the pages of the *Annales de la philosophie chrétienne* in four consecutive issues, between May and September, a book-length study of the history of the famed motto 'to save the phenomena,' from Plato to Galileo.⁷⁵

The last work, a sort of gem even for a classical scholar, was also a proof that Duhem's chief interest in the history of physics remained firmly rooted in his quest for a proper understanding of physical theory. For even in those very years of 1907-09, during which his publications may have given the impression that Duhem was exclusively a historian and had no other obligations, he remained the theoretical physicist he always considered himself. Of course theory for him was above all the proper classification of data which only thorough experimentation could obtain. There he faced considerable odds as attested by a paragraph in the section drafted by dean Padé for the *Rapport du Conseil*, which may very well have had Duhem as its inspiration:

71. *Ibid.*, p. 974.

72. *CR* 148 (1909):458 and 149 (1909):1279. As if by irony, the same page carried the notice about the awarding of the freshly established Médaille Berthelot.

73. 1907 (5-7), 1908 (1-9), 1909 (10, 11).

74. 1909 (1).

75. 1908 (19), 1969 (1), and 1982 (1).

A proper storage room of physics instruments, the object of the most legitimate pride of any science faculty, does not exist here, and we could not, without blushing, show to any professor, however insignificant, or to a foreign scientist coming to visit our installations, our collection of instruments, of which several are not without value, but which are dispersed in cabinets wherever they could be placed, in the most diverse corners and hallways. The few rooms, where research in physics can be (and is indeed) carried out, are just as deficient from the point of view of lighting and would in no way suffice for work for a diploma of higher studies in physical science if *two* candidates presented themselves at the same time for such a purpose.⁷⁶

Whatever the cramped and haphazard circumstances, Duhem did not fail to assert his love of order. An unexpected witness of this was the British physicist, G. H. Bryan, who went in 1901 to Bordeaux to see Duhem and who recalled years later the efficiency with which Duhem performed experiments in radioactivity with a simple apparatus, which Bryan favorably contrasted with the more elaborate but 'more dusty' pieces which he had seen in Boltzmann's laboratory in Vienna.⁷⁷ While with respect to doctoral research carried out under Duhem's guidance Bryan's other remark, that Duhem needed no elaborate instruments, was wide of the mark, it could be justified with respect to Duhem's own preferences in theoretical physics. Duhem not only had been wedded to it since his days 'at the Ecole Normale, but relentlessly worked on its further elaboration to the very last, even when his voluminous publications on the history of science seemed to leave him with no time for anything else.

The special advanced course which he gave each year was devoted between 1904 and 1909 to generalized thermodynamics under the name of energetics.⁷⁸ Once more he gave evidence of the rigor with which he was able to arrange his material years ahead of the actual discussion of particular topics. Thus no sooner had the course been completed than the manuscript of the *Traité d'énergetique* went to the publisher Gauthier-Villars which brought out the entire work in two massive volumes in 1911.

His wholehearted devotion to the experimental basis of theoretical physics was certainly in evidence in the doctoral research which Mme H. Baudeuf (née Bayard) defended in 1908 under the title, 'Action de la lumière sur les faux équilibres électriques.'⁷⁹ But other doctoral candidates failed to come forth. Also, although for years the students, whom he prepared through special courses for the competitive exams for agrégation in Paris, had invariably scored very high, his efforts were increasingly thwarted by official directives concerning the aspect of

76. *Rapport 1906-07*, pp. 105-06.

77. So Bryan recalled shortly after Duhem's death in *Nature* 98 (1916):132 (October 19). Bryan was the leading exponent of classical thermodynamics at that time in England and was invited to write the book-length essay on the general foundations of thermodynamics in the *Encyklopedie der mathematischen Wissenschaften* Bd. 5, Teil 3 (Leipzig: B. G. Teubner, 1904), pp. 71-160.

78. Duhem used the word energetics in that sense already in the first volume of his *Traité élémentaire de mécanique chimique* (1897). The course which Duhem gave in 1898-99 on 'thermodynamique générale' had 'énergétique' for its unofficial title, as attested by Paul Saurel's notebook, of almost 200 pages, of it.

79. *MSScPhNB* 4(1908):161-268.

physics to emphasize for such exams. As a result, from 1908 on he left these courses to his colleagues. His regular course in advanced physics was between 1904 and 1908 on generalized thermodynamics (energetics) and from 1908 on various aspects of optics, especially in reference to crystalline and isotropic media. That his teaching load was small finds its explanation in the small number of physics majors and the growth of the physics faculty to five members (another professor and three assistant professors). It was the latter who took care of the general physics course to be taught to non-physics students.

Following the death of Bizos in 1905 there was no further hindrance within the University to let its appreciation flow freely toward Duhem. Gone were the years when Duhem was depicted in the confidential yearly reports as one 'who breathes constantly division and discord' (1901-02), 'a perpetual firebrand who carries war everywhere he goes' (1902-03), qualifications which curiously contrasted with Duhem's description in the same reports as an 'incomparable teacher most devoted to his task.'⁸⁰ But already in May 1905 it was stated in the report that his 'rights to generous considerations on the part of the Administration keep increasing.'⁸¹ Although the new rector, Padé, still felt it necessary to speak of Duhem's 'bad character,' he added almost apologetically: 'Men of such caliber must be taken as they are.' He saw with his own eyes that caliber as he attended in 1905-06, as part of his official duties, a lecture of Duhem: 'Although the lecture was above my competence, everything appeared magisterial: the audacity of the debate, the elevated viewpoints, the ease of solving the difficulties raised.'⁸² At the end of the next year, Padé, in recommending Duhem for the Cross of the Légion d'honneur, added: 'The University honors itself by honoring him.'⁸³ By 1909-10 Padé was forced to admit not only that 'a sort of veneration surrounds Duhem,'⁸⁴ but also, unwittingly, the real reason for Duhem's difficult character: 'As a man he is apt to be indignant. But I have never seen him cause any difficulty except when he believed that common interest was violated.'⁸⁵ In 1911-12 Duhem was a 'professor who brings the greatest honor to the University of Bordeaux.'⁸⁶

In 1913-14 he was described as 'an admirable professor; a scientist whose praises I cannot emphasize enough; but who works' often to the exhaustion of his strength.'⁸⁷ In all likelihood it was that last remark that pleased Duhem most.

80. Dossier Duhem, p. 56.

81. *Ibid.*, p. 60.

82. *Ibid.*, p. 56.

83. *Ibid.*, p. 50.

84. *Ibid.*, p. 38.

85. *Ibid.*

86. *Ibid.*, p. 32.

87. *Ibid.*, p. 20. Those who were not biased against Duhem could be appreciative of his contributions with no reservations whatsoever as shown by the letter which Radet, dean of the Faculty of Letters, wrote on May 18, 1912, to Duhem: 'Cher ami, je t'adresse au nom de la Faculté et au mien nos remerciements les plus vifs pour la série de leçons que tu a très bien voulu faire à nos étudiants d'agrégation. Le Recteur m'a dit qu'elles avaient été admirables de maîtrise et de clarté. Je n'en suis pas surpris. Mais il est toujours agréable de pouvoir renforcer et rajeunir un vieux fond d'estime et d'affection. A toi de tout coeur.'

It was almost symbolic that the last confidential remark sent about Duhem to the Ministry in June 1916 attested to his renown as a historian of science. It was as such that Duhem worked during his last five years to exhaustion. Part of his strength was spent on his public course given since November 1909 on a subject which first reveals his groping toward the gist of the *Système du monde*⁸⁸ and, from 1911 on, the successive steps he made in the execution of the great project. These courses were announced on large posters⁸⁹ which had the general heading: LEÇONS SUR L'HISTOIRE DES SCIENCES. The poster for 1909-10 carried no specification of the subject. The poster for 1910-11 specified the general topic as LA FORMATION DU SYSTÈME DE COPERNIC, with a subtitle, 'La Période Gréco-Arabe.' From 1911-12 on the general title was LES DOCTRINES COSMOLOGIQUES DE PLATON À COPERNIC which became the subtitle of the *Système du monde*. Duhem gave as subtitle 'La scolastique latine jusqu'à l'an 1277' (1911-12), 'Les Ecoles dominicaines et franciscaines au XIII siècle – L'astronomie parisienne et l'astronomie italienne au XIV^e siècle' (1912-13), 'Le néoplatonisme arabe et les moteurs des cieux' (1912-14), 'La création de la mécanique moderne à l'université de Paris au XIV siècle' (1914-15), 'La science parisienne au XIV siècle – Equilibre de la terre et des mers. Origines de la géologie' (1915-16). The lectures, held on each Tuesday at 5:30, drew over the years a steady audience of about a hundred to one of the great amphitheatres of the University at the Cours Pasteur from late November until late Spring.⁹⁰

In his whole academic and scholarly career nothing gave him as much satisfaction as the decision, in early 1913, of the Ministry of Public Instruction to buy 300 copies of each volume of the *Système du monde*, a decision which secured publication for that monumental opus. His first reaction was to write to the directress of the Maison St. Agnes: 'I have promised the Virgin Mary that if I succeeded in publishing my great work . . . I would give to [the Maison] St. Agnes 100 francs. Here it is.'⁹¹

With the publication of his great work secured, he wanted to eliminate as much as possible all projects, invitations, and offers that would interfere with its being carried to completion. In 1914 he declined a lucrative commission which in itself would have demanded of him no special effort, Hanotaux, chief architect of a multivolume history of France, including cultural as well as political development,⁹² did his best though in vain⁹³ to secure Duhem for writing the section on

88. It is well to recall that after the *Origines de la statique* he wanted to write a similar book on dynamics. It was that book, projected as 'Origines de la dynamique,' that finally became *Le Système du monde* (see *Un savant français*, p. 191).

89. A copy of these posters was promptly secured for the Archives of the University of Bordeaux, in evidence that by then awareness was growing of their historical importance.

90. According to the 'renseignements' in the Dossier Duhem, his audience in 1911-12 varied between 50 and 200; in 1913-14 averaged about 60; in 1915-16 about 100 (Dossier Duhem pp. 29, 19, 11).

91. Quoted in Garzend, 'In Memoriam P. Duhem,' p. 1082.

92. Published between 1920 and 1929 in fifteen volumes under the general title, *Histoire de la nation française*, (Paris: Plon-Nourrit).

93. In three letters in early December 1913.

the history of physics, including medieval science. Duhem undoubtedly could have done it in two months' time as the subject was not to be heavy on scholarly details.⁹⁴ With an eye on the *Système du monde* Duhem said no, although the honorarium would have almost equalled his yearly salary. To friends, who felt that a lifetime was required for bringing the *Système du monde* to completion, he kept saying that if the work was useful in God's eyes He would not let it go unfinished. Duhem certainly looked forward to the day when, as he told Jordan, following the completion of the *Système du monde* 'I would closet myself during the summer vacation in Cabrespine and would extract, without a scholarly apparatus, its essential conclusions.'⁹⁵ He did not live to see that day which would have regaled the historiography of science with a great classic enjoyable by a very large public.

The decision of the Ministry of Public Instruction, a signal recognition of Duhem's scholarly excellence, was an anticlimax. When on March 17, 1913 legislation was passed on behalf of a long-delayed project to add six non-resident members to the Académie, it was inevitable that Duhem's name be high among those to be considered. In fact some with distinct ambition had begun a year earlier to mobilize forces. Duhem wanted none of that. When approached in early January 1912 by Charles Depéret, professor of geology in Lyon and a corresponding member of the Académie since 1898, for help to pool the signatures of such members for the best candidates, Duhem replied:

The possibility of becoming a member of the Institut is a desire to become one. This means getting involved in irksome procedures, yielding to thousands of small improprieties in which the most proud and independent honor can easily be lost from the moment one is a candidate. We in the provinces cannot become members of the Académie, those in Paris have reserved to themselves that problematic advantage. In return what a real and incontestable advantage have they bestowed on us! They have assured our quiet and have protected us against ambitions. You want us to renounce that privilege. It seems to me that this would amount to letting go of the bounty in return for the shadow. I don't have the courage either to associate myself with your petition or to wish it success. If I were to take the steps you ask me to, and if I rejoiced for the sake of confrères whose desires would be fulfilled, I would watch lest it instill in me the ambition to become a member – even a free member – of the Académie.

For such a man Paris had to come at long last, and all the more so as the world at large had already paid homage to him. He was elected corresponding member of the Dutch Society of Experimental Physics in Rotterdam (July 7, 1909) and of the Reale Istituto Veneto di Scienze, Lettere, e Arte (March 24, 1912). Soon afterward, the Reale Academia de Scienze of Padua made him honorary associate (May 18, 1913).⁹⁶ Paris and France joined at long last in the parade, although the hurdles which some noble minds had to overcome in securing the appropriate honor for Duhem form a story with an interest of its own.

94. He certainly could have written within that time the 250-page history of physics (less than 100,000 words), which ultimately was done by Charles Fabry (14:167-420).

95. Jordan, 'Duhem' pp. 165-66.

96. These Italian honors were in part an expression of the esteem in which Favaro held Duhem as a historian of pre-Galilean science.

A drawn-out election

The story begins with a letter which Duhem received on April 9, in which his old mentor Darboux, Perpetual Secretary of the section of mathematical sciences of the Académie since May 21, 1900, noted that several of its members had already spoken to him of Duhem as a good possibility for one of the six places: 'I think that if you present your candidacy you will have very good chances of being elected. Please let me know how you feel in this regard.' For Duhem the really important and electrifying news in Darboux' letter was the release of 2000 francs from the Debrousse-funds to support the publication of the first volume of the *Système du monde*. 'What gratitude should I feel!', wrote Duhem back on April 10.⁹⁷ 'For two years I have been engaged in an enormous project and I often strongly feared that it would remain useless because of the impossibility of publishing it.'

Compared with Duhem's joy over the help from the Académie and his sense of relief over the prospect of support for the subsequent volumes, his reaction to his possible membership in the Académie was sheer perplexity. He described to Darboux the writing of a letter to the Académie as a 'ridiculous' act, and voiced his utter dislike of the idea of going around in Paris to collect votes. Last but not least, he begrudged the two months to be taken away from writing the *Système du monde*, the time needed to write for the Académie a Notice summing up his achievements. But if there was somebody he did not want to hurt, it was Darboux. 'I leave blindly to you the decision [as to what I should do].'

Darboux was not the person to be impressed with such argumentation. On April 14 the 'Secret Committee' of the Académie heard Darboux present a two-and-a-half-page summary of Duhem's work.⁹⁸ It began with a reference to the admiring report which Prof. Sarrau read to the same committee in 1900, prior to Duhem's election as a corresponding member. (The report, which Darboux and some other members of the committee still remembered, could not however be found any longer in the archives of the Académie.) At the end of his report, Darboux referred to the use of the Debrousse-fund to support the publication of a work which 'would comprise ten volumes, half of which at least are ready for printing.' For those to whom this statement was addressed, it must have been an overpowering signal of Duhem's productivity. For posterity, the same statement, obviously written on the basis of information from Duhem, holds the solution to the last five of the ten volumes of the *Système du monde*. He was already writing them when he read the proofs of the first volume.

After his work on the 'Secret Committee' Darboux turned to working on Duhem. The next day he gently but firmly lectured Duhem in a letter. He assured him that visits in Paris were not necessary and that the Notice was not urgently needed. Then he took Duhem to task at the very center of his self by underlining certain words: 'I believe you are very wrong in trying to decline the honor which

97. Today, it should seem frustrating that letters between Paris and other major cities in France were delivered within one day.

98. Archives, Académie des Sciences.

we want to confer on you. One must not see in the title of member of the Institut a mere reward. The title gives you above all a greater authority which permits you to do more good.' Darboux also informed Duhem that his name was among the six selected by the 'Secret Committee.' The six names formed three groups, Duhem's name being the second in the third group which comprised three names. A day or two later all this became public knowledge through the issue of the *Comptes rendus* which covered the session of April 14 of the Académie des Sciences.⁹⁹ The list was drawn up so that the Perpetual Secretary could confidently expect an impressive majority of ballots for the one listed in the first place, in this case Paul Sabatier, professor of chemistry in Toulouse, co-winner in 1912 of the Nobel Prize for chemistry and, it may be noted, member of the Société scientifique de Bruxelles. Sabatier received a week later 46 of the 51 votes cast. Henry Bazin, Inspector General of Ponts et Chaussées, and Louis Gouy, professor of physics in Lyon, listed in the second group, received 1 and 3 votes respectively. No votes were cast for anyone in the third group, that is, Depéret, Duhem, and Fabre. On April 28, Gouy, placed a week earlier at the head of the second list, was elected with a substantial majority. Bazin, in second place, received 9 votes, whereas of the four making up the third group – Depéret, Duhem, Fabre, and Gosselet – Duhem was the sole recipient of a vote. On May 5, Bazin, at the head of the third list, was elected, whereas Depéret and Duhem, who formed the second group, received 7 and 6 votes respectively. The third group consisted of Cosserat, Fabre, and Gosselet.

Having his name in the second group together with that of Depéret was a clear indication for Duhem, or anyone else, that he would be placed on the top of the list either on the fourth or the fifth balloting, to take place in the Fall. Meanwhile he completed, on May 3, his Notice and had it immediately printed in Bordeaux.¹⁰⁰ That printed copies were by late May in the hands of members of the Institut is clear from a letter which Edouard Branly, discoverer of wireless telegraph, sent to Duhem on May 25. In congratulating him for the Notice he remarked: 'I have already voted for you at the second and third ballotings.' The Notice was by its very extent, 125 pages, a powerful reminder of what Duhem could accomplish in six weeks. The contents, a cogently argued synthesis of 316 publications, including a dozen or so massive volumes, was no less impressive. Being engaged in writing about oneself could have naturally given Duhem an infatuation with the goal, membership in the Académie, which the Notice was meant to implement. Duhem remained deeply detached, as shown by his reaction to a piece of news about which he learned on May 9. The next day he wrote to his daughter a letter, a priceless document of the measure of an integrity imposing utter unselfishness:

If you are too eager to see me become a member of the Institut, you would blame me for what I have just done. But no, I rather believe that you will approve.

You know that following the last election, they put me in the second group with Depéret, designating us thereby for the next two places, and that they left in the third

99. CR 156 (1913):1196.

100. 1913 (1).

group Henri Fabre, this great Christian and a genius as a natural scientist, who is *ninety years old* and can die at any moment. I have already told you that this is scandalous.

Yesterday, I was informed that Edmond Perrier, director of the Muséum [of Natural History in Paris], had already written in *Le Temps* an article in which he demanded that the Académie put Henri Fabre in first place. Now, I have written to Perrier that I would be pained to be nominated ahead of Fabre and if he found appropriate to declare this in my name to the Académie, he has my authorization for doing so.¹⁰¹

Once this is kept in mind, Duhem's elaboration on his views of his prospective election, set forth the next day in another letter to his daughter, will not be taken for an expression of sublimated contempt, self-pity, or vindictiveness:

I have just read your letter of yesterday. It seems to me that you entertain plenty of illusion concerning the importance which that title of 'Membre de l'Institut' will have for me. I will be asked, a little more frequently than in the past, to preside over committees and assemblies – things which I abhor –, but my books will not be more read, my ideas will not be more discussed, the only thing which I desire. You tell me that I have more influence since I am a corresponding member of the Institut; I believe the opposite is true; my works have passed more and more unnoticed. This year, one copy was purchased of my great treatise of electricity. For me that title will have the effect of a crown deposited on the coffin into which fellow-physicists have nailed me alive.¹⁰²

Perrier, member of the Académie since 1892 and its president in 1915, was deeply touched by the letter of Duhem, who had Rémi, Perrier's son, among his younger friends:

Hello there, my dear friend, always modest and concerned for complete justice, be it at your own expense. I have written, in fact, in *Le Temps* an article on Fabre. When I took to him in Serignan the Medal commemorating his jubilee, I said that I would hope for him one of the next places in the Académie des Sciences, but I did not mean that it should be yours. I hope that you both will be elected and I would not risk troubling – even once – the clear waters of the ballotings by raising the question of precedence, not even after reading your letter which does much honor to you. Here nobody has forgotten you, neither Rémi, nor his wife; all send their best to the courageous soul you are and their respects to the scientist. Devotedly yours, Edmond Perrier.

In spite of authorization from Duhem to make his letter public, Perrier kept for months its contents to himself. But in early October he must have spoken of it informally in the Académie as elections for the last three posts became an urgent business, together with the question of Fabre's place on the list. Rumors spreading about Duhem's readiness to yield to Fabre gave quite an anxiety to Darboux who felt that Duhem's chances might suffer while Fabre had little support anyway. That Darboux's apprehension must have been rather serious may be gathered from the letter which Duhem wrote to him on October 11: 'I would be dejected if my respect for Fabre would be taken for a lack of deference on my part toward the Académie. I count on your goodness to forestall a deplorable interpretation of it in that respect.'

101. *Un savant français*, p. 172.

102. *Ibid.*, pp. 170-71.

That Fabre had no broad support was clear from the list set on October 20 where he was the fifth (or the second in the third group).¹⁰³ Depéret, who headed the list, was duly elected on October 27. Since Duhem was second (the first in the second group which included Jules Gosselet, retired professor of geology in Lille), it seemed to be a foregone conclusion that two weeks later he would head the list and be elected in another week. Such was the expectation which prompted the astronomer Picart, future dean of the science faculty of Bordeaux, to write in late October in the *Rapport* for 1912-13 ready for the printer: 'Duhem has already several times been proposed by the Committee of the Académie . . . for a place of non-resident member, and his election, which will make us happy and proud, will undoubtedly take place in a few days.'¹⁰⁴ Although about that time both Hadamard and Picart assured Duhem in separate notes that his election was imminent, on November 10 Gosselet was placed on the top of the list, perhaps in consideration of his advanced age (he was then eighty-one). However, since Duhem followed him alone in the second group (Fabre was no longer included even in the third group, possibly to avoid further embarrassment), Duhem's election seemed to be assured for the sixth and only remaining place. This assurance was not satisfactory to quite a few. Duhem received 9 votes in the election which gave Gosselet the fifth post. At long last, on December 1, Duhem's name was put on the top of the list. His election took place on Monday, December 8, afternoon. Of the 57 votes cast, he received 45.¹⁰⁵

The day was not over yet when Darboux composed the letter of notification signed by him and van Thiegem, president for that year of the Académie. Duhem's reply, dated December 12, was, as in 1900, a classic of brevity and dignity:

Messieurs les Secrétaires perpétuels! By naming me a non-resident member, the Académie conferred on me an honor which far surpasses all my ambitions. Please, be so kind as to convey my gratitude and to accept the expression of my profound respect.
P. Duhem.

By then he was greeted with a standing ovation at his public lecture on Tuesday, December 9, and work began on a silver medal, a testimony from the alumni of Stanislas in southwest France, which, when presented on January 7th, moved him to tears. Meanwhile congratulations poured in by the hundreds. Among the first to send a telegram was Hélène: 'Félicitations, une fille heureuse.' Hélène's co-workers at the Atelier St. Agnes, already the repeated beneficiaries of Duhem's generosity for the poor, wrote:

It is rather presumptuous for women workers to celebrate an academician. But your goodness has already bridged the distance and made possible for Mlle Hélène to call herself our sister. We are proud as the beneficiaries of a family honor. Your modesty would suffer if we were to recite tonight from our books the dates of your generosity. They are deeply inscribed in our hearts.

103. *CR* 157 (1913):662.

104. *Rapport 1912-13*, p. 104.

105. *CR* 157 (1913):1119.

Duhem's relatives – sisters-in-law, brothers-in-law, cousins, nephews among the Chayets, the de la Fayes, the Labroustes – pressed forward to embrace him with all their hearts. Old friends wrote to their 'cher vieux.' One of them, Jean de la Laurencie, who expressed his wish to see him after so many years, received from him the following words:

I, too, my dear friend would very much like to see you. Since Stanislas I have seen you only once, and that too was twelve years ago. Don't congratulate me. If courage was needed to fight the antipatriotism of intellectualism, I hope I have it, but concerning what I did, no courage was necessary because I had nothing to lose. Our great intellectuals have known for long where I stand. I wish that next year good Frenchmen may on New Year's Day exchange greeting cards of joy and not, as this year, cards of condolence.¹⁰⁶

If Duhem's election was a victory, it was in his eyes a victory of patriotism in which country and faith were united in genuine intellectual pursuit.

The Bishop of Lourdes began his congratulations with the words 'mon cher Pierre.' Monseigneur Andrieu, Cardinal Archbishop of Bordeaux and a spokesman for the ralliement, was somewhat late in greeting an 'integriste.'¹⁰⁷ Scientists from Italy, Germany, Great Britain, and the United States joined in the chorus. French men of science were divided, in telling testimony of the truth of Duhem's words to his daughter. A part of them already considered him non-existent. One would look in vain in the large envelope, in which Duhem kept the congratulatory notes, for the names of a Langevin, a Perrin, a Weiss, a Mme Curie. But many others were jubilant, and certainly his friends in the Académie. Boussinesq sent him, immediately after the election, the piece of paper on which he marked the ballots. After 12 marks he could not continue for joy. Roux, a member since 1899 and head of the Institut Pasteur, who once hoped to have Duhem as his associate, wrote: 'Your merit is obviously above any and all official recognition.' Camille Jordan expressed his hope that henceforth Duhem would be seen more often in Paris. Jordan's note was also a rebuke of the Académie concerning Fabre. Possibly the Académie ignored him because he was not a Darwinist. For many years, Jordan added, 'the Académie looked askance at Darwin, but one error does not make up for another.' Former colleagues in Lille and Rennes remembered him in a way which far exceeded the measure of ordinary courtesy. The Science Faculty of Lille, with Damien at its head, sent a message signed by all, which touched Duhem deeply as shown by his reply written on December 17:

Certainly I shall never forget the six years of my stay in Lille where my life had known its greatest joy and most painful trial. With my hand trembling with gratitude I beg you all not to see in me a former colleague but a friend from past days. I am sending you as a sign of appreciation a copy of my Notice. I will be honored if it is kept in memory of a former maître de conférences.

106. A photocopy of that card was kindly provided to me by Mme François Merveilleux de Vignan, daughter of Jean de la Laurencie.

107. The Cardinal's congratulatory letter, dated January 10, 1914, contained the wish, 'perhaps selfish' as he put it, that Duhem would always remain in Bordeaux, and praised Duhem for the 'prodigality' with which he shared his intellectual riches with the young.

The surrender of officialdom was symbolized by Liard's sending from the Ministry 'toutes mes félicitations.' The best comment on this came from Duhem's publisher, Hermann: 'I was somewhat irritated to see your nomination being postponed week after week. At long last . . . You can now be relaxed, freed of all irritating polemics.'

The French Press woke up at long last to Duhem's presence. All the great dailies of Paris gave an account of Duhem's work. The one in *Figaro* was penetrating and lively:

At four in the afternoon the urns circulated for taking up the ballots for the election of a non-resident member; almost unanimously Duhem was elected . . . the session ended at half past four. The new academicien will be one of the youth in the Institut. He is hardly fifty. His works have borne on mathematical physics and his initial effort was a master stroke, because his first book was that *Potentiel thermodynamique* where he showed to chemists a road to follow and signalled a method whose direction proved its fruitfulness. He studied, from the mathematical point of view, almost all branches of physics. A universal mind, he mined deep the history of science. He is a highly cultured humanist and published a remarkable study of Leonardo de Vinci. Duhem defends his own ideas with verve. He belongs to the race of fighting scientists. Within the young school of contemporary physicists Bouasse, Turpain, and others walk in his footsteps. At any rate, those disputes, lively as they are, cannot but be profitable for science. When the exchanges are made in a style as clear and beautiful as that in which Duhem writes, their reading is for all of us a common profit: It is from the shock of ideas that light has always sprung forth.¹⁰⁸

Le Temps made up for its dry account of the event in its December 10 issue¹⁰⁹ at the end of the month when its *Feuilleton* carried a discussion by L. Houlléviqgue, Duhem's classmate at the Ecole Normale, of the science of Leonardo as reconstructed by Duhem. He must have been deeply satisfied with Houlléviqgue's description of scientific truth: 'It resembles more a woman in veil than the resplendent nude which painters make arise from a well.' Houlléviqgue's conclusion was no less a genuine rendering of Duhem's thought: 'The history of science carries a great lesson because, by showing us vividly the successive errors of the human mind, it makes us realize that truth is seized not through a sudden intuition but through patient analysis.'¹¹⁰

For the big Republican newspapers in Bordeaux Duhem's election was not a cause for elation. Editors of *La Gironde*, *La Libre Parole*, and *La Petite Gironde* strained themselves by reciting mere facts in order not to reveal too much of their displeasure.¹¹¹ The unrestrained joy was reserved for *Le Nouvelliste*:

108. The report was written by Alphonse Berget in the December 9 issue; see clipping in the Duhem folder in the Archives de l'Académie des Sciences.

109. In listing Duhem's scientific achievements, *Le Temps* (p. 3, col. 4) failed to mention thermodynamics!

110. Section 'Causerie scientifique,' p. 3.

111. *La Gironde* carried, though, the news on its front page (col. 7). *La Libre Parole* had only four lines for it (p. 3, col. 1). The reporting in *La Petite Gironde*, which claimed itself to be the largest newspaper, was similar though shorter (p. 2, col. 3) to the one in *La Gironde*.

This election greatly honors our University. All his colleagues extended to Duhem their congratulations. One of them repeatedly told the students: 'Remember that we have here in the Faculty some men of talent, but also a man of genius, Mr. Duhem.' We do not wish to add to that witness, more authoritative than all others. We, however, want to bow before a man of heart and faith whose entire life has been a sublime lesson of independence, pride, and dignity. The world knows him as the master of French physics. We have physicists who are experimentalists of great merit, but as far as theoreticians, that is, creators are concerned, we have only one, Duhem.¹¹²

The University officially voted its homage to Duhem on December 12. Its tone was reflected in the *Rapport* for 1913-14. Duhem's election 'was a rare honor but could not have been better placed. The whole world applauds this choice.' wrote G. Ferron, dean of the law faculty, in the name of the University Council.¹¹³ Picart, dean of the science faculty, with an allusion to Duhem's publications in the same academic year, wrote: 'It is our joy, while voicing our congratulations to Mr. Duhem, to register that this supreme honor has not at all stopped his activities and has further enhanced his scientific production.'¹¹⁴

It would now have been the proper time to make Duhem, professor of second rank since April 30, 1910, with an annual salary of 10,000 francs, professor of first rank, with an additional 2,000 francs to his salary. Another such golden opportunity to make amends did not come.

A student forever

In the published records of the University there could, of course, be no reference whatever to Duhem's liberally spending his energies on behalf of the Association des Etudiants Catholiques de l'Université de Bordeaux. A brainchild of his friend Dufourcq, the idea of the Association was at first strongly opposed by Duhem. Or, as Dufourcq reminisced:

Duhem was one of the first to know of my project. He did everything to make me abandon it. I still can see myself in his study in the Rue de la Teste. He kept playing with his tweezers as he talked. He pointed out the necessary hostility of all the neutrals, of all the scornful, etc. . . It was his friendship for me that spoke. When he learned that I had persisted with my project, he was, the very next Sunday, in the first row of our audience. And I do not think he has missed since a Sunday meeting. When I left Bordeaux a few months before the war, to pursue certain studies in Paris, I could depart without fear. My work was in good hands: his hands. He adopted it. With all his authority, he helped a marvelous priest, the Abbé Bergereau, to let the Association have its impact on the student body of the University.¹¹⁵

In early 1913 the Association had its bylaws drawn up, elected its officials, and began its program. Among the founding members were Prof. P. Courteault, already well known for his books on the historic and artistic monuments of

112. Dec. 11, 1913, p. 2, col. 6. Two days earlier *Le Nouvelliste* carried a shorter account of the news (p. 3, col. 1).

113. *Rapport 1913-14*, p. 14.

114. *Ibid.*, p. 93.

115. *Un savant français*, pp. 211-12.

Bordeaux, and the young A. Fliche who was to earn membership in the Académie Française for his work as a church historian. A three-story house (7 Rue Canillac), five-minutes' walk from the University, served as headquarters of the Association, still at its original place. The house allocated, among other things, a meeting room, a library, and a recreational room, all open every day from 8 in the morning until 10 in the evening. The program of the Association included biweekly conferences on social studies, political science, and medical problems. A retreat shortly before Holy Week and an excursion on Ascension Day were annual events. The 10:30 mass on Sundays in the Chapelle de la Madeleine, near the headquarters, was followed by a conference relating to theology and the Church. The Association was not to see Duhem attend the conferences on social and political questions. He somehow felt that they smacked of the kind of politics he had always abhorred. In fact, his original opposition to Dufourcq's project lay in his fear that the Association might turn into a political organ. The conferences on theology and Church Duhem never missed. He even cut short his rare trips to Paris to arrive on time for the Sunday gathering.¹¹⁶ Needless to say, he was an enthusiastic participant in the annual excursions.

In three short years he became the Association's focal point to which students flocked as if he had been just another camarade. It was as a fellow student that everybody remembered him:

In his extreme modesty¹¹⁷ he did his best to appear a mere 'old boy.' We persisted in seeing him very young, possessed of a youth which, as we at times flattered ourselves, he recovered through his contact with us. In order to forget that his beard was white and that he even passed fifty, it was enough to see him in our midst with his bearing so simple and yet so imposing where one could notice an uncommon physical vigor, with his magnificent face which radiated the power of his intelligence, the proud independence of his character, the frank and strong goodness of his soul – with his élan, gaiety, and untiring verve. Thus we counted on having him with us for a long time. Well, accustomed as we were to see him in our midst, not even the thought occurred to us that we might lose him one day.

He was in fact present at all our meetings. Did it not occur to him to leave Paris on Saturday evening, depriving himself of one more day which he could have spent with his daughter, in order not to miss our mass the next day? In our study group, where especially during these recent times he made it his duty to assist, with what exquisite benevolence did he listen to the poor lecturers we are, and to each question how many appropriate, luminous, and delightful things he could always add by tapping the treasures of his knowledge! Who has not admired him, as the days of communion came, kneeling down side by side with us at the Holy Table? At all our banquets he had his place and how quickly he became there the Normalien, and that impish mind which he once was! You have not forgotten that delightful companion which he was at Verdélais

116. Jordan, 'Duhem,' p. 171.

117. The following is the portrayal of Duhem by the Abbé Bergereau in his eulogy, 'Pierre Duhem . . . membre fondateur de l'Association Catholique des Etudiants de l'Université de Bordeaux' (Bordeaux: Wetterwald Frères, 1916), 23 pp; for quotation see pp. 6-8.

on the day of Ascension.¹¹⁸ With a joyful and brisk step, laughing with one, arguing with another, on the road from Langon to Verdélais, he climbed the banks of the Garonne in the morning and then descended in the evening. Lucky the one who could manoeuvre himself to his side! Everybody wanted him to himself alone. I had to admire on seeing with what a simplicity this great man, by eliminating without any fuss the distance between him and others, became all to all and succeeded in being for you another camarade! He succeeded so well that at times you did treat him as one.

I remember that several times some of you, after having entered before the Sunday Mass the meeting room and surprised at not having noted him immediately, (some of you) simply asked: 'Where is Duhem?' Certainly, Duhem was not far. He was indeed so close that he happened to hear the question. Red color rushed into the faces of these daring fellows. But Duhem smiled contentedly. One felt that he was happy. He knew well that these little familiarities took nothing away from the respect and high regard we had for him but rather witnessed the prominent place which we have made for him in our hearts. It is not astonishing that he became the soul of our group to the extent that, in speaking of us, the public began to say: The work of Mr. Duhem.

Duhem's immediate involvement is well attested by his letter of August 13, 1913, to the Abbé Bergereau in which he registered his pleasure concerning the appointment of Augustin Fliche as a professor: 'May he stay long in Bordeaux! Let us move, God does not want the death of our dear little student association!'¹¹⁹ Had Duhem done no more than attend faithfully with the students the Sunday mass and conference, he would have more than sufficiently benefited the Association by his prestige which after his election as non-resident member became widely acknowledged even well outside the University. In addition to his prestige and presence he gave the student-members of the Association his elevated mind and soul. He did so in a manner which combined moral authority with touching informality. He was clearly just another student when in their midst. That they looked at him as a camarade was very clear from the opening phrases of the toast which he delivered at the annual banquet of the Association on June 4, 1914. Otherwise he could not have replied to the invitation of the master of ceremonies with the words:

118. The famed statue of the Virgin, which did not cease attracting pilgrims since the twelfth century, had an added significance to the Association. Its members gathered for Sunday mass in the Chapelle de la Madeleine served by the Marianist Fathers. Their founder, the Abbé Chaminade, obtained his miraculous cure in Verdélais and exercised his ministry during the Terror from the house which became the headquarters for the Association, where a marble plaque recalls his memory. Duhem and the students may have learned that the painter, Toulouse-Lautrec, brought his mother to Verdélais every Sunday over several years. More recently the Nobel-laureate François Mauriac was a frequent visitor at the sanctuary.

119. Written from Cabrespine, the letter is in the possession of the Association. Prior to his active involvement in the Association, Duhem had a reputation, spreading far beyond Bordeaux, as one who could be confidently approached by students interested in the spiritual welfare of their camarades. Pierre Poyet, who graduated from the Ecole Normale in 1910 as a physicist with great promise and who became there known as the 'apostle of the Ecole' (being instrumental among other things in the conversion of Lavisse himself!), recalled, following his visits with Duhem in 1912, the latter's enthusiasm for the spiritual retreats which Poyet organized in the *grandes écoles* and other universities (see A. Bessières *L'Apôtre de Normale Supérieure Pierre Poyet (1887-1913)* [4th ed.; Paris: Spes, 1935], pp. 130 and 174). Needless to say, Duhem was also consulted by Poyet in matters of his doctoral research in physics.

You touched me to the heart by calling me a student. The title of student is one which I think I deserve most. I hope to deserve it for a long time to come. Only when I am no longer a student, when I no longer study, shall I think that I have nothing to learn on this or that point. This will be for me the unquestionable sign of senile degeneracy.¹²⁰

Taking his cue from the fact that he was addressed by the master of ceremonies as 'faithful student,' Duhem noted that it was relatively easy for him to be such having had some model professors for teachers. They all pursued their careers bravely and energetically, that is, in the very sense in which Prof. Arnozan, of the Faculty of Medicine and toastmaster of the previous year, urged students to be intent on their own careers.¹²¹ Duhem, well known for his warnings against careerism, had to explain himself. He proposed to do so by making his toast¹²² a commentary to Prof. Arnozan's speech and in a manner of medieval scholars – he hardly needed to remind the audience of his medieval studies – who presented their own views almost invariably in the form of commentaries. But as was often the case with the medievals, Duhem noted with a sparkling sense of humor, a commentary could easily turn into a negation, at times only apparent, of the text commented. Duhem's urging the students not to pursue their careers at any price contradicted Professor Arnozan's theme only in appearance. For what the latter had in mind was not the sort of careerism, analogous to heliotropism, that is, to an invincible fixation of the mind on some chair, title, or post.

The students, to whom Duhem's selfless readiness to let Fabre be elected before him could hardly be unknown, must have immediately sensed the weight of moral authority as Duhem switched from commenting to an unabashed moralizing. The way he did it was as unusual as was the standard he held high. His starting story suggested something of the crucible in which alone can credible moral authority develop:

One evening about thirty years ago the pillars of free thought were assembled in Taine's home. Marcelin Berthelot chatted with the host. Leaning on a table, the corpulent Renan scribbled something on the end of a sheet of paper. Renan's sketch showed a tombstone with the epitaph: Here lies Berthelot. He occupies the only place which he never requested.

My dear friends, Duhem continued, don't desire all the places. When a place will be vacant, you will ask your conscience: To fill that place am I the man who is needed, the right man in the right place? And if your conscience tells you no, you will not go forward.

If your conscience tells you yes, you cast a glance around. You will search whether among your fellow applicants there is not one who is worthier of the post which is your ambition. If you notice one, you will yield so that he may advance; indeed, I say, you will help him advance.

120. See reference 122 below, p. 39.

121. It was Arnozan who proposed in 1898 a vote of confidence on behalf of Duhem in the Conseil d'Université from which Duhem resigned following a rude attack against him by Bizos.

122. The text of Duhem's toast was printed in the *Compte rendu annuel 1913-1914* of the Association, a booklet of 44 pages, printed in Bordeaux in 1914, pp. 39-44, and also as a booklet together with the next entry.

If you have recognized deep in your heart and conscience that you are the most worthy of the post, you will still forbid yourself any means which cannot be used in broad daylight, any procedure which would not be of the most scrupulous loyalty.

Real life being what it is, were not such counsels destructive of most, if not all, advancement? Duhem was ready to acknowledge that they were not in a sense too helpful, though supremely useful in the most important sense, the one relating to good conscience. Anyone obeying those counsels will be saved of the burden of being forced to address to oneself certain reproaches:

Undoubtedly I am overwhelmed with commissions and loaded with honors; but while people smile in my face, I hear them laugh behind me. I know they call me incapable, a nullity . . . I am worthy, true, of the rank I occupy, but such and such was worthier than I, and because I have vanquished him he is poor, humiliated, unfortunate . . . You were worthy of the place you occupy, you were the worthiest. But in order to obtain it, what platitudes, what dirty tricks, what apostasies [were necessary]!

The ultimate perspective of careerism now could be spelled out by asking some questions and answering them as well with no words minced as to what was really at stake:

Do you believe, my dear friends, that the happiness of escaping all such reproaches, the pride of holding high one's head without blushing, would not be sufficient consolation for some disfavours and injustices? Do you feel that you will receive your recompense in this world? What should I say of the recompense which is waiting for you in the world to come? Well, being careerists, though better advised than Berthelot, you will have requested the only place which is worth the effort, because no reversal will deprive you of it as one holds it for eternity.

Within that perspective there could be no conflict between Duhem's counsels and those given by Prof. Arnozan. For the perspective was that of the banquet described in that parable which warned against seeking the first place. Within that perspective the toast, usually a good wish, could be turned into a prayer:

When one is a Christian, when one does not believe in luck, when one believes in an appeal to Providence, a good wish is a prayer. Do not be astonished that my toast takes the form of a prayer. As you take your place at the banquet of life, I implore God to go along the tables often enough to notice the humble place where your modesty made you sit down and, taking you by the hand, tell you: My friend, move higher up.

Such a toast, which would be labeled in some circles as a hollow sermonizing, a mere preaching, deeply moved Duhem's audience. When young women formed their own Association with headquarters at 10 Rue des Etuves (a small street running parallel to the main facade of the University), Duhem was asked to preside at their general assembly on June 25, 1916, and give the principal address.¹²³ He was a bit reluctant. Although not unfamiliar with student life — he

123. 'Discours de M. Duhem,' in *Groupe Catholique des Etudiantes de l'Université de Bordeaux . . . Année 1915-16. Compte rendu de l'Assemblée Générale du 25 Juin 1916* (Bordeaux: Imprimerie Nouvelle F. Pech & Cie, 1916), pp. 11-18.

himself was one, he noted, and still felt himself to be one – he was unsure of himself in facing so many young women. ‘Between you and me,’ Duhem turned to them with an unmistakably personal touch, ‘there rises that wall behind which the most loving and most confiding daughter remains, even for her father, a mysterious enigma.’¹²⁴ The only person, Duhem continued, for whom a woman is an open book is her own spiritual advisor. Such was Duhem’s way of paying respect to the chaplain of the Association. Nor did he forget the nuns in charge of its headquarters. ‘They offer you hospitality but with what a touch and delicacy! You are ‘chez elles’ but they want that you should pronounce the word so dear to every woman: ‘chez moi’.’

Dufourcq’s remark, already quoted, about Duhem’s natural gracefulness with women, has a perfect illustration in the introductory part of his address of which a few short details have just been given. And so does the rest of it in which he first compared the role of women in the academe to the instinctive act of a young housewife who upon installing herself in a well-appointed study or living room

slightly displaces a table, moves another piece of furniture, puts a bouquet of flowers into a vase, with an easy touch adds another fold to a curtain. All this is small matter, to be sure, but all is changed thereby. In the living room, once so somber and austere, all shines and smiles now. The light invites your eyes to be fixed on that watercolor which you have not previously noticed, a ray of light caresses the strong shape of that bronze which an obscure corner was hiding. With a young woman charm has come into the house. Those who dwelt in it do not recognize their old lodgings. It appears to them that a fairy has turned it into a palace. Into the manor of studies, you let elegance and clarity enter, through you this antique habitat becomes lovable and charming.

It was now the turn of the historian, the philosopher of science, and last but not least of the Christian patriot, all of whom formed in Duhem an indissoluble unity. First, he disclosed something of his solitary life. In the evenings, being tired of putting together long equations or deciphering ancient manuscripts, he used to seek relief in reading an old book in which physics was set forth not only with clarity but also with ease and charm, as if the paragraphs succeeding one another

were so many bouquets of flowers which painters of those times put, with a studied neglect, between the fingers of ladies whose portraits they painted. The authors of the book in question, the *Institutions de physique*, had indeed, I imagine, the fine hands needed to hold such a bouquet, because her name was Gabrielle-Emilie de Breteuil, marquise du Chastelet.¹²⁵

When I close the *Institutions de physique* of Mme. du Chastelet, I dream at times: How feminine! Even more often, I think: How French!

It seems indeed to me that the French mind is essentially feminine. I cannot speak of it without imagining a very noble and beautiful lady whose smile and composure are yet all grace and simplicity.

124. This remark may have been prompted by the relation between Duhem and his daughter.

125. Published in 1740. The Marquise (1706-1749), who is best remembered for her liaison with Voltaire, was also an accomplished linguist and musician.

Duhem now was at his life-long favorite topic, the respective merits of the English, German, and French minds. The latter, Duhem admitted, brings at times only clarity to what already had been proposed by the first two, through discarding unnecessary details and, by rearranging the data. Pascal had already had something profound to say in this respect. Duhem in turn let the imaginary young woman say: 'These are the same furnishings, the same bronzes, the same pictures, but I arrange them better.'

The presence of French women in French universities could furthermore be portrayed as a patriotic vocation which was at the same time a Christian vocation as well. For, as Duhem argued, the same aspects in foreign methods, so popular recently in French academic circles, which pose a threat to the French mind, threaten also the Christian way of thinking:

What are, Duhem asked, the dangers posed to the Christian soul by the study of science? They are of several kinds but it seems that they can be grouped under two principal heads. The laborious mind can easily attach itself in an exclusive manner to the study of facts. Immersed in the meticulous analysis of all details, which can be felt and seen or which can be counted and weighed, such a mind lets the myopia of his attention readily grow. Soon it will be incapable of contemplating an idea. It finds ideas too elevated or far removed. Instead of recognizing there the only truth worth seeking, it takes idle dreamings for ideas because for it there is no certainty apart from the witness of the senses. It falls and rolls by the degrees of a suspicious positivism toward an abject materialism. At times the reasoning spirit falls prey to the play of deductions without foundations. It finds pleasure in mounting the narrow and shaky scaffolding of theories. It does not investigate whether this fragile construct rests on secure bases. It only wants the construct to be able to rise to the clouds which it takes for the sky. Soon it is seized by a vertigo and yields to the vaguest pantheism and to the most nebulous mysticism.

To save one's self from both extremes one therefore needs 'the qualities which adorn the intellect of the French woman.' Her horror of all that lacks grace will by the same token be a 'safeguard against the brutalities of materialism.' This common perspective of the common fortunes of natural science and Christian faith were prefigured, so Duhem unfolded his theme's ultimate perspective, in the bodily coming of Eternal Reason, the Word of God, to man through the instrumentality of a young maiden. To be sure, the prevailing intellectual trends have long since ceased in France to be an echo of that Divine Word. But the prospects had their bright side:

On the soil of our beloved country your brothers shed their redemptive blood without counting it. Will the price of such a sacrifice not become the reconciliation of French thought and Christian thought? Are we not going to see again what was a living reality during the Middle Ages and in the century of Pascal and Bossuet? In order to secure its progress along the road which is suited for it, would not the human reason march again, as it did before, with eyes fixed on the divine revelation? And is it not for preparing that Christian renaissance of science, for giving voice to the Word of God, that the Holy Spirit puts in the hearts of so many young women the desire to learn and the sacred vocation to teach?

Waging his war to the end

When Duhem spoke, France had just gone through a traumatic bloodletting. The fall of over a quarter of a million of her sons around Verdun during the previous four months brought not so much a victory as the standstill of exhaustion. Duhem himself was more exhausted than he suspected. The preceding year saw the appearance of the third volume of his *Système du monde*, the fourth volume was just about to appear, and the fifth, in which he carried his story well into the thirteenth century, was being given the last touches for publication the next year. In addition he had piled up thousands of manuscript pages which, as turned out to be the case decades later, were in publishable form, amounting to another five volumes of the same work. This was far from everything. His election to the Académie spurred him to reassert himself as a theoretical physicist with a steady flow of articles in the *Comptes rendus* and elsewhere. He spared no time and energy if the intellectual cause of his country was to be served, as shown by his over fifty-page essay for the 200th anniversary of Malebranche's death.¹²⁶ His self-imposed, top-heavy workload had further increased since he wrote on February 25, 1913, to his daughter: 'My life is too overloaded with work for me to use for travel the holidays which come during the academic year. During the weeks, when the courses are in full swing, I do not succeed in doing all that needs to be done. If the holidays did not come from time to time to allow me to keep afloat, my life would be an exertion which I would not have the strength to cope with too long.'¹²⁷ Yet he kept repeating a favorite phrase of his: 'Work has never killed anybody.'¹²⁸ Little did he suspect how misplaced the phrase was in his own case.

He saw no excuse to spare himself when it came to that warfare which, since the outbreak of World War I, was waged by scientists and scholars on both sides. Yet, just as unlike most French academics, he had not gone previously to the extreme of worshipping the Teutonic mind and method, he now refrained from denying any virtue and talent to the other side. Or, as he wrote to his daughter:

Not too long ago I made everybody turn his back on me, because I did not admire the ridiculous theories coming out of German laboratories and considered German philosophy to be dangerous and false, and its historical method to be steeped in bad faith. Everybody with us before the war was on his knees before Germany; the very same fashion now makes everything German to be denigrated across the whole spectrum. I have said what I had to say, I am not going to repeat myself endlessly; at any rate, in order not to act as everyone else, I am going to say something good of the 'Boches'.¹²⁹

Duhem in fact began his article, 'Quelques réflexions sur la science allemande,' which appeared in the February 1, 1915 issue of the *Revue des deux mondes*,¹³⁰

126. 1916 (12).

127. *Un savant français*, pp. 194-95.

128. *Ibid.*, p. 195. Another of Duhem's encomiums of hard work, 'le travail abattit beaucoup de besogne,' was recalled by the Abbé Peillaube, *RP* 26 (1919):461.

129. *Un savant français*, pp. 222-23. The whole topic is discussed in great detail and with ample documentation by H. W. Paul in his *The Sorcerer's Apprentice: The French Scientist's Image of German Science, 1840-1919* (Gainesville, Flo.: University of Florida Press, 1972).

130. 1915 (3).

by holding high Gauss and Helmholtz as ones in whose scientific work there appears the pure genius of mankind untainted by national proclivity. While he singled out Newton as a similar genius among the English, Duhem did not put any Frenchman on the same pedestal. He also emphasized that the German bent on deductive rigor was necessary to weed out 'paralogisms from the science of algebra.'¹³¹ The stressing by Duhem of the indebtedness which French scientists incurred to their German colleagues during the previous half century was also a point rarely heard in the din of that intellectual war which echoed the sound of guns. Much less could one hear at that time a French intellectual warn against the excessive reliance of his compatriots on intuitive finesse.

Duhem would not, of course, have been the patriot he was, had he not indulged in drawing too strongly some unappealing traits of the German mind. They were, he argued, the result of a total yielding to sweeping deductions from principles whose agreement with commonsense truth was not investigated. In German philosophy such a principle was the identity of opposites which led to rank voluntarism in the hands of Hegel and his successors. But it was above all in mathematical and physical theories as cultivated in Germany that Duhem sought examples of impeccable deductions resting on assumptions that flew in the face of common sense. What Duhem said in this connection about the genesis of Riemann's work on non-Euclidean geometries and of the theory of relativity¹³² may not have been readily grasped by the average educated French reader, he could savor Duhem's essential point, namely, the superiority of the *esprit de finesse*, which judges by common sense the truth of principles from which deductions depart, over the rigorous chain of deductions, a product of the *esprit géométrique*. Frenchmen could only relish Duhem's grand conclusion that in virtue of the foregoing superiority it was correct to say: *scientia germanica ancilla scientiae gallicae*. Undoubtedly they relished just as much the brief and vivid sketches in the article, as, for instance, that of a typical German professor. Being a prisoner of the principle of the identity of opposites he would comfortably live at the same time in two worlds: one purely intellectual, where reality disappears in idealist philosophizing, and another, starkly concrete, where reality reenters through beer, pipe, and sauerkraut.

Such an article could only enhance the appeal of the four lectures on German science which Duhem was to deliver shortly afterwards under the auspices of the Association des Etudiants Catholiques on four successive Thursdays between February 25 and March 18. The four lectures, whose contents will be discussed in later chapters, dealt with philosophy, the sciences, historical studies, and reasoning anchored in order and clarity. Duhem's chief aim was to make students more aware of the need of resisting foreign, especially German, influences and of adhering to the French ideal of clarity which demanded full respect for the dictates of common sense as the essential tie to the world of reality. How deeply Duhem felt on this point can be gathered from his letter of January 3, 1915, to F. Mentré:

131. Duhem singled out Weierstrass; *ibid.*, p. 663.

132. To be discussed in Ch. 8.

Neither you nor I have the satisfaction of collaborating through bearing arms for the physical expulsion of barbaric hordes from inside our borders. But we too have a task. We had to wait for the declaration of war to undertake it and, undoubtedly, well after the signing of peace we will have to carry it on, namely, to purify the intellect of the country of all foreign contamination, that is, to rehabilitate French thought and French thinkers. May God grant that we not fail!¹³³

In his letter of May 5, 1915, to Dufourcq on the battlefield Duhem broached the same point with the freedom of talking to a trusted friend:

I believe as you do that it will be our duty after this terrible storm to maintain and strengthen national unanimity. But, precisely, we will not be able to do this except with an intransigent severity toward all those who for such a long time troubled the intellectual and moral unity of France, and especially toward those who would start it all over again. We will not spare them and, especially, we shall mercilessly defy them. We will treat them as so many Germans and we shall not lose any occasion to prove the extent to which they have turned into 'Germans.' A broad smile will very often be our best weapon. We shall use it often. Before the defenders of foreign mentalities we shall no longer be the timid little boys, overawed by the 'monsieur très savant,' as we have been until now. We shall laugh into their faces, broadly and insolently. I am really counting on having plenty of enjoyment from this during the years which God may allow me to spend in His service and the service of our beloved country.¹³⁴

The intense feelings of the letter may have been triggered by the news that Dufourcq had already read and immensely enjoyed *La science allemande*, which was printed with all possible speed. A hundred or so copies Duhem himself sent to former colleagues and students, especially to members of the Association fighting on the battlefield. The impression made by the book¹³⁵ was electrifying. Inquiries were made from Basel, so Duhem informed Dufourcq, about the possibility of translating the book into German. Favorable reception to *La science allemande* was less a factor than was Duhem's sense of patriotic duty that despite the consuming task of pushing toward completion the *Système du monde* he found time and energy to carry on with the defense of French intellectual heritage. In the summer of 1915 he completed a booklength vindication of Lavoisier's pioneering originality against the claims of some German chemists¹³⁶ and contributed with an article on German science and German virtues to a book in which almost thirty prominent

133. F. Mentré, 'Pierre Duhem: Historien et philosophe,' in *Revue des Jeunes* 15 (août 1917):130. For others, viewing the war in the same perspective, see E. Weber, *The Nationalist Revival in France 1905-1914* (Berkeley: University of California Press, 1959), p. 144. Delbos, Duhem's good friend, expressed himself in the same vein a few days before his death in a letter to the Abbé Wehrlé, quoted in the introduction to his posthumously published *La philosophie française* (Paris: Plon, 1921), p. iii.

134. Published with the permission of Mr. Norbert Dufourcq.

135. Copies were available already in May.

136. The title of the book, 1916 (2), was a variant on the phrase, 'La chimie est une science française,' which opened A. Wurtz's introductory essay, 'Discours préliminaire. Histoire des doctrines chimiques depuis Lavoisier jusqu'à nos jours,' to his *Dictionnaire de chimie* Tome I. Pt. 1. A-B (Paris: L. Hachette, 1868), p. ii.

French scholars rallied to the defense of French science and culture.¹³⁷ Although the tone of the book was more elevated than the one typical of most pieces of 'war literature' produced by scholars on both sides, Duhem here too distinguished himself by his restraint. He in fact urged his compatriots to strengthen the *esprit géométrique* in themselves and to secure thereby to their work 'all the solidity, all the precision, all the rigor, all the continuity of which German science is rightly proud.'¹³⁸

As to the 'insolent and broad smile' which Duhem relished in advance following the happy outcome of the war, it should appear a very mild weapon when compared with the institutional oppression waged by those who also defended the 'French soul,' though in a sense diametrically opposite from that advocated by Duhem. For the time being the national unity required by the war imposed a restraint on the campaign against Christianity in general and the Church in particular. It was, however, to be expected that once the war was over there would be a fresh resurgence of the antireligious crusade which ranged from boastful oppression to vituperative diatribes. An example of the former was Aristide Briand's declaration made on April 10, 1910, that having allowed the faithful to go to church 'to draw some consolation from religious sources, the Republic demonstrated a most liberal attitude toward the Church.'¹³⁹ As to those diatribes, a most memorable example of them was the work, *Défendons l'âme française* (1910), by Noel-Auguste Delpech, senator and master of Grand Orient who, on taking the latter office in 1902, had declared:

The triumph of the Galilean has lasted twenty centuries. He is dying in his turn. The mysterious voice which once on the mountains of Epirus announced the death of Pan, today announces the death of the deceiver God . . . The illusion has lasted very long. The lying God is now disappearing. He goes to rejoin in the dust of ages the other divinities of India, Egypt, Greece, and Rome who saw so many deluded creatures throw themselves at the foot of their altars. Freemasons, we are pleased to state that we are not unconcerned with this ruin of false prophets. The Roman Church, founded on the Galilean myth, began to decline rapidly on the day when the Masonic association was constituted. From the political point of view Freemasons have often varied. But in all times Freemasonry has stood firm on this principle: War on all superstitions.¹⁴⁰

To be sure, both sides made ample contributions by their heroism on the battlefield. Delpech himself was wounded and decorated in the Franco-Prussian war. But on another level Duhem's view of the French soul was to receive telling support from the Delpech camp. Raymond Poincaré, President of the Republic during World War I, felt the need to admit, though privately, as he saw in the early 1930s a far worse storm gathering:

137. 1916 (3).

138. *Ibid.*, p. 152.

139. As pointedly recalled and quoted by G. Sorel in his *Illusions of Progress*, tr. John and Charlotte Stanley, foreword by R. A. Nisbet, introduction by J. Stanley (Berkeley: University of California Press, 1969), p. 181.

140. Quoted in W. J. Whalen, *Christianity and Freemasonry* (Milwaukee, WI.: Bruce Publishing Co., 1958), p. 124.

You see, my dear Abbé [Berger], when one's hair becomes white, when one has reached the end of a life devoted loyally and disinterestedly to most cherished ideas, one feels the need to retrace the long course travelled. Then one can see the things one has vanquished or weakened. One sees far less the things one has put in their place. In this very hour there will not be too many Frenchmen of good will to enable their country to face the future already in the making. You priests, with your faith, with your example, with your discipline, you can contribute a great deal to save what this country is now losing, her very soul.¹⁴¹

Whatever the intensity of Duhem's feelings toward some intellectual antagonists, he was tactfulness itself in helping innocent victims of the war, regardless of their persuasions. When in July 1915 a Committee was organized on behalf of war orphans of the greater Bordeaux area, he was asked to explain at its first public meeting, on August 1, to two hundred war widows the aims and activities of the Committee. As an observer recalled:

When among those widows, a bit frightened by the name, 'Orphanage of the Armed Forces,' the fear arose lest their children be taken away from them, lest some try to inculcate in them religious or social ideas at variance with those of their parents, Duhem knew, with infinite tact and with very fortunate words, how to convince them that they could without worrying accept the material and moral aid offered to them.¹⁴²

Then came the Fall of 1915 when on every Sunday the Committee distributed aid and inscribed new orphans, Duhem was there as often as he could be and, as the same observer noted:

Each time it was a new case of astonishment and admiration to see him receive with the refined courtesy of a man of high standing the widows coming to enroll in the Committee's program, putting in writing at their often unskilled dictation the information requested, and sending them away with such words of encouragement and comfort that none of the widows inscribed through his efforts had ever forgotten that 'monsieur si bon' who had received them.¹⁴³

The summer of 1915, which saw his *La science allemande* sold out in two months, found him writing, while he was receiving many congratulatory letters,¹⁴⁴ a book-length reply to the contention that chemistry was a German science. At immediate issue were the respective merits of Stahl and Scheele, on the one hand, and of Lavoisier, on the other. Duhem would not, however, have been himself had he not put this restricted issue into the broader perspective of the history of chemistry during the 17th and 18th centuries. The book, carefully documented throughout,¹⁴⁵ was written in a few weeks 'as a relaxation,' as Duhem's daughter

141. Quoted in Choucri Cardahi, *L'Académie Française devant la foi* (Paris: Editions de la Source, 1964), pp. 93-94.

142. Jordan, 'Duhem,' p. 172. Jordan quoted from a note sent to him by the Secretary of the Committee.

143. Ibid.

144. As was the case with the congratulatory notes sent to him on the occasion of his election as corresponding member and as non-resident member of the Académie, Duhem kept these notes too in a special envelope.

145. See note 136 above.

recalled.¹⁴⁶ Her witnessing is all the more telling because her father read every chapter aloud to her as it was completed.

The word relaxation in the foregoing context tells much of Duhem's extraordinary mental energies and also of his depriving himself of much-needed rest. He felt that resting was inappropriate at a time when most painful news was brought to many families to which he was tied either by blood or by friendship. He knew what lay between the lines of the long letter of October 4, 1914, of Mansion who singled out the severance by the Germans of any postal communication with relatives caught behind their lines 'as one of the sorrows of German occupation.' In late May 1916 the death of Hadamard's youngest son, a casualty of Verdun, was announced to him by a mourning mother in the kind of letter which is sent only to close friends. A month later the sudden passing away of Delbos, professor at the Sorbonne, dealt him a great blow. His heart ached for his sister-in-law who, trapped behind enemy lines in Lille, remained unaware of the fact that two of her sons had already fallen on the battlefield. The cheers caused by the heroic exploits of the French flying ace, Georges Guynemer, a graduate of Stanislas,¹⁴⁷ were greatly offset by the impasse on the battlefield and the murmurs of defeatism at home. The drain of his energies was further increased by his accepting functions which he was in no way obligated to assume. Such was the exhaustive role, in the heat of the summer of 1916, to preside over the baccalaureat exams in the Lycée of Périgueux. He soon had to pay a fatal penalty. From Périgueux he went to Cabrespine with ever fresh projects in his head. In particular, he planned to write a lecture series to be delivered the next spring in Bordeaux. The success of his lecture series, *La science allemande*, was so great that he was unable not to promise another series on a no less timely topic. He planned to discuss the dangers to which science is exposed by utilitarianism. Were not the horrors of World War I the result of a science forced to accept the primacy of what is useful and forced to ignore the truth and the good? In a France, which had been for some time under the sway of scientism, Duhem now wanted to develop the following ideas:

For a long time science has ceased to be a disinterested search so that she might put herself in the service of utilitarianism. This is a kind of sin against the Holy Spirit. Because of this God has in a sense abandoned man. As a result, science turned against man. It is through science that the actual war is the most barbarous of all wars.¹⁴⁸

Back in Cabrespine, a letter from E. M. Guitard, head of the municipal library of Toulouse was waiting for him. The librarian recommended that Duhem correspond with a young man in Toulouse who wished to obtain bibliographical details.

146. *Un savant français*, p. 222.

147. The motto of Guynemer, 'Faire face,' is solemnly recited every year in the French Air Force. A special chapter in H. Bordeaux's *Le Collège Stanislas* (Paris: Gallimard, 1936, pp. 145-68) is devoted to Guynemer whose bas-relief portrait is the chief décor of the main foyer of the Collège.

148. As reported by the Abbé Bergereau in his speech devoted to Duhem's memory; see note 117 above, p. 10.

Duhem was more than willing until he learned from Guitard's letter of August 8 the name of his prospective correspondent, Mr. Marcel Huc, son of the director of *La Dépêche* (of Toulouse) and a Radical activist of the Delpech kind. Attached was a letter from young Huc doing his best to flatter Duhem who wrote back to the librarian on August 9:

I regret not having known right away the name of the researcher who wished that I give him information. It would not be proper on my part to enter into correspondence with the son of the director of a newspaper which carries on, in the times in which we live, with the [divisive] work which is all too well known. If therefore Mr. Huc [jr.] writes to me, his letter will be left unanswered. I would be very much obliged if you would kindly notify him of this.¹⁴⁹

Young Huc was duly notified and elder Huc outraged. In his view, Duhem, an employée of the state, refused to serve the public. Duhem, of course, was under obligation only to serve his students and no one else. And certainly the outraged father had no right whatsoever to make the matter public by printing on the front page of the September 10 issue of *La Dépêche*, the letter he sent to Duhem on September 7th.¹⁵⁰ The seventy-line column headed by the word TOLÉRANCE in bold-face type, was placed, obviously for better psychological effect, under a photo showing French soldiers marching to the front line. The column started with a description of young Huc's request and was followed by Duhem's letter of refusal to help. Huc Sr's letter centered on two themes. First, Duhem was charged with abusing the privileges of his chair for 'sectarian' purposes. Then the great logician, Duhem was reputed to be, was portrayed as being guilty of flagrant inconsistency. The latter led, Huc Sr. argued, to either of two alternatives, namely, whether Duhem read *La Dépêche* or not. If he did, he sinned against his professed principles forbidding him to let himself be contaminated by non-sectarian views. If he did not read *La Dépêche*, then, Duhem the scientist, observant of facts, made up his mind about Mr. Huc with no factual knowledge about him.

When this pathetic diatribe came to Duhem's notice, he had already become the victim of a far more serious attack which, he knew well, beckoned death for him. He suspected nothing when on Saturday, September 2, he experienced to his great surprise, great difficulty in returning home from a walk into the hills. In the middle of the following night he suffered a cardiac seizure. In spite of the enormous pain tormenting him, he decided not to disturb the sleep of his daughter and much less of her guest, a poor orphan, whom she brought down from Paris to the good air of Cabrespine for the summer. Hélène learned about the tragedy only when, after waking up in the morning and passing in front of her father's bedroom, she heard him sobbing inside. He could hardly speak. On being asked whether he was suffering much, he replied: 'I am waging my war.' The gravity of his condition was made clear to him on the first visit of the physician who diagnosed angina pectoris. Duhem received the verdict with calm. The next day he remarked: 'I

149. *Un savant français*, p. 182.

150. Reproduced in part *ibid.*, p. 183.

understand. This means: think of death.' The thought of his death was lurking behind the remark he made a few days later: 'I have never asked from God anything except that He keep me until my daughter can safely leave me.' Clearly, what he meant was: 'Now I can depart.'¹⁵¹ As a Christian he was ready to depart. He went, still in apparently perfect health, to communion in the little church of Cabrespine on the Feast of the Assumption which in the eyes of French Catholics is also the feast of the Virgin as Patroness of France.

To the doctor who diagnosed his condition it was clear that there had been earlier signs of the crisis which Duhem apparently ignored. Perhaps, in addition to past symptoms, Duhem gave the doctor a glimpse of his work schedule, but probably nothing of the many setbacks of his career that obviously took their inexorable toll. Possibly he spoke of his agonies over the war. Joffre's inconclusive counteroffensive on the Somme, extremely high in casualties, was under way. Duhem was pained that he had no sons to fight on the battlefield. 'If you were the little Pierre whom I wanted so much,' he kept teasing his daughter, 'I would have at least one son fighting.'¹⁵² He was now drastically limited in his own way of fighting the war. For a few days he was forbidden to take the short walk to the Post Office where he loved to put the latest war bulletins in the best possible light for the anxious villagers. Then he was allowed short walks, always on the same level, hardly a possibility in a village nestling in the mountainside, where he could not reach from his own house even the nearest path without first climbing fifty yards or so. The prospect of giving up hikes for good was almost unbearable to him. 'Goodbye,' he wrote at that time to a friend in Bordeaux, 'to the outings in our beautiful mountains which brought me, during vacation time, the physical and intellectual repose. For the moment, I am restricted to walks of five hundred meters taken at a snail's pace.'¹⁵³ To satisfy his irrepressible love of nature he now had eyes to see its wonders at his very doorstep. He now discovered views worthy of his pencil visible from his front yard: the chestnut tree bending over the little river at the edge of his garden and the spire of the church barely rising over the roof. He now discovered an old wall, almost within arm's reach, a plethora of strange plants worthy of study. 'I have never busied myself with botany,' he told his daughter. 'I will tackle it. We shall herborize and we shall find many things to occupy ourselves right around us.'¹⁵⁴ Inside, in his study, he was correcting the proofs of the fifth volume of his *Système du monde*.

His real thoughts and concerns reached far beyond him. He began to worry about his students, whom he was to face again in October. He was concerned about his audience in the big lecture hall. Would his voice be strong enough? Would he be allowed to teach again? The news of his illness spread and well-wishes were pouring in. Mr Huc's assault merely amused him. Almost immediately he penned a letter to the librarian in Toulouse:

151. Reported by the Abbé Bergereau; see note 118 above, p. 11.

152. *Un savant français*, p. 219.

153. Reported by the Abbé Bergereau; see note 118 above, p. 12.

154. *Un savant français*, p. 233.

I have come to regret having made Mr. Huc [Jr.] responsible for the disunity fomented by his father's newspaper. I was about to write to you when I received from Mr. Huc Sr. an unqualifiable letter. Would you please have the kindness to tell Mr. Huc Jr. that in spite of his father's letter I am ready to communicate, concerning the manuscript of interest to him, the information which he requested and which I may have.

To his daughter, who could not understand his conciliatory attitude, Duhem remarked: 'Believe me, this is more Christian.'¹⁵⁵ While the ailing Duhem could readily cope with such matters, very small in most eyes, his confinement to the immediate surroundings of his house loomed much too large on his horizon. A letter of his, probably the last one he wrote, leaves no doubt:

Madame, you are very kind in your interest in such an old wreck as I am. Oh! The long walks in our mountains! This was each year my great fortune and my great relaxation. The doctor has just come to say: This is finished – A small sacrifice to accept, the first announcement of the old age that comes. When in this moment, so many young men leave everything with such complete abnegation, it would be improper for the old ones to complain on account of such a small self-denial.¹⁵⁶

Duhem instead complained about the rainy weather which was spoiling the vacation of his daughter and of her orphan guest.

Apparently he must have felt better because he could not resist the call, if not of the mountains, at least of an adjoining hillcrest. He slowly walked up there, only to find himself in great pain as he descended. In the morning of September 14, Thursday, he was in his study as his daughter entered. He stopped working on a sketch he had begun the previous day of the church-spire as seen from his window, and made ready to go to the Post Office to see the latest war bulletin. To please his daughter, he settled into an easy chair. Before long, the conversation turned to the war. On hearing a 'defeatist' word leave her lips, he began to list all the reasons which obviated a French defeat.¹⁵⁷ 'Then all of a sudden he falls silent, begins to gasp, and a few seconds later, without regaining consciousness, he breathes his last.'¹⁵⁸ So was his death recorded by his daughter, the obvious source of the more graphic portrayal of Duhem's death by his lifelong friend, Jordan: 'His face suddenly contracted under the impact of an enormous pain. He expired in a few minutes without being able to say a word.'¹⁵⁹

155. *Ibid.*, p. 184 He did not live to read the reply of the librarian who expressed his deep regret in a letter dated September 15 over the entire matter which started as a pure scientific consultation.

156. Quoted by the Abbé Garzend; see note 56 above, p. 1086. The lady in question was in all likelihood Mlle Girennerie, Hélène's 'superior' at Atelier St. Agnes in Paris. By making a special effort to reply Duhem obviously wanted to serve Hélène's well-being there.

157. Among the fresh reasons Duhem could list was the successful stand of the French Army around Verdun. He would have been most pleased to read the report in the September 13 issue of the *Morning Post* (London) and savor its 'English' spirit: 'The supreme hopes of Imperial Germany had been shattered against the walls of Verdun where the Germans had tried to secure an astounding spectacular success. With tranquil success France had replied: 'You shall not pass.'⁷ (p. 3, col. 7).

158. *Un savant français*, p. 234.

159. Jordan, 'Duhem,' p. 173.

The little village of Cabrespine gave him the greatest honor of which it was capable, the very center of its little cemetery. There, in a stone crypt, his body was laid to rest. The body of his daughter joined his following her death on April 24, 1974. The small white marble plaque of H  l  ne Duhem is at the base of a slab of grey stone which rises at the head of the grave. Engraved on that stone are the names of Duhem's wife, parents, sisters and brother – some of the lines hardly legible. The grave itself is covered by red marble ornate with the inscription:



Ici repose

Pierre Duhem

Membre de l'Institut

d  c  d   le 14 7bre 1916

   l'  ge de 56

RIP

On June 25, 1980, when the author of this book paid his respects at the grave, it was watched over by dark cypresses dashing against an azure sky, by green mountainsides interspersed with stretches of bare rock, and by elderly villagers still fond of his memory. The only sounds to be heard were the ones which had given him ever-fresh delight: The whisper of the summer breeze overhead and, below, the murmur of the little river, Clamoux, which from a few hundred yards higher was bringing down to his remains the caresses of the maternal home.

7. IN MEMORIAM

Din of war and summer lull

Never a part of the 'establishment,' Duhem was not the kind of eminent figure whose death would have been very newsworthy even in normal times. In the din of war, with death taking its toll at a frightening rate, Duhem's passing away was not to create a stir. Owing to the circumstances, his memory could not be properly celebrated for another five years in the Académie des Sciences where prompt notice was taken of Hélène's telegram. As an expression of mourning, Camille Jordan, President of the Académie, restricted its regular weekly meeting on Monday, September 18, 1916, to his reading a two-page-long summary of Duhem's main aim and accomplishment in physics, a summary which would certainly have met with his approval. Jordan, who as editor of the *Journal de mathématiques pures et appliquées* had for many years welcomed some of the most 'esoteric' of Duhem's memoirs, was a competent judge. His concluding words referred to the *Système du monde*, in course of publication with the 'subvention of the Académie,' as he pointedly noted: 'In the four volumes already published, one does not know what to admire more: the author's vast erudition or his immense labor. The glorious role played by the University of Paris is set forth there in its full light.'¹

Regret that Duhem never arrived in Paris save as a non-resident member of the Académie also transpired in the eulogy which Henry Joly delivered on Duhem on October 25 at the combined meeting of the five Academies. Duhem, Joly noted, would have been a credit to the Académie des Inscriptions by his historical studies, and to the Académie des Sciences Morales by his philosophical works. Duhem's rehabilitation of the Middle Ages as an age of science was a welcome complement to the recognition, already achieved, of medieval arts and letters. It was not the 'result of personal infatuation, or of current fashion, or of clever reading of obscure texts,' but of 'the competence of a genuine savant, a most authentic physicist . . .' Equally to the point were Joly's words on Duhem as a 'man of faith whose

1. CR 163 (1916):38-39.

researches will forever remain an example of the cohesion of all studies and of the harmony of most elevated thoughts.' To this Joly added Duhem's extraordinary devotion to the cause of war orphans: 'a great mind he was as well as a great heart.'² A year later the Académie des Sciences gave once more a striking proof of its appreciation of Duhem's work by awarding to him for the second time the Petit d'Ormy Prize for 'his entire work and in particular for his work, *Le système du monde*.'³

It was through Jordan's eulogy on September 18 that *Le Temps* took notice at long last. The next day, its 'Nécrologie' was headed by the name of Duhem printed in block capitals, not a daily feature in that section. Duhem was described as a 'savant de plus haute valeur,'⁴ a characterization which was not followed up within a few days or even later by something more on him. As could be expected, rightist newspapers were quicker and certainly effusive in deploring Duhem's death. *L'Action Française* saluted Duhem as a 'soldier of the pen.'⁵ *La Libre Parole* recalled his lectures on German science as the 'most devastating criticism levelled at intellectuals beyond the Rhine.'⁶ In *La Croix* Duhem's 'religious convictions' were celebrated.⁷ The best journalistic recall of Duhem's death appeared in the independent *Journal des Débats* from the pen of Augustin Fliche. A historian himself and a colleague, whom Duhem esteemed also as a friend, Fliche by his words seemed to echo his conversations with Duhem. Fliche's remark that astronomical questions disputed in the Italian universities in the 15th and 16th centuries had already received their solution in Paris in the 13th and 14th centuries, was the type of daring generalization with which Duhem loved to intimate the novelty of his findings. Again Duhem seemed to reappear on the scene as Fliche wrote: 'His old teachers, how he loved them! In fact he never abandoned them. Deprived very early of his most cherished affections, free of any ambition, he lived rather apart, admitting to his privacy only a few intimates for whom he was a very reliable, most affectionate friend, always ready to help . . .' Fliche could see at close range that Duhem 'was a master teacher in the very strength of the word. He exercised an incontestable influence on the students of Bordeaux by his rare eminence, by the intransigent firmness of his character, and the fatherly simplicity with which he received them.'⁸

2. *Institut de France. Séance publique annuelle des Cinq Académies du mercredi, 25 octobre 1916. Discours de M. Henri Joly* (Paris: Firmin-Didot, 1916), pp. 23-24.

3. *CR* 165 (1917):912.

4. *Le Temps* (19 sept. 1916), p. 3, col. 4. On the same day the *Echo de Paris* had five lines (p. 3, col. 3) on Duhem with a special mention of his *La science allemande*.

5. Ironically, Duhem was called Louis and not Pierre (Sept. 18, 1916, p. 3, col. 4). That necrology might have prompted the first line, 'Cher ami, et voici le pauvre Duhem! Delbos et lui, c'est vraiment trop,' in the letter which Bremond wrote to Blondel on Sept. 18 (*Henri Bremond et Maurice Blondel. Correspondance*, ed. A. Blanchet [Paris: Aubier Montaigne, 1971], 2:306). At the end of that letter Bremond asked, obviously with an eye on the still unpublished parts of the *Système du monde*: 'Qui se chargera du pauvre Duhem?'

6. Sept. 18, 1916, p. 2, col. 2.

7. Sept. 19, 1916, p. 2, col. 4.

8. The report was put on the front page, col. 3.

While the daily newspapers reacted, though belatedly in some cases, scientific weeklies or biweeklies devoted to current issues showed little eagerness. The *Revue scientifique*, which reported Duhem's death in two lines in its September 16-23 issue, failed to make good its promise that 'in one of our forthcoming issues we shall publish a detailed notice of the work of this eminent and much regretted physicist.'⁹ If the *Revue générale des sciences pures et appliquées*, another bi-weekly, which twelve years earlier welcomed in its pages Duhem's series of articles on the history of mechanics, did not commemorate Duhem's death until January 30, it was largely due to the care with which Jouguet prepared for that issue his survey of the work of Duhem, the theoretical physicist.¹⁰ There is something surprising in the absence of any reference to Duhem's death in *Science*,¹¹ the leading scientific weekly in the United States, where Duhem had many admirers among physical chemists and where periodicals were far less threatened by pressures of war than in France and England. The notice on Duhem in *Nature* (London) was significant with respect to both speed and length. From the *Morning Post*, the first foreign newspaper to report Duhem's death,¹² the news quickly found its way into the September 21 issue of *Nature*.¹³ Its editor also took pains to find in the person of George H. Bryan, president of the London Mathematical Society, and since 1896 Professor of Pure and Applied Mathematics at the University of Bangor (Wales), a truly competent person to write an obituary commensurate with Duhem's achievements. It saw print less than a month later, in the October 19th issue. Bryan had for some time been the outstanding British thermodynamicist whose work was also in high regard on the Continent. The reason for this, in part at least, was Bryan's sustained attention to what was the latest and best there, an attitude which brought Bryan in close contact with, among others, Boltzmann and Duhem. 'The writer of this notice,' Bryan stated, 'visited Duhem in Bordeaux in 1901. He was a shortish man with a very pleasing manner, in whom one could

9. *RSc* 54 (1916):571.

10. To be discussed in the next Chapter. In the September 15-30 issue there was a necrology (on the first page!) of Metchnikoff and a similar necrology of Sir Victor Horsley in the October 15 issue. There (p. 570) it was simply mentioned that Duhem's death was commemorated in the Académie a month earlier. Perhaps the director of the *Revue* felt that a summary of the third volume of the *Système du monde* (pp. 693-95) made up for an obituary.

11. Between September and December 1916 the columns of 'Scientific Notes and News' were full of obituary notices, which included even German scientists, and items were often borrowed from *Nature*.

12. The caption, 'The Death of a French Physicist,' headed the news: 'The death is announced today of Pierre Duhem, a leading French physicist. Duhem was a professor at the University of Bordeaux, and was particularly well known for his studies on the origin of modern physical theories. He recently delivered a series of lectures on German science, where he showed the weakness of the German claim to be regarded as a nation having seriously contributed to the grand advancement of science' (p. 8, col. 6).

13. 'We regret to see in the *Morning Post* the announcement of the death of Pierre Duhem, professor of theoretical physics in the University of Bordeaux and the author of several works of wide interest on the history of natural philosophy and physical subjects' (No. 2447, vol. 98, p. 52).

observe that element of preciseness which characterizes his writings . . . If Duhem did not concentrate his main efforts on the discovery of new phenomena or the measurement and remeasurement of physical constants, he has at least played an equally important part in the advancement of our knowledge by evolving order out of chaos, and uniting isolated portions of mathematical physics in the form of a connected and logical theory.' Such was the conclusion of an obituary which showed a thorough familiarity with Duhem's work, 'a large portion of which is in a high degree original,' according to Bryan's verdict. No wonder that he noted already at the outset with a touch of puzzlement that 'although for a considerable time a corresponding member of the Academy of Science, it was not until 1913 that the distinction of full membership was conferred on him.'¹⁴

Shortly afterwards, on October 29, the Reale Istituto Veneto heard Antonio Favaro, the greatest of all Galileo scholars, eulogize Duhem as its foreign associate.¹⁵ Favaro knew Duhem not only through his publications but also through a correspondence which contained such details as Duhem's anxiety about his sister-in-law and her daughters in Lille, a town where women were atrociously treated by occupying forces. Favaro also knew of Duhem's farewell greetings to students departing for the battlefield: 'Au revoir,' and 'May God protect you,' he told them with the faith of a patriot and a Christian.' Favaro, who, as will be seen, saw especially well the lack, understandably enough, of Italian manuscript material in Duhem's portrayal of pre-Galilean history of science, was not one to dwell on a missing or broken stone in a magnificent edifice: 'After the disappearance of the unforgettable Paul Tannery, Duhem remained practically the sole representative of the study of the history of science in France. In turning his attention to that study more intensively for the past ten or so years, he advanced it with giant and pioneering steps as one who by quality of genius, soundness of learning, vastness of erudition, and bent on the rigor of scientific method, seems to have been born to give that study a fruitful direction.'

Only three weeks later the Reale Accademia delle scienze fisiche e matematiche of Naples heard Duhem eulogized by R. Marcolongo, professor of theoretical mechanics at the university there.¹⁶ The eulogy, Marcolongo noted, was not only a tribute to 'one of the most illustrious and most genius-like representatives of French science whose death is an irreparable blow at the scientific world, but also to the man who over twenty years honored me with his friendship.' Marcolongo first gave an account of the coherence of Duhem's work as a physicist inasmuch as that entire work aimed at unfolding the immense potentialities for all fields of physics of what Duhem so aptly described as the thermodynamic potential. But for Italy, Marcolongo declared, Duhem had a special significance:

The illustrious scholar knew profoundly the glories of our country and dedicated to

14. 'Prof. Pierre Duhem,' *Nature* 98 (1916):131-32.

15. *Atti del Reale Istituto Veneto di Scienze, lettere ed arti*, Tomo LXXVI, Parte prima, p. 3.

16. *Rendiconti della R. Accademia delle scienze fisiche e matematiche. Classe della società reale di Napoli*. Fascicoli 1 & 2. Anno LV, Genn. e Febb. 1916, pp. 147-51.

Leonardo da Vinci, the great precursor of modern times, the most beautiful years of the laborious life of a scientist and writer. In the presence of such monumental research, though cut short at the most grandiose juncture of the history of human thought, one feels utterly prostrated: so enormous is the amount of fruitful work which he was able to tackle alone; so great is the erudition; so complete is the scrutiny of what the human spirit has produced; so suggestive are the comparisons, the reconstructions, the interpretations, both daring and ingenious; the loftiness of thought, the facility of a lucid and incisive writer . . . Now he has disappeared. He died as a soldier in the breach, killed perhaps by a superhuman expenditure of labor, on a field different from the one in which that sister nation battles, but for the same ideas of peace, justice, and work.

By November 11, when that eulogy was delivered in Naples, Duhem received the proper commemoration in Bordeaux for which his death in Cabrespine would have been a far away event even if it had not come in the lull of the summer vacations. Hélène's telegram sent to Picart, dean of the Faculty of Sciences, at 15:40, was received in Bordeaux twenty minutes later, but was slow in reaching the University which was practically deserted. Nobody at the Faculties of Law and Medicine answered until next morning the telephone of the attendant who jotted on the telegram the note: 'September 14, evening; telegram sent to Picart; Radet telephoned; Rector notified.' Apparently nothing was done to alert the Bordeaux newspapers which broke the news only in the morning, Saturday, September 16. *La Gironde* was brief though respectful: 'Everybody knows in what esteem was held the man and the savant in France, one of the most distinguished members of our higher education.'¹⁷ *Le Nouvelliste* wrote: 'A great mourning strikes suddenly the University of Bordeaux. Duhem is no longer . . . The immense misfortune brings, at the dawn of the new academic year, black draperies to the façade of the University.'¹⁸ The newspapers were as much in the dark about the funeral as was anybody at the University. 'R. [adet] does not know. No news,' is the telling note jotted on the telegram which Prof. Vizès sent at 10:15 Saturday morning from nearby Mornac-sur-Seudre, to the secretary of the Science Faculty requesting information about the place and time of Duhem's funeral at which, to all appearance, nobody from the University was represented. Then as now it was easier to go from Paris, than from Bordeaux to Cabrespine. From Paris Edouard Jordan arrived in time for the funeral, his first visit to Cabrespine, which after so many talks with Duhem looked very familiar to him.¹⁹ No less familiar, and symbolic, must have appeared to Jordan the absence from the funeral of notables, though many of them would have certainly attended in a more convenient place and time. Very appropriately, Duhem's body was accompanied to the grave by a throng of simple folk, led by their curé, the Abbé Louis Blanc, a close friend of Duhem and until his death in 1936, at the age of 85, a great support for Hélène.²⁰

17. A phrase added to the statement that 'the special nature of Duhem's works can only be appreciated by his peers' (p. 4, col. 4).

18. According to the paper Duhem was 54 and died on Thursday evening (p. 2, col. 7).

19. Jordan, 'Duhem,' p. 158.

20. See note 58 in the preceding Chapter.

Bordeaux remembers

To commemorate Duhem appropriately, the University of Bordeaux, once out of its summer lull, seized its very first opportunity, the publication in late Fall of the *Rapport* for 1915-16. Among the necrologies of four deceased faculty members, which opened the *Rapport*, the most conspicuous was that of Duhem, written by P. Cousin, professor of mathematics, who with his opening phrase struck the note which Duhem would have held to be most essential: 'Duhem's first scientific memoir was an act of scientific independence. He never bowed before the sole authority of a name, however illustrious. He claimed his right to have his views discussed and always used that right with scientific honesty, having no other aim than the unfolding of truth.'²¹ Duhem's public courses attracted, Cousin continued, 'not only the students of the Science Faculty. Many came from the outside, drawn by the personality of his teaching, and the originality of the theories he developed. They all felt reassured that a harvest of clear and new ideas would be reaped from each of his courses.' Reference to the belated crowning of Duhem's eminence by his election to the Académie was inevitable. Another telling remark of Cousin was that the 'manuscripts Duhem left behind would permit the publication of the *Système du monde* beyond its fifth volume, already in press, although the work would unfortunately remain incomplete.' That Duhem criticized German science with 'his customary loyalty [to truth] and without any tendenciousness' was a remarkable point at a time when mutual vilification by academics on both sides of the Rhine was the prevailing norm.

Twice as long, six pages, was the length in the same *Rapport* of the portrayal of Duhem, the scientist, in the section reserved for the Science Faculty. Dean Picart started by noting that Duhem's life and work not only deserved a detailed study but that his colleagues and friends had already decided to undertake it.²² 'Few men,' Picart continued, 'were so endowed as Duhem with the qualities of a teacher. The clarity of his papers gives but a meager idea of what his oral teaching was. He put in the service of mind, before which there arose immediately the fundamental idea, an exact and ample flow of words stamped with warmth, and the formulas, which his neat and large handwriting lined up on the blackboard, became readily engraved in the memory of the students.' Picart then portrayed with two lengthy and aptly chosen quotations from Duhem's *Notice* to the Académie the very essence of his notion of physical theory and the chief aspects along which it contrasted with the prevailing views. As to Duhem the historian, Picart provided another public notice that the fifth volume of the *Système du monde* was already being printed. According to Picart, two other volumes were ready in manuscript. He could hardly suspect that the manuscript, enough for five other volumes and already deposited with the Académie des Sciences, would not be given a proper study by historians of science for the next three decades and even after their long-delayed publication in the 1950s. What Picart certainly knew was that

21. *Rapport 1915-16*, pp. 5-8.

22. For Picart's 'notice' on Duhem, see *ibid*, pp. 89-94.

It is not only a professor and a scholar that disappeared but also a noble character. Duhem was frankness incarnate. He did not solicit anything from those in power, but he did not spare them either when their ideas did not seem to him to be right. At the same time, all students were certain to find from him a fatherly reception. An ardent patriot, he has never, since the start of the present conflict, despaired of the ultimate success of our cause. In order to help his students love their country more, he composed two small volumes, *La science allemande* and *La chimie est-elle une science française?*, in which the legitimate concern for the superiority of the French method never excludes scientific impartiality. May I be allowed to recall in a word the dignity of his private life, saddened by the premature end of a tenderly loved spouse, and his inexhaustible beneficence all too familiar to the poor of his neighborhood.

Duhem's labor of love, during his last three years, the Association des Etudiants Catholiques, celebrated his memory on Sunday, November 19, 1916, at a mass in the Chapelle de la Madeleine. The sermon preached by the Abbé Bergereau was immediately printed,²³ partly for the benefit of former members of the Association fighting on the front, hardly a place for the safekeeping of a booklet which not only saw a very limited circulation but most copies of which perished. Rather limited also was the number of those who heard the sermon. Only a handful if any of those students who saw Duhem help establish the Association in 1913 could be present. But even those who knew him only during the previous academic year must have heard their own sentiments echoed in that profoundly moving sermon, perhaps the most intimate portrayal sketched of Duhem. Following a portrayal of Duhem's relation to the Association, already quoted,²⁴ the Abbé Bergereau gave an account of Duhem's last weeks in Cabrespine and especially of the circumstances of his death, the death of a Christian. Of course, Duhem's deep Christian convictions were no secret in Bordeaux where some even remembered that professor with a still black beard who led his only daughter by hand to the weekly catechism at Sainte Eulalie, his parish church. Those living in the neighborhood, the Abbé continued, after giving a touching glimpse of the loneliness of Duhem's last seven years,²⁵

could see him every day take a short walk. He used the opportunity, from time to time, to enter into the lodging of the poor. The misery of the unfortunate tore his heart. He knew that paying the rent was a heavy burden for someone without work, that the winter is harsh on the sick who have no firewood, and on the poor who have no bread. And, as befits the truly charitable, only God can tell the extent of his charity.

Before returning home to resume work, to fathom the problems of physics, to decipher old manuscripts, he passed in front of the small chapel near his home and often entered to kneel down for a few moments before the Blessed Sacrament. These prayers of Mr. Duhem in the chapel of the Franciscan Sisters on the Rue de la Teste, what would we not give to penetrate their secret! Was it not there, near the Crucified Lord, that he drew in a large part the strength to stay always erect in the midst of trials? How well he kept there the promise he made to the students that he was to

23. A booklet of 23 pages, under the title, 'Pierre Duhem, membre de l'Institut, Professeur à la faculté des sciences, Membre Fondateur de l'Association Catholique des Etudiants de l'Université de Bordeaux' (Bordeaux: Imprimerie Wetterwald Frères, 1916).

24. See the preceding Chapter.

25. Ibid.

pray for them as he told the ones leaving for the battlefield: May God protect you! And what is more truly beautiful than to see this illustrious *savant*, humbly bow his head before the One who alone is Light! I love to think that to help him pursue his work and, appreciative as He certainly was of his service, our Lord made him hear, in the depth of his heart, the words: I am satisfied with you.

With this the eulogy came to its concluding part, a portrayal of Duhem's intellectual work as a service to Christian faith. The service could hardly be easy at a time when a Renan was applauded for having declared that the enigma of existence, left unresolved by the Gospels, would be unraveled by science 'which will organize God,'²⁶ and a Berthelot was celebrated for his claim that science left no more mysteries.²⁷ The times were the apogee of the view of history according to which Christianity had to be sidelined once and for all to let reason through science prevail. In this view, the Christian centuries of European history had to appear unqualified darkness, and to illustrate this the Abbé could have found a hundred phrases similar to the one he quoted, an utterance of Taine: 'Three hundred years at the bottom of that dark ditch have not furnished one insight to the human mind.'²⁸ This much celebrated darkness of the Middle Ages was shown by Duhem to be a myth. His achievement was all the more telling because he found the medieval centuries to be productive of scientific light, immersed as they were in faith. Duhem arrived at this conclusion after decades of unremitting research, the outcome of which was wholly unforeseen by him:

Scientism was on the rampage and its victims multiplied. In spite of the authority of scholars who propagated it, Duhem did not allow himself to be taken in by the mirage of that false doctrine. Dedicated to theoretical physics, the science of his choice, he investigated, with his powerful capacity for work, almost all of its problems, one after another, for more than twenty years . . . After that he believed himself to be in the position of doing a little synthesis. 'Ten years of analysis, for one year of synthesis,' he used to say. He remained faithful to the advice he gave . . . He wrote his beautiful book on physical theory where he shows himself as profound a philosopher as excellent a physicist. For him the physical theories are more commodious than true. Nevertheless, they can give a certain knowledge of the true nature of things . . . And this true nature of things, as he perceived it at the conclusion of his work, far from conforming to old atomism, more or less assumed by the majority of unbelieving scientists, comes fairly close to what Aristotle has thought of it . . . By marking the just limits of science . . . he contributed to dissipating the false hopes that used to be put in science . . . These masters of the Middle Ages were almost all sincere believers. For them there was no conflict between Science and Faith . . . And this conflict would not have arisen if the scientists, staying within their domain, had not deviated from their proper road. Duhem saw it well. This is why, as an eminent scientist and a convinced Catholic, he took his

26. 'La science organisera Dieu,' was Renan's famous remark.

27. In the preface to his *Les Origines de l'Alchimie*. The best commentary to it came from none other than Jaurès in his speech delivered in the Chambre des Députés on January 21, 1910: 'L'admirable savant qui a écrit un jour 'le monde n'a plus de mystère,' me paraît avoir dit une naïveté aussi grandiose que son génie' (quoted in A. Witz, 'Le conflit sur la valeur des théories physiques,' *RQSc* 77 [1920]:86).

28. *Histoire de la littérature anglaise* (see note 33 to Ch. 10).

place in that array of great intellects who thought, at diverse epochs, that serving Science did not prevent one from bowing before Faith.

The Abbé Bergereau could have formulated this moving summary of Duhem's work – a summary faithful also in its shortcomings to the flaws of Duhem's reconciliation of Faith and Science – even if he had known that work only through reading. But, as he noted, he became imbued with that work through many conversations with Duhem. These conversations began after the Abbé took up residence in the fall of 1912, shortly before the Association was formed, in the Grand Séminaire of the Archdiocese of Bordeaux in the Rue St. Genès, a block away from Duhem's house. Almost neighbors, the Abbé and Duhem soon became close friends:

During those last two years hardly a week passed without his crossing the gate of the Seminary. I cannot say what I owe to these marvelous conversations. Incredible is the number of ideas that left his lips and from which I tried to profit as best I could. Naturally, the Association was often discussed. How precious were his counsels and his encouragements! After the Association he usually spoke of his students. I could see that this remarkable teacher was also for them a true father. And at the end, at the very end, he unveiled at times a corner of his very soul.

Of all this the memory which I will keep with the greatest joy is that of a solitary worker, for whom life had its rude blows, who was willing to honor me with a friendship very strong and very secure and who, I believe, was happy during his last years to come and talk with a priest who had a great admiration for him and was deeply attached to him.

Thus, at the news of his death, you who have known him somewhat specially, and whose tears I have seen flow, you could notice how my heart cried with yours. It took me some time to convince myself that I must resume the task without him. In families, where death has just struck the head, the youngest ones, and especially the ones who are still to be born, don't know the departed except through what they hear said of him. They listen with emotion and are grieved for a moment. Then rather quickly, they return to their joyful and lively games. The older ones, especially those who are left to guide the family, are obliged to make an effort to smile. But the thought of the dead never leaves them. They go on in life as if accompanied by a shadow. This is what I have felt and you, I believe, with me since the death of Mr. Duhem.

Less than a month after the Abbé Bergereau eulogized Duhem, the young women of the Association held their yearly assembly. In addressing them Paul Courteault, professor of history, felt it imperative to devote much of his speech²⁹ to the memory of Duhem whose death 'was felt perhaps nowhere more vividly than in the small group of Catholic women, students at the University.' He knew that the 'hearts of young women, hearts of fervent students, were broken.' Many of them felt as if they had lost 'not only a founder, an incomparable teacher, but a benefactor, a protector, a father.' Courteault gave a résumé of the address Duhem gave the Association the previous June and apologized for falling short of the exquisiteness with which Duhem drew the picture of the characteristics of the in-

29. *Compte rendu des Assemblées générales des Etudiants 1916-17* (Bordeaux: Imprimerie Nouvelle F. Pech, 1917), 44pp. For Courteault's address, see pp. 9-13; and p. 11 for the long quotation afterwards.

tellectual contributions of women. That address, Courteault added,

forms perhaps the last pages Duhem wrote. they are truly exquisite. In the imposing vastness of his work, so diverse and yet so unified – unfortunately incomplete – they are entitled to a special place. Are not they like the blossom of his thought? And when he read to you some of the ideas which were dearest to him, when he offered them to you with a gesture so simple and cordial, and invited you to breathe their fragrance, was this not like a bouquet which he put together of the most beautiful thoughts his vigorous mind distilled in the course of thirty years of labor, through more than three hundred articles, memoirs, and books? The gesture was charming; it remains a very sweet thought in our inconsolable mourning where it evokes the uppermost image of Duhem – of the great Duhem as we were wont to call him already at the Ecole Normale – who leans toward those whom he loved to call his adopted nieces and make them share, with a graceful gesture and serene smile, in his great treasury of ideas and wisdom.

The first anniversary

The small group of young women could not hear enough of Duhem. At their annual dinner on June 17, 1917, the Abbé Bergereau devoted therefore the better part of his toast³⁰ to Duhem's memory, obviously with an eye to the first anniversary of his death:

In your wish to be reminded of Duhem, do you take into account, – the Abbé asked his audience – the mysterious influences which the dead can from their tomb exert on the living? I see, as if it were yesterday, Duhem enter my room, sit in a chair, and put on his knees a briefcase bursting with books. It was the end of last May. He came as if on a mission. Who sent him? For what reason? What was the result of his plea? You know. What you don't perhaps know is the manner in which he pleaded your cause. He did it with that true eloquence which he himself once defined: 'a generous heart laid bare'. I was moved on seeing that member of the Institut putting so much feeling into so small a matter. Truly, I have never seen better how he loved you.

The Abbé then recalled Duhem's opinions about Catholic attitudes toward the state university system of which Catholics should have taken greater advantage:

In addition to the not-at-all-negligible benefit of taking the chairs occupied by neutrals or antagonists, the Catholics would have been more successful in discrediting, to some degree, the unjust charge which their adversaries are most fond of levelling at them: the fear of science.

As the Abbé disclosed, Duhem was much distressed by the fact that some Catholics, unmindful of the contribution of those universities, looked askance at devout Catholics serving as professors there.

Of this he kept a painful memory. He told me that he had suffered much on that account, and all the more so because he saw himself sidelined, precisely because of his Catholicism which he was never so weak as to conceal. Though he much regretted such a state of affairs, this did not prevent him from recognizing that the defiance of the Church with respect to the official educational system was perfectly justified. Knowing

30. *Ibid.*, pp. 25-34; for quotations, see pp. 27-28.

from a close range what to expect, many times he was tempted to propose to his students the following problem: 'Show by careful experiments how, in our country, every discourse, including agricultural lectures on the cultivation of potatoes, ends with an anticlerical ditty.'

The day of Duhem's anniversary was duly marked by the loyalty of his friends. One of them was the Abbé Lethellieux, director of the *Revue des Jeunes*, a bi-monthly aimed at university students, who secured two contributions on Duhem. The first, to appear in the August 10 issue, was written by François Mentré who, as a specialist on Cournot's philosophy, was, as will be seen, very familiar with Duhem's works pertaining to the philosophy of science. Almost an entire shelf in his library, Mentré noted at the outset,³¹ was filled with Duhem's publications. Mentré had hoped to meet Duhem in person at the Congrès de philosophie et d'histoire des sciences in Geneva in 1904, but Duhem, who at the urging of Paul Tannery sent a paper,³² informed Mentré in a letter of his horror of attending such 'Babylons.'³³ Whereas Duhem's dislike of congresses was fairly well known, it is only through Mentré that a precious glimpse of Duhem's reflections on the history of experimental method became available to the public. Mentré quoted from a letter, which Duhem wrote on October 24, 1913, in response to Mentré's congratulations on Duhem's findings about Buridan, Oresme, and others: 'Your letter,' Duhem wrote, 'showed me that you have been greatly preoccupied by a thought which has been haunting me for a long time. The progress of experimental method has been conditioned by the progress of industrial technique and, in particular, by the [progress of] the glass industry. This was, I believe, the topic of my last conversation with my venerable friend Jules Tannery . . . I would gladly know of an alert investigator who would do on this topic a research which neither you nor I can undertake. I bet he would arrive at interesting results.'³⁴

Mentré emphasized in his presentation of Duhem's intellectual heritage the 'Aristotelianism' which Duhem found underlying the development of modern physics, the analysis of the notion of quality which he took for the high point in Duhem's *Théorie physique* and which, Mentré thought, undermined Bergson's 'mystical epistemology where quality was absolutely distinct from quantity.'³⁵ Mentré did not fail to mention Duhem's discovery of medieval science which he saw as the crowning phase of a rehabilitation of the Middle Ages that had been under way since Chateaubriand (arts) and Comte (social organization), though not with respect to science. In a footnote Mentré felt it important to warn against what he termed an already widespread misinterpretation of Duhem's thought: 'Duhem does not say that modern science is a product of Christianity; he rather says that Christianity has been an auxiliary, and an indispensable one, to the

31. 'Pierre Duhem: Historien et Philosophe,' *Revue des Jeunes* 15 (10 août, 1917):129-41.

32. A massive contribution it was! See 1904 (20).

33. Mentré, 'Pierre Duhem,' p. 130.

34. *Ibid.*, p. 138.

35. *Ibid.*, pp. 131 and 134.

scientific development.³⁶ The background against which Mentré sketched Duhem's accomplishment was his intellectual self-discipline which made him devote many years to specialized studies prior to undertaking the work of interpretation and synthesis: 'The value of Duhem's work [relating to the history and philosophy of science] is due to his scientific authority, to his teaching experience, to the serene maturity of his mind. He was first an accomplished expert in science and ventured but rather late into sensitive areas.' The moral could now readily be drawn for the readers of the *Revue des Jeunes*: 'Be first men who are fully what they are and then, when you confront the public, your work will have a persuasion which has greater value than an ephemeral reputation.'³⁷

The author of the second contribution was the Abbé Bernies³⁸ whose recollections of priceless details about Duhem have repeatedly been utilized in the foregoing pages. He first portrayed Duhem, the friend:

The famous scientist had a simple and honest heart, somewhat overcast – so many people had not understood him – but a heart at its depth very affectionate, delicate, tender even in his manly reserve, when he felt touched. A friend he was, devoted, trusting, ready to serve, to be oblivious of himself and to sacrifice himself when needed. This is all too well known to those who lived in his intimacy and enjoyed those hours of expansiveness which he granted but rarely. The friend in him evidenced himself more in action than in sentiments.³⁹

A close friendship with Duhem naturally presupposed a genuine interest in his thought, and the Abbé Bernies, who was fortunate to have been instructed by Duhem himself, could, in the second part of his contribution, which had Duhem the savant as subject, easily render the essentials. After recalling the charges of Kantianism levelled by some at Duhem at the Congress of Catholic scholars in Bruxelles in September 1894, he showed, with many brief quotations from Duhem's reflections on experimental physics,⁴⁰ that Duhem could not have been more emphatically attached to a realistic philosophy of common sense, a stance hardly compatible with Kantianism. Yet, as the Abbé Bernies also correctly argued, Duhem's main attention was riveted on articulating not so much the philosophy of common sense, as the limitations of physical theory. One of those limitations was that physical theory ultimately made no sense if the commonsense grasp of reality no longer was held valid and meaningful. Thus Duhem could effectively combat the extremes of scientism and of a scientific philosophizing which, in

36. *Ibid.*, p. 139 note. This is an all-important point, often forgotten in sympathetic portrayals of the role of Christianity in the rise of science.

37. *Ibid.*, p. 141.

38. V. L. Bernies, 'M. Pierre Duhem,' *Revue des Jeunes* 15 (10, 25 novembre et 9 décembre 1917):513-20, 603-13, 681-85. The Abbé Bernies, who served between June 1, 1897 and July 16, 1903 as curé at Pradelles-Cabardès, the village immediately to the north of Cabrespine, was the host there to the three founders of the *Revue de philosophie* in the summer of 1900 (see Ch. 5). He died as canon of the cathedral of Carcassonne in 1929 while on a pilgrimage to Lourdes.

39. *Ibid.*, p. 519.

40. 1894 (5).

order to assure respectability for philosophy, subordinates its principles to the presumed final validity of this or that form of physics. As to Duhem, the Christian, his portrayal by the Abbé Bernies contains phrases of penetrating directness:

Was he [Duhem] ever troubled [in his faith]? Who will tell us? Externally, nothing ever transpired in this respect. We conclude that his faith never knew crises. Duhem was sincerity itself. If there had been a struggle within him, he would have let it be seen. Neither his family, nor his most intimate friends have ever noticed in him the shadow of a serious doubt . . . He was simple in the manifestations of his religious sentiments. Neither display nor dissimulation. He was seen in the poorest and lowliest churches of our villages as docile and collected as the most modest and uneducated of the faithful. He was seen, on occasion, in the most solemn ceremonies of our cathedrals, always devout and dignified, without pose, with no longing for being noticed. He detested affected postures and gestures . . . All his friends and foes alike have always granted that he was simplicity incarnate. He was such especially as a Christian. Without weakness or provocation, without fear or pride, he let himself be seen for what he always was, a deeply convinced Christian.⁴¹

For all the depth of his Christian convictions, Duhem never thought that he was to take up the role of an apostle: 'He did not believe that he was obligated to defend the faith by his pen or to engage in religious proselytizing either through spoken or written words with respect to souls subject to his influence . . . He never thought himself qualified to be an apostle and, if the circumstances were not pressing — he spoke out when he thought he had to and with a courage that has not been forgotten — he obstinately kept silent.' Whatever he accomplished in clearing up misunderstandings with respect to the relation of science and faith, he never meant to harness science for the purpose of apologetics: 'We have often heard him declare that science properly spoken was neither Christian nor anti-christian, once it kept itself within its limits. It was simply science. Science and Revelation have one domain, but absolutely different methods . . . Duhem was an apologist in the sense that on occasion he put in evidence the lack of foundation of schools [of thought] negative [in their attitude toward Revelation].'⁴²

About the very core of Duhem's religious convictions, the Abbé Bernies also said words behind which there may lie glimpses gained perhaps during Duhem's last vacation in Cabrespine.

As Pascal, on whom he was feeding and whom he loved to quote, he had relived the mystery of Jesus within the framework of our times. All his life he read and reread the Gospels, he made an effort to study and practice the counsels of the Master . . . Inasmuch as we can witness this, he was even more faithful, if possible, during his last years, the last months of his life when a secret presentiment obscurely made him understand that the supreme hour was approaching . . . Mysterious premonitions led him little by little to sense what was in store for him and some words of resignation and courage, that left his lips, were suggestive of the supernatural work being accomplished in him.⁴³

41. Bernies, 'M. Pierre Duhem,' pp. 682-83.

42. *Ibid.*, p. 684.

43. *Ibid.*, p. 685.

Whereas the essay of the Abbé Bernies appeared two months after the first anniversary of Duhem's death, and the one by Mentré preceded it by a month, an essay on Duhem in the widely circulating literary weekly, *Revue hebdomadaire*, appeared exactly on the anniversary. Such was no coincidence. It was also a touching gesture for at least one reason which would have pleased Duhem very much. A little over a year earlier, the author of that essay was one of those who heard the toast Duhem gave at the banquet of the Association of Catholic coeds at the University of Bordeaux. Jeanne Alleman Bladé was not a student, to be precise. She was a young professor teaching French literature at the Lycée for girls in Bordeaux and was on her way to literary fame. Her first volume of poetry and her first novel had already been crowned by coveted awards and eventually she became, in 1928, the recipient of the Grand Prix of the Académie Française. Being a regular contributor to the *Revue hebdomadaire* she obviously could arrange for the timely publication of her essay, a short piece but very impressive because of its unpretentiousness. Mlle Bladé, who published under the male pseudonym Jean Balde, offered a graphic analysis of Duhem's thought by recalling the main themes he had developed in *La science allemande*. The essay also contained paragraphs which were so many unintended illustrations of the special touch which a woman's hand could give to a room or to almost anything, Duhem's starting remark in that toast. This graceful touch was at work as Mlle Bladé reminisced:

I see him again, radiating serenity, as he spoke for the last time. It was a very modest gathering. There were, around him, thirty or so young women . . . Once more he showed that he had, in his heart, as well as in his mind, the rarest gentleness. We had expected from him only a few words. But to these young women, professors of tomorrow, he wanted to do more honor and good. With what tact he spoke to them of their mission, of the French qualities which they must guard zealously, jealously! . . . We listened to him entranced by the horizons which he unveiled for us. We were far from thinking that the memory of that hour would be for us, less than three months later, as heart-rending as it was beautiful.⁴⁴

As a teacher Mlle Bladé knew how to appreciate the master teacher in Duhem, the main topic of her essay. For Duhem was a master teacher not only because of his intellectual eminence and his gifts to communicate, but above all because of the ethically exalted view he took of the vocation of a teacher. This fact could not escape students, mostly young men, and especially the members of the Catholic Student Association. None of them would have been able to express sentiments with that feminine grace and insight which Mlle Bladé commanded on their behalf:

Mr. Duhem greatly loved his students. And he loved them more and more to the very end. But he was particularly close to a group, that of the Catholic Students of the University of Bordeaux which he founded in 1913 together with Mr. Albert Dufourcq. To them, who feel crushed since his death as if they had lost a father, Duhem let his entire soul be seen. They knew him as he was, not at all severe and closed to all joys of life, as some pretended, but always young, possessed of an inexhaustible and strong

44. J. Balde, 'Un Maître: Pierre Duhem,' *Revue hebdomadaire* 26 (1917):383-93; for quotation, see pp. 392-93.

goodness. He was happy among them. His faith radiated and so did those deep and gentle qualities of his heart which could be seen only in intimate circles. Thus today, even in the trenches and in the turmoil of war, these students have forgotten nothing about their master. They see him with his noble forehead, his refined mouth in the white beard, his eyelids often lowered as is customary with a meditative being, but which were raised in the course of a discussion, unveiling clear and marvelously luminous eyes. They remember with emotion the atmosphere created by his presence in their modest circle. They see him in their chapel, going to communion alongside them, or turning to them with those expressions of familiarity which abolish all uneasiness between them and him . . . To these young men he brought resources of emotion all the more abundant as his personal life had been painfully tried. In their midst, toward the end of an often solitary existence, God had reserved for him the joy of being able to expand at long last.⁴⁵

Duhem would have nodded in agreement and he would have done so after the last and almost eerie line in the 10,000-word-long biographical notice which his close friend E. Jordan completed for the first anniversary of his death and which has been much relied upon in the foregoing pages. Jordan was a sympathetic and close witness of Duhem's life ever since their paths met forty years earlier in the Collège Stanislas. The informative value and moving tone of that biographical notice were fully present in its concluding lines relating to the final phase of Duhem's life:

If, in addition to his paternal affection [toward his daughter] far surpassing all his other concerns, there was something which attached him to this life, it was the *Système du monde*. When he began it, I asked him one day, certainly not with a foresight of his premature death, but with an awareness of the enormity of the undertaking, if he was not on occasion afraid of never seeing it being completed? 'I am not concerned with that. If God judges that work useful, He will give me the time to complete it, if not, what does it matter?' In spite of that resignation, he would have enormously suffered [at the prospect] of leaving behind his monument incompleting. It was perhaps God's grace, granted to one always so ready, which spared him of that frustration and which also spared of all debility his magnificent mind.⁴⁶

Jordan's biography was published simultaneously in the annual bulletin of the alumni of the Ecole Normale and in a somewhat amplified form in the first part of a memorial volume which several of Duhem's friends and colleagues, some of them associated with the Société des sciences physiques et naturelles de Bordeaux, had decided, immediately after his death, to put together. The main item in that first part was a reprint of Duhem's *Notice* to the Académie which contained a list of his publications, a list which grew between 1913 and 1916 from 318 entries to 352.⁴⁷ The second and more massive part of the volume did not appear for another ten years and, as will be seen, not entirely according to the original plans.

45. *Ibid.*, pp. 385-86.

46. Jordan, 'Duhem,' p. 173 (see note 91 to Ch. 1).

47. The volume was published as Premier Cahier of Tome I of *Mémoires de la Société des Sciences physiques et naturelles de Bordeaux* (Paris: Gauthier-Villars; Bordeaux: Feret et Fils, 1917) 169pp.

Had Jordan's portrayal of Duhem appeared in a learned periodical of world-wide circulation, the sprouting of many clichés about Duhem the man and the savant might have been prevented. The *Annales de physique* was certainly such a periodical, but the almost forty pages devoted in its November 1917 issue to Duhem would have given him very mixed feelings.⁴⁸ Not that E. Doublet, astronomer of Bordeaux and the author of those papers, lacked admiration for Duhem whose work as a historian was presented there with great care. But Doublet may very well have been under instruction to be as brief as possible on Duhem the physicist and make rather much of the publication, earlier that year, of the fifth volume of the *Système du monde*. Such a procedure, all too transparent and hardly Doublet's choice, put very much on the spot the *Annales de physique* which never carried articles on the history of physics, let alone on its medieval phase. In late 1917 there were still many, in France at least, among the readers of the *Annales de physique* who knew all too well that its editor-in-chief, Lippmann, had been a chief antagonist of Duhem. This was certainly true of Bouty, associate editor of the *Annales de physique* and one of the examiners of Duhem's second and successful thesis. He could therefore hardly invite or consent to the publication in the *Annales de physique* of a commemorative article on Duhem unless in it all references to Duhem the physicist were restricted to such platitudes as his having learned from Moutier the love of physics. The year of the first anniversary of Duhem's death was a war-year in France in more than one sense.

Were second anniversaries to be celebrated, the months preceding that of Duhem would hardly have been the time for anticipating such an occasion. When on May 15, 1918, there appeared in the *Revue des deux mondes* a long article on Duhem, France lived through one of her gravest hours. The Germans threatened at the Marne and Paris was once more within the reach of their biggest guns. For another fortnight the enemy kept advancing. At a time when France had to draw on her last energies, as if in a panic, there could hardly be any interest in an article 'Energétique et la Science du Moyen Age.'⁴⁹ Its author, Louis de Launey, a geologist and member of the Académie, certainly meant well but was not up to the task of doing justice to Duhem's thought. Nor would anyone else have been at a time when physics was entering into a new phase, the real nature of which was hardly decipherable even much later. In 1918 nobody doubted any longer the reality of atoms and in that sense an article on energetics, let alone when combined with the science of the Middle Ages, could but appear a plea on behalf of a bygone cause. At any rate, de Launey should have at least warned that for Duhem the question of atoms was not a decisive issue about physical theory. Not that Duhem had been fully articulate on this point. No thinker has ever succeeded in setting forth all the implications of his system and presuppositions even when

48. 'A propos de la publication du Tome V du *Système du monde* (Histoire des doctrines cosmologiques de Platon à Copernic), par feu Pierre Duhem. Notice biographique, bibliographique et critique,' *Annales de physique* 8 (1917):207-44.

49. Perhaps its length, 31 pages (54 [1918]:363-94), did not help either; for quotation see p. 369.

possessed of the willingness, as was Duhem, to disclose as much as possible about the innermost recesses of his mind. Duhem indeed gave a memorable warning about the reluctance of physicists on that score. He did so in a long essay on Gibbs out of which de Launey quoted a passage which was well ahead of the times when such passages would be eagerly rescued by historians and philosophers on physics from periodicals of no significance whatever compared with the *Revue des deux mondes*. In spite of the *Revue's* availability in all major libraries not one of them was attracted for almost eighty years to a capital passage there in which Duhem spoke of the unwillingness of the physicist 'to make public those thoughts which are at the back of his mind.' The reason for that reluctance resided, according to Duhem, in the close ties between his choice of theories and the philosophical considerations which dominate his 'moral beliefs and organize his interior life.' Unlike Duhem, who never hid his innermost beliefs, most modern men of science skirt the warfare of beliefs by adopting the dubious tactic of withdrawing behind the convenient screen of an 'objectivity' which claims to have no presuppositions that relate to innermost beliefs and aspirations.

Postwar reminiscences

Appropriately enough, the first recall of Duhem's memory, once the din of war was silenced, came from the Société scientifique de Bruxelles. In speaking of the deceased members of the Société on May 1, 1919, its first general assembly in five years, A. Witz, the president, made no secret of the impossibility of summarizing in a few lines the 'marvelously fruitful work of thirty years of studies entirely devoted to science. Duhem's work is immense, of a remarkable depth and of astonishing variety . . . Posterity will rank Duhem among the greatest intellects of our age.'⁵⁰ The member commemorated immediately after Duhem was Fabre, 'the incomparable observer' in Darwin's words, whose membership for the Académie was championed by Duhem with no less incomparable selflessness.

The generous space allowed to Duhem's memory in the first postwar issue of the *Revue de philosophie*⁵¹ certainly attested the esteem of a journal for one of its founders. And so did the special studies both there and in the *Revue des questions scientifiques*⁵² devoted to Duhem's work in the philosophy and history of science. For all their rich contents these studies suffered much the same oblivion as the great memorial lecture which Emile Picard, perpetual secretary of the Académie des Sciences, delivered in the afternoon of December 12, 1921, as a sequel to the annual public session of the Académie.⁵³ The official business of the session was the announcement of the recipients for that year of the many awards and

50. *Annales de la Société scientifique de Bruxelles* 39 (1919-20):90-91.

51. September 1919, pp. 457-62. The necrology was written by E. Peillaube.

52. These articles, written by F. Mentré, V. Schaeffers, and H. Bosmans, will be discussed in Chs. 9 and 10.

53. E. Picard, 'La vie et l'oeuvre de Pierre Duhem,' Document Institut 1921-34 (Paris: Gauthier-Villars, 1921), 44pp. This éloge is the first in a collection of essays which Picard published under the title, *Discours et mélanges* (Paris: Gauthier-Villars, 1922), pp. 1-39.

prizes of the Académie, an affair, which, however time-consuming, always draws a large crowd. Much of the audience stayed for almost another two hours, the time it took Picard to deliver his lecture. Its biographical data, already repeatedly utilized here, were no less valuable an evidence of Picard's first-hand knowledge of its subject as were the sections on Duhem's work in physics, and in its philosophy and history — topics which will require a recall more than once of Picard's lecture in subsequent chapters. By the time Picard was approaching the concluding part of his lecture, where he dealt with the complete harmony of natural science and Catholic faith in Duhem's thought, the hush of silent solemnity could be felt throughout the amphitheater. The only light under the great cupola was a small lamp which an attendant placed near Picard so that he might continue with his lecture while evening descended on Paris. His words seemed to come, as someone present recalled, as if uttered from an altar.⁵⁴ After Picard finished with the words, 'France lost in Duhem a good servant, the Académie . . . one of her members who brought her most honor,' the amphitheater 'resounded with prolonged applause from all sides.' So went the report next day in *Le Temps*, the leading Parisian daily, which devoted to the public meeting of the Académie half a page or three long columns of which two were filled with excerpts from Picard's lecture.⁵⁵ Its culminating point, the harmony in Duhem of science and faith, was not reported.

The irony of this could be perceived only by those who attended Picard's lecture and only a fraction of them noticed a few days later the irony lurking between some of the lines of the next issue of the *Comptes rendus* of the Académie. In its section where the memory of Lippmann, who had died a few days earlier, was celebrated, it was claimed that Lippmann was 'exclusively devoted to a disinterested research, possessed of a reserved personality, modest and benevolent, who had everywhere but friends.'⁵⁶ Such a portrayal hardly accounted for his having killed Duhem's brilliant doctoral thesis and for his having assisted Berthelot in barring Duhem from Paris. The irony grew to massive proportions when a year and a half later Paris celebrated the 100th anniversary of Berthelot's death with an extravaganza and superficiality that should have shamed any serious academic. In the sumptuous quarto volume printed for the occasion, now deservedly gathering dust in the few places where it still can be located, all of Berthelot's obstinate misconceptions about chemistry were carefully glossed over.⁵⁷ The procedure could all the less be excused by ignorance as the head of the celebrations was none other than Painlevé. He, if anyone, knew the facts and from Duhem himself. Clearly, the latter was not at all wrong in warning his friend A. Dufourcq, over-

54. The Abbé Léon Garzend, at the start of his commemorative article quoted below (note 59).

55. December 13, 1921, p. 3, col. 2.

56. *CR* 173 (1921):1207-08.

57. *Le centenaire de Marcelin Berthelot, 1827-1927* [edited by Paul Painlevé] (Paris: Vaugirard, 1929). Camille Matignon, member of the Institut, who discussed Berthelot's work in chemistry (pp. 77-95), did not as much as mention the principle of maximum work, though he referred to Thomsen as one whose work could be improved upon! Needless to say no reference was made to Duhem (see especially pp. 84-87).

whelmed by Painlevé's performance in 1897 at the centenary celebrations of the Ecole Normale, against trusting him too much.⁵⁸

Picard's lecture, quickly printed, was heavily relied upon by the Abbé Léon Garzend, who completed on January 13, 1922, a memorial notice on Duhem for the February 10 issue of the *Cahiers catholiques*.⁵⁹ The outstanding value of that notice derived from quotations from letters which Duhem sent to various persons at Maison St. Agnes. The priceless glimpses, which those quotations (all of which have already been reproduced here)⁶⁰ allowed into Duhem's humanness, cannot help evoke deep regret that no effort was made to collect Duhem's letters at a time when many of the recipients were still alive. Had the Abbé Garzend waited a little longer, he might have included in his notice a coincidence in the March 1922 issue of *Larousse mensuel*, a coincidence worthy of a comment or two. The issue contained two columns on Duhem written diligently but without enthusiasm.⁶¹ Immediately there followed a much longer and glowing account of Anatole France, occasioned by the recent publication of some of his private interviews. The much applauded novelist was described as a champion of generosity and compassion, a modern Socrates combatting prejudice everywhere. Duhem would have been one of those relatively few not to be taken in by such a portrait of France, at complete variance with his indefatigable sneering at everything sacred and noble.

Meanwhile the Rue de la Teste had been renamed Rue Pierre Duhem with a promptness and enthusiasm which are not always the characteristics of municipal actions of this kind.⁶² The move came from Professor Sigalas who, as already noted, lived in the same street. By 1920 he had turned into one of the most influential professors at the University, partly through the role he had taken in the massive development of its Medical School. As a member of the City's commission for education, Sigalas presented to the Conseil Municipal, at its meeting of June 25, the request that the Rue de la Teste be renamed Rue Pierre Duhem:

I have come to propose to assign to a street of Bordeaux the name of a great savant who has greatly honored our City and University . . . In the death of Duhem our University and French science suffered an irreparable loss . . . He was named, at the age of thirty-three, professor of theoretical physics at the Science Faculty of Bordeaux. It was there that, during twenty-two years spent in our City, he spread on the University the most vivid rays of glory by the brilliance of his teaching, by the most powerful and fertile originality of his research . . .

58. *Un savant français*, p. 211.

59. L. Garzend, 'In Memoriam P. Duhem,' *Cahiers catholiques*, February 10, 1922, pp. 1078-86.

60. See section, 'Twice bereaved,' of the preceding Chapter. In all evidence, the Abbé Garzend must have been a frequent visitor at the Atelier St. Agnes and on good terms with its directress, Mlle Girennerie. He was the author, among other books, of a long study of the Galileo question, *L'inquisition et l'hérésie* (Paris: Desclée, de Brouwer, 1912).

61. *Larousse mensuel*, Mars 1922 (Nr 181) pp. 732-33. The article was written by G. Boucheny.

62. The documents quoted are in the dossier on Duhem in the Archives of the University of Bordeaux.

After a detailed review of Duhem's work in physics, history, and philosophy, Professor Sigalas concluded:

May I be allowed to add that in his case the man rose to the height of the savant. All those who knew him and approached him admired the proud independence of his character, his unbending conscience, and the goodness and firmness of his heart.

A month later, Sigalas had the satisfaction to inform, on behalf of the City of Bordeaux, the Académie des Sciences, that the Conseil Municipal had responded favorably to his proposal, and that now a street of Bordeaux carried the name of Pierre Duhem, past member of the Académie.

This was not the last such gesture of Bordeaux. Duhem was in a class by himself in an essay on the intellectual status of the University, contributed by its former rector, Raymond Thamin, member of the Institut and director of Secondary Education in the Ministry of Public Education, to a handsome volume on Bordeaux published for the benefit of the participants of the Congress in late July 1923 of the Association Française pour l'Avancement des Sciences.⁶³ Restricting himself only to the deceased 'whose renown radiates far and wide,' Thamin declared: 'Such was Duhem, one of the foremost scientists in the world whose name was given to the street where he lived.'⁶⁴ Of the twenty other names listed by Thamin, without any commentary, today's reader would be familiar only with that of Durkheim. Participants of the Congress could also learn from that book that Duhem was among the nine who enriched the University Library with a large collection of books.⁶⁵ But even those participants who missed these details, were reminded of Duhem when they were officially greeted by Fernand Philippart, Mayor of Bordeaux. In making himself the spokesman of those illustrious Bordelais men of science whom untimely death prevented to be present at the Congress, the Mayor began with 'Pierre Duhem, a genius as a physicist, a mathematician, and a philosopher.'⁶⁶ Undoubtedly, those of Duhem's friends who had six years earlier published the first part of a commemorative volume on Duhem, hoped to complete the massive second part by 1923 for that Congress. Perhaps they also thought of it as a most appropriate place and time for a series of papers on Duhem and as a golden opportunity for the French scientific and philosophical world to redeem itself vis-à-vis Duhem. The lasting value in Duhem's philosophical and historical writings should have been obvious. As to Duhem, the physicist, the papers read at that Congress on physics and chemistry were not much beyond the stage where these two fields were in Duhem's publications in the years before his death. Although that second part, published in 1928, went through an im-

63. *Bordeaux Métropole du Sud-Ouest* (Bordeaux: Gounouilhou, 1923), 376pp.

64. *Ibid.*, p. 251.

65. *Ibid.*, p. 282. The number of books donated by Duhem was over two hundred and mostly on the history of science, details made public a year earlier by H. Teulié, librarian of the University, in an article in the April 28 issue of the *Sud-Ouest économique*.

66. *Association Française pour l'Avancement des Sciences . . . Compte rendu de la 47^e session. Bordeaux 1923* (Paris: au Secrétariat de l'Association, 1924), p. 17.

mediate re-impression,⁶⁷ it did not measure up except in one respect to the high standards of Duhem. Of the volume's 554 pages, 428 were taken up by Manville's study of Duhem physics,⁶⁸ a study originally assigned to Marchis, another and certainly much more brilliant student and colleague of Duhem. The study of Duhem's chemistry, assigned to Pélabon in Lille, failed to be delivered. The same was also true of the study of Duhem's philosophy, assigned to Le Roy, Bergson's successor. While Hadamard contributed a splendid essay on Duhem the mathematician,⁶⁹ Darbon, of the University of Bordeaux, who wrote the chapter on Duhem's work in the history of science,⁷⁰ was not a historian, let alone a historian of science.

Some noble efforts

The 1930s saw several noble efforts to keep Duhem's memory alive. The first to mention is a modest volume published in 1932 by Pierre Humbert, professor of physics at the University of Montpellier and examiner at the Ecole Polytechnique, who treated in five chapters of Duhem the man, the physicist, the philosopher, the historian, and the teacher, almost exclusively from published material.⁷¹ The year 1933 saw the publication of an essay by Maurice d'Ocagne, member of the Académie des Sciences and professor at the Polytechnique, in the June 9 issue of *Figaro*, an essay which found its way into the third volume of d'Ocagne's *Hommes et choses de science* published in 1936.⁷² In that same year Duhem's daughter published her priceless biography of her father⁷³ which received wide publicity in France at least, owing to large excerpts from it in the April 15 issue of the

67. The work, *L'Oeuvre scientifique de Pierre Duhem*, was published only in 1928 as Cahier 2 of Tome I of série 7 of *Mémoires de la Société scientifique des sciences physiques et naturelles de Bordeaux*, 554pp. A second printing was issued in the same year (Blanchard: Paris; and Feret et Fils: Bordeaux).

68. *Ibid.*, pp. 7-435.

69. 'L'Oeuvre de Pierre Duhem dans son aspect mathématique,' in *L'Oeuvre scientifique de Pierre Duhem*, pp. 465-95.

70. *Ibid.*, pp. 499-548, 'L'Histoire des sciences dans l'oeuvre de P. Duhem,' an article to be discussed in the last Chapter.

71. *Pierre Duhem* (Paris: Bloud et Gay, n.d.). It appeared in the series, 'Les Maîtres d'Une Génération.'

72. Paris: Vuibert, 1936, 'Pierre Duhem: Savant, philosophe, humaniste, historien,' pp. 221-27.

73. The 280 manuscript pages of *Un savant français* were turned down by the publishing house, Marcel Rivière, on April 25, 1935, with the remark that the investment of 3,500 francs in its publication would be a great risk. The publisher felt that 'the book would fall into immediate oblivion in view of the slackening of publishing business and of the total stoppage of exports at this moment.' Actually, Hélène Duhem had to contribute 8,500 francs to Plon for the publication of the book. 'I would have very much hesitated,' she wrote on March 9, 1936, to Albert Dufourcq, her trusted advisor and support, 'if I had not placed the dear memory of my father above all my material interests. In meditating and writing about his life I have understood it better than ever, and I have a painful admiration for that life, so beautiful yet so unfortunate, which had known but injustice, neglect, and opposition.'

*Revue universelle*⁷⁴ and to a lengthy account in the literary supplement of the August 11 issue of *Le Temps*.⁷⁵

Partly under the impact of these publications, the French section of the Académie Internationale d'Histoire des Sciences decided, in 1936, to focus attention on Duhem during the following year. The section, under the presidency of Henri Berr, Director of Centre International de Synthèse and a former fellow student of Duhem at the Ecole Normale, devoted its meeting of January 27, 1937, to Duhem's memory. Maurice d'Ocagne, Abel Rey, Hélène Metzger (Mme Bruhl), Aldo Mieli were among the speakers whose roster included also Duhem's daughter and Jean de la Laurencie, a close friend of Duhem in the Collège Stanislas.⁷⁶ The main result of the meeting was a resolution calling for the speedy publication of the still unpublished parts of the *Système du monde*, a resolution published in *Archeion*⁷⁷ as well as in *Isis*.⁷⁸

The same appeal was carried far and wide through the efforts of Abel Rey, professor at the Sorbonne and director there of the Institute for the history of science and technology. Rey's article, 'Un grand historien des sciences — Pierre Duhem,' covered half a page in the March 1, 1937 issue of *Le Temps*' weekly supplement for the latest literary, artistic and scientific events.⁷⁹ Already the first paragraph in Rey's article was such as to stir the attention of even the non-specialist: 'For Duhem, a born historian, the history of science is not that hollow and childish caricature to which historians of science often committed themselves: a chain of facts glued to one another, in at least the not too useless cases, with a discussion of their often dubious authenticity.' Duhem, Rey argued, was indeed so superior to that brand of historians of science as to have achieved in his field a 'Copernican revolution' through massive works of which the crowning piece was the *Système du monde*. Clearly, such a work deserved to be published in full, especially if it was true that volumes VI-IX were 'completely finished in manuscript.' While it is unlikely that Rey based this judgment on a direct study of those manuscripts, and although by then, as will be seen, he had served proof of his slighting of Duhem's studies of Greek science, he rose to the occasion:

The France which Duhem served and honored, the scientific bodies of which he was a member, all those who profited and still profit from his labors, cannot let so many

74. 'Un savant français. Pierre Duhem raconté par sa fille,' covered over thirty pages (vol. 65, pp. 154-85) and was largely documentary. A good part of it was taken up by a reproduction of Chevrillon's letter to Hélène Duhem and by Duhem's letter to P. Bulliot concerning the teaching of history and philosophy of science at the Institut Catholique. The article contained no material additional to what was available in the book itself.

75. The almost two-thousand-word article was written by L. Houlevigüe, professor of physics at the University of Montpellier, who minced no words about Berthelot's role in Duhem's career.

76. For the *procès verbaux* of the meeting and the text of speeches delivered, see *Archeion* 19 (1937):121-51.

77. *Ibid.*, p. 123.

78. *Isis* 26(1937):302-03.

79. Rey's article covered the upper half of p. 5 and half a column of p. 6.

admirable pages remain in oblivion. The disputes of schools and persons must fall silent and bow before a tomb and a glory. To a Duhem who unjustly suffered enmities in high places, to a Duhem often forgotten while still alive, to a Duhem who was not-at-all given his due, we owe this reparation: the bringing to light of everything that is left for us of his thought.

Deep in his heart Rey must have known that his call was not to be heeded by an officialdom which had its purse open only for intellectual causes that duly served scientism which the Front Populaire made its official doctrine and found for it ready and voluble scientist-spokesmen in a Langevin and a Perrin, to mention only some chief figures. At any rate, had any official subvention been assigned to the publication of the remaining parts of the *Système du monde*, the carrying out of the project would have come to a halt shortly. Still the catastrophe that befell France in 1940 was no excuse for letting the 25th anniversary of Duhem's death pass unnoticed a year later. The sole exception was somewhat tainted by that politicking which Duhem always shunned whatever his distinct political sympathies. In his article in the September 16, 1941, issue of the *Journal Echo de Paris* Jean Lebrun, who pleaded there for Duhem's 'rehabilitation,' mentioned by name Berthelot as one of the many who 'for the past 150 years led France away from the road to national recovery.'

After World War II the first notable step in keeping Duhem's memory alive was the placing on Monday, October 27, 1952, of a marble plaque on the house in which he died.⁸⁰ Picart, prefect of Aude, was so eager that someone from the Académie be present as to notify it by telegram about the shifting of the ceremony from 11 in the morning to 4 in the afternoon.⁸¹ The Académie was indeed represented by Laurent, its inspector, at the ceremony which was the idea of Dr. Jean Girou of Carcassonne.⁸² The University of Bordeaux was represented by Prof. Calas, from its newly enlarged department of physical chemistry. That Prof. Calas recalled Duhem's early awareness of the importance for France of physical chemistry, a field eagerly cultivated in Germany, was only natural. But Duhem's impact on the University of Bordeaux, Prof. Calas emphasized, went far beyond his scientific excellence or his renown as a spellbinding teacher. Duhem's most valuable legacy derived from his character: 'Duhem the scientist was not looking for honors, and even at the loss of his advancement was never willing to sacrifice anything of what he considered to be the truth, either from the scientific or from the personal point of view. It is undoubtedly to men like Duhem that French universities owe that perfect independence which they now enjoy.'⁸³

80. The plaque over the main door of the house carries the inscription: A la mémoire de/ Pierre Duhem/ membre de l'Institut/ mort en cette maison/ le 14 7^{mbre} 1916.

81. This telegram is in the Archives of the Académie des Sciences.

82. The ceremony and the speeches given there were reported in full in two installments of *La Croix de l'Aude*. Copies of the clippings were kindly sent to me by Mr Benjamin Tissières, maire de Cabrespine.

83. Quoted from the typewritten text of Prof. Calas' speech which he kindly put at my disposal.

The ceremony started at the mairie where the entire town gathered to greet the prefect of Aude, the bishop of Carcassonne, and other dignitaries and delegates. At the grave of Duhem, from which one cannot help admiring the slopes of the Montagnes Noires, Duhem's sketches of the scenery were evoked by the mayor of a neighboring village who as a youth remembered the hiker accompanied by his daughter. Such excursions hardly ever lacked their humane touch. The Abbé Marcellin Gabaude, parish priest of Citou and Lespinassière, related Duhem's and his daughter's encounter on the fields of nearby Rias with a poor family of five children – all undernourished – of whom the eldest, a shepherdess, was suffering from bone tuberculosis. Before long she was in a sanatorium in Le Molleau with results already told. This was one of countless instances of Duhem's concern for the poor of the area, as noted by the Abbé, of whom many of those in the gathering knew that he was the youngest brother of that shepherdess. Indeed, that concern of Duhem was so great that many villagers took undue advantage of it. But Duhem, although aware of this, preferred to be misled rather than make the mistake of not responding to a truly deserving case. Such was one of the points made by the bishop of Carcassonne, who spoke of Duhem the Christian. Duhem's house in Cabrespine was indeed the home of the entire village. As Duhem's daughter asked in thanking the participants: 'Who in Cabrespine could not enter there with confidence and not feel assured of the advice and support sought there?' She rightly saw in the plaque placed on the house a symbol of permanent recognition of her father's Christian humanity.

Missed anniversaries

The publication between 1954 and 1959 of the last five volumes of the *Système du monde* prompted only book reviews⁸⁴ but no symposia or monographs on Duhem. This was all the more ironic because some of the reviews appeared around the centenary in 1961 of Duhem's birth. The irony heightened as leading periodicals on the history and philosophy of science ignored the centenary of Duhem's birth and reached its apex on July 9, 1961, the opening day of a prestigious congress in Oxford on the notion of scientific change. That exactly a month had gone by since that centenary seemed to be remembered by nobody there present, not even by H. Guerlac whom the entire congress heard declare: 'Pierre Duhem is the acknowledged teacher of us all.'⁸⁵ Acknowledgment of the anniversary came from non-historians, the Société Hydrotechnique de France, whose bulletin carried Duhem's picture on the cover of its first issue of 1961.⁸⁶ That the centenary was ignored at Duhem's own university in Bordeaux was all the more puzzling because awareness there of Duhem's greatness was not absent. When the new modern campus at the

84. To be discussed in the last Chapter.

85. H. Guerlac, 'Some Historical Assumptions of the History of Science,' in A. C. Crombie (ed.), *Scientific Change. Symposium on the History of Science. University of Oxford, 9-15 July 1961* (New York: Basic Books, 1963), p. 809.

86. Under the title, 'Notre Frontispice,' (p. 3) a six-hundred-word recall of Duhem's life and work was given in parallel columns in French and in English.

University was dedicated on April 15, 1961, in the presence of President De Gaulle, the official gift offered him was a copy of Duhem's biography by his daughter.⁸⁷

The fiftieth anniversary in 1966 of Duhem's death witnessed only one and very modest celebration which, owing to the zeal of Dr. Girou, took place in Cabrespine.⁸⁸ French scientists, whom the annual meeting of the Association Française pour l'Avancement des Sciences brought together in Rouen that year heard there of a 'forgotten French scientist,' but he was not Duhem.⁸⁹ A reason may have been the location, Bordeaux, of the next year's meeting which indeed heard the delivery of three papers from young faculty of the University there on Duhem the physicist, the philosopher, and historian of science.⁹⁰ The historians and philosophers of science in Paris took no notice of an anniversary which certainly would have justified a major international conference. Their numerous confrères in the United States could hardly claim forgetfulness as an excuse. It was there that Donald G. Miller, physical chemist at the Livermore Laboratories of the University of California, authored an article whose title, 'Ignored Intellect: Pierre Duhem,' (lavishly illustrated with previously unpublished photographs) could not have been better chosen. Nor could have been wider publicity provided for it than by the pages of *Physics Today*.⁹¹ Its French translation received much more restricted publicity through the *Revue des questions scientifiques*.⁹² Even more limited was the impact of a charming, almost full-page interview which the *Midi Libre* (Montpellier) had in 1971 with Hélène Duhem, then almost eighty, in her ancestral home in Cabrespine.⁹³ The title of the report, 'Une gloire de la science française dort son sommeil à Cabrespine où le village entier garde son souvenir,' contrasted sadly with the disinterest of Duhem's country as a whole. French scholars, and especially the ones at Duhem's own university, largely missed the opportunity for a proper celebration of his memory when in April 1979 the 104th Congrès National des Sociétés Savantes took place in Bordeaux. The two papers on Duhem, read in the section 'Méthodologie de l'histoire des sciences,' were

87. Personal communication from Prof. André Charru, professor of physics at the University of Bordeaux, present occupant of Duhem's chair.

88. My information is based on the photocopy, sent to me by Mr and Mme Jarreau, of a clipping of Dr. Girou's report, 'Cinquantenaire d'un grand savant: Pierre Duhem,' in *Midi Libre* (Montpellier), which has September 1966 as its sole specification.

89. The scientist in question was 'Descroizilles, inventeur de la volumétrie.'

90. The three papers formed a session dedicated to 'la pensée de P. Duhem,' with hardly a reference to the anniversary. See *Comptes rendus du 86^e Congrès de l'Association Française pour l'Avancement des Sciences. 6^e Groupe de Sections. Sciences économiques et humaines* (Bordeaux: Imprimerie E. Drouillard, n.d.), pp. 41-45. These papers, published in full in the October-December issue, carrying the subtitle, 'L'épistémologie de Pierre Duhem,' of *Les Etudes philosophiques* (pp. 399-438), will be discussed in the last three Chapters.

91. December 1966 (vol. 19) Nr. 12, pp. 47-53.

92. 'Pierre Duhem, un oublié,' *RQSc* 28 (1967):445-70.

93. The report, which I know from a photocopy of a newspaper clipping in the possession of Mr Tissières, maire of Cabrespine, carries three photos, one of Duhem, another of Hélène Duhem showing to the reporter of *Midi Libre* an album of drawings by Duhem, and an exquisite sketch by Duhem of a mountain capped by the ruins of the castle of Cabrespine.

lost in an avalanche of sections and papers. A further irony was that one paper in that section was on Marcelin Berthelot, as a historian of chemistry, as if the latter as a historian of science could be mentioned in the same breath with Duhem.⁹⁴

About the same time a movement was initiated⁹⁵ in the United States that a plaque be placed on the house of Duhem in Bordeaux. The unveiling of the plaque took place on March 26, 1980, with the enthusiastic assistance of the Municipality and the University of Bordeaux and of the present owners of the house, Mr. et Mme. A. Jarreau.⁹⁶ In the words of one of the speakers⁹⁷ at the ceremony, its chief reason had to do more with the future than with the past. The course of physics during the past 50 years as well as the course of the study of its philosophy and history suggest that the time is ripe for a sustained look at Duhem's work in all three fields. In physics the need of reality, which Duhem wisely left to be satisfied by reliance on common sense, instead of leaving it a prey to methods foreign to reality, asserts itself with an elemental force in the wake of a growing disillusion with subjectivism and solipsism generated by the prevailing interpretation of relativity and quantum mechanics. As the practicing of the philosophy of science seeks a way out of the labyrinths of facile games with logic and from the morass of misplaced psychological and sociological analogies, Duhem's philosophy, born of a first-rate scientist's concern for science, may prove a storehouse of wisdom. History, which through its proverbial complexity seems to justify the claim of its every practitioner to submit *his* story, will keep its instructiveness only if the origin and growth of science, as portrayed in monumental dimensions by Duhem, is permitted to give a sense of proportion between Facts and facts. The rest of this book is in a sense an argument on behalf of these views.

94. The two articles on Duhem were 'L'histoire des sciences dans l'élaboration et la diffusion de la connaissance scientifique chez P. Duhem' by P. Brouzeng, and 'Pierre Duhem, historien de l'astrologie' by M. Lejbowicz, neither of them a historian of science. The same is true of R. Halleux (of the University of Liège), who gave a paper, 'Marcellin Berthelot, historien de la chimie.' They were published in the résumés of papers presented to the section of philology, history, and history of the sciences at the 104^e Congrès National des Sociétés savantes. Bordeaux 17-21 avril 1979.

95. By the author of this book.

96. Reported in *Le Sud-Ouest* (28 mars 1980) Section Bordeaux, p. A. The plaque carries the inscription: Pierre Duhem (1861-1916)/Physicien – Historien des Sciences/habita dans cette maison/de 1894 à 1916.

97. The author of this book.



Father (c.1860)



Mother (c. 1860)



Sister Marie (c. 1874)



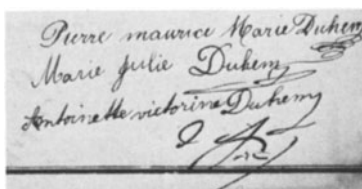
Wife (c. 1890)



At two



At fourteen



Signatures of Pierre (at eleven), Marie, and Antoinette on Jean's baptismal record (1872)

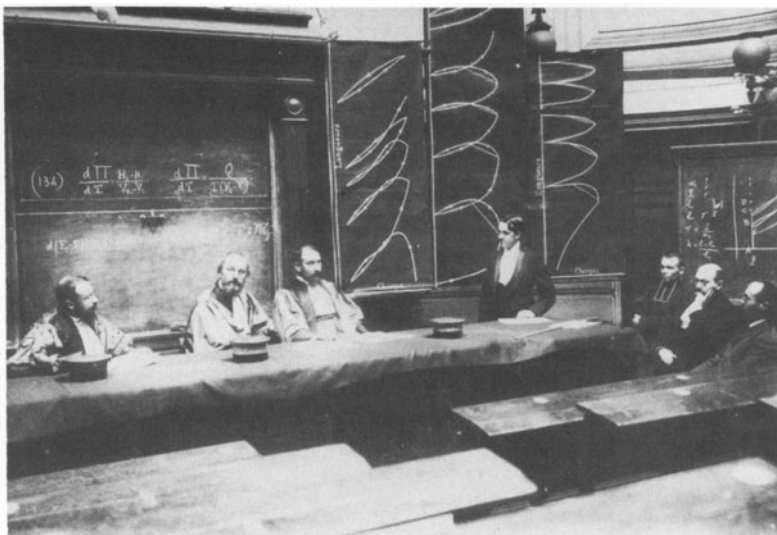


At seventeen



At nineteen

(in the uniform of Collège Stanislas)



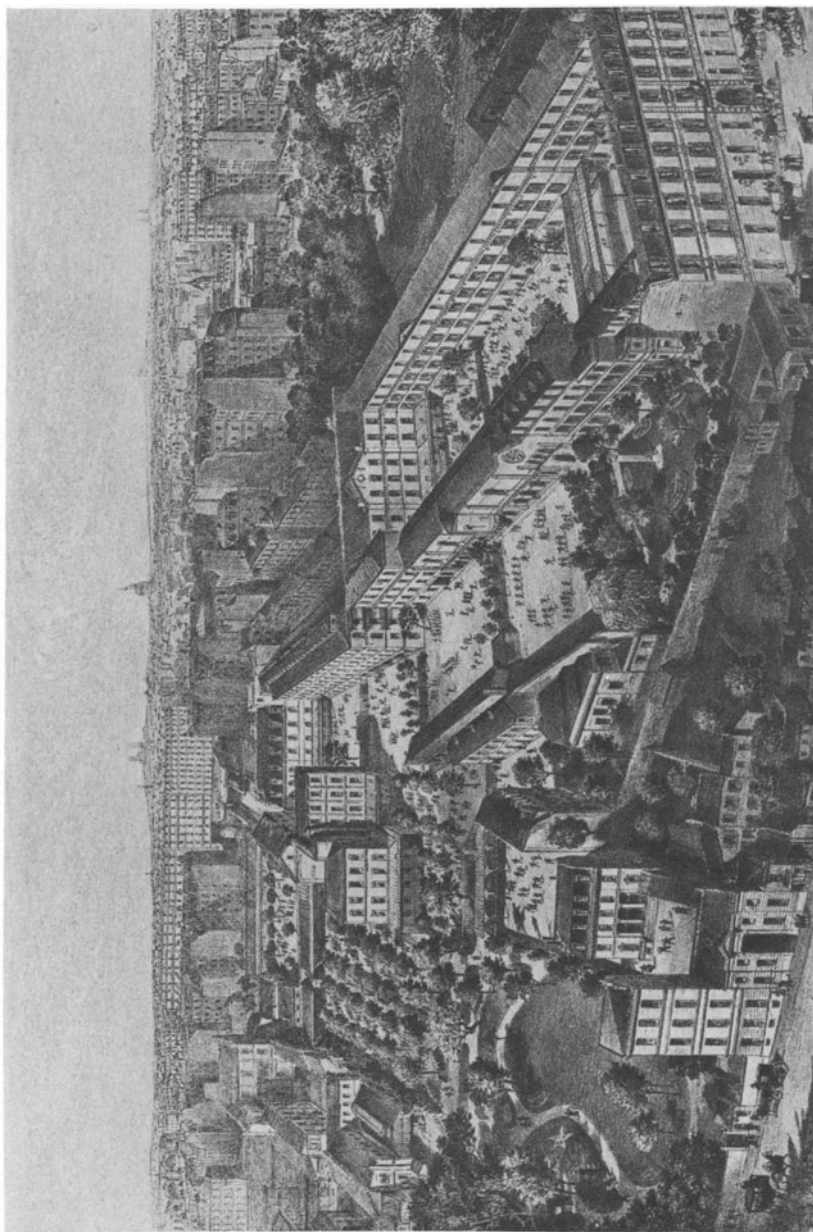
At Saurel's defense of thesis (far left)



In academic gown (1900)



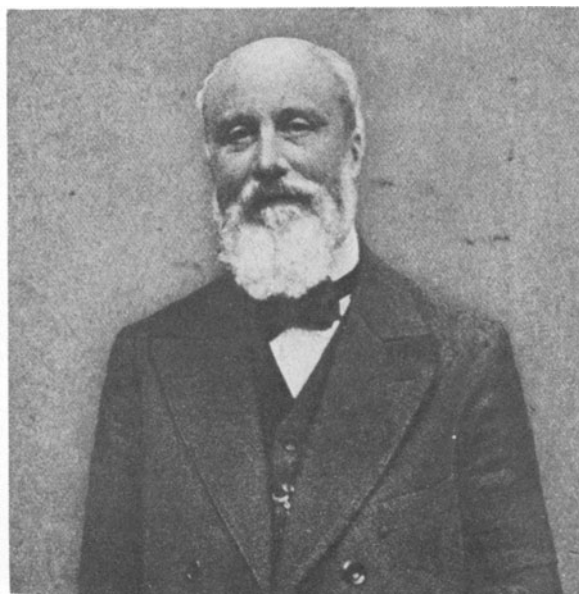
In his study with his mother and daughter (c. 1900)



Collège Stanislas (c. 1880)



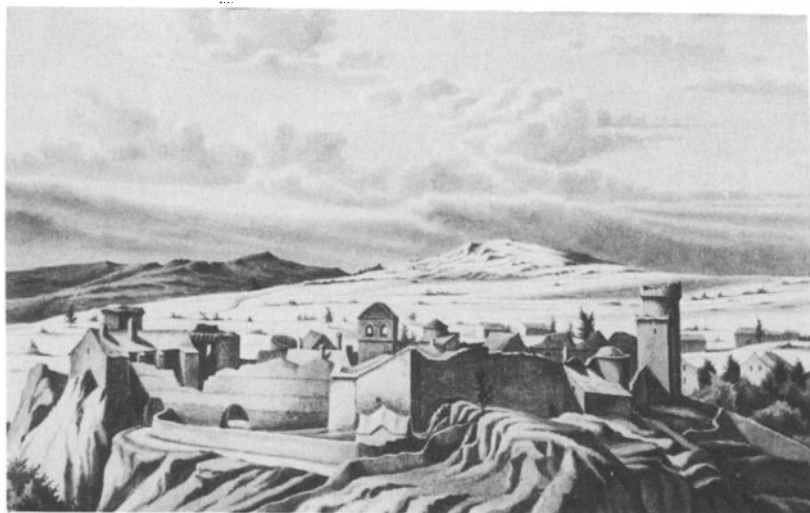
Ancestral home in Cabrespine



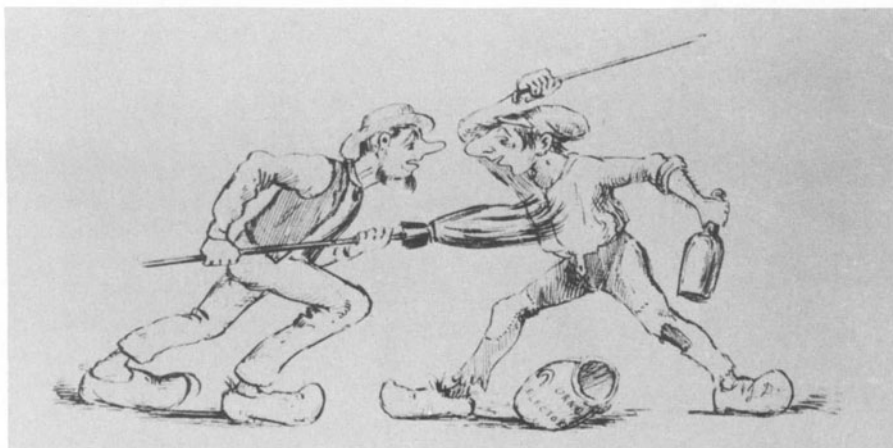
At fifty-three



Gorge du Tarn – India ink drawing, Sept. 1895 (25 × 18 cm)



La Couvertoirade – India ink drawing, Sept. 1895 (25 × 16 cm)



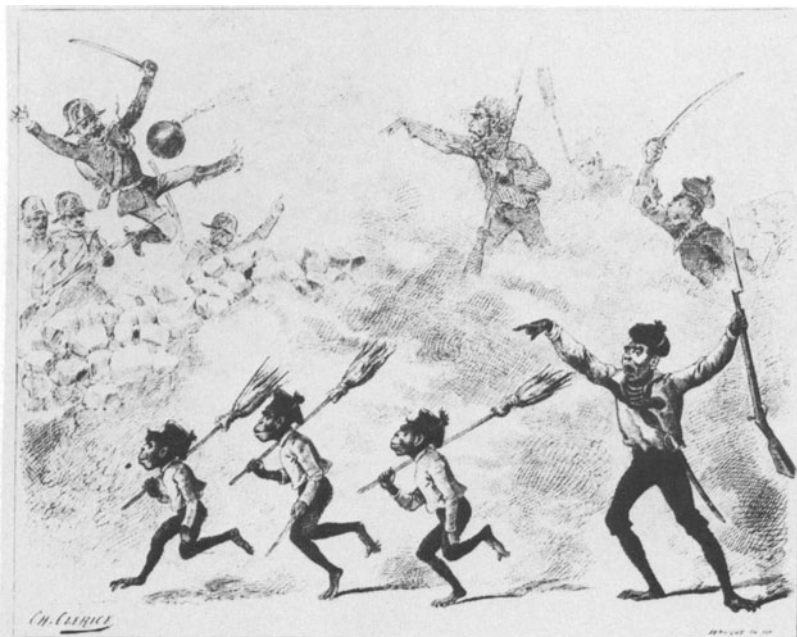
Sketch in ink given to 'Jo' Récamier (c. 1883) (10 × 6 cm)



Sketches in ink sent as postcards to 'Jo' Récamier (c. 1883) (8 × 12 cm)



From *Au pays des gorilles* (20 × 16 cm)



From *Au pays des gorilles* (20 × 16 cm)





Plate marking the street in Bordeaux named after Duhem



The house in that street in which Duhem lived (1894– 1916)



Commemorative plaque on the house above

8. DUHEM THE PHYSICIST

The making of a physicist

'I have held it my duty as a scientist as well as my duty as a Christian never to cease being the apostle of common sense, the sole foundation of all scientific, philosophical, and religious certainty.' So Duhem told a friend since youth in a letter of which four more phrases are known owing to the perspicacity of E. Picard, perpetual secretary of the Académie des Sciences, who made them the culminating point of his great eulogy of Duhem.¹ In the same letter Duhem met head-on the classic objection to the central role of common sense. Were not its claims, he asked, 'tantamount to some philosophical and religious beliefs, all resting on worthless reasonings which invariably imply undefinable notions, so many empty words void of meaning?' As he tried to come up with an answer Duhem noticed that

the same could be said in connection with all the sciences, including those which are considered the most rigorous among them – physics, mechanics, and even geometry. The foundations of any of these constructs are formed by notions, which one pretends to understand although one cannot define them, or are formed by principles which one feels assured about, although one has no proof of them whatever. These notions, these principles are formed by common sense. Without this basis provided by common sense, a basis not at all scientific, no science can maintain itself; all of its solidity comes from there.

Such a declaration would more appropriately introduce a chapter on Duhem the philosopher, had Duhem not declared in the same letter that his philosophical work had the purpose of bearing out the 'scientific truth' of the primacy of common sense. To be sure, common sense was much more than mere consensus for Duhem, whose work as a physicist had dissent from consensus as a major characteristic. Lasting instructiveness is not, however, a necessary quality even of that dissent, such as Duhem's, which is fully conscious and vastly articulated. That such a

1. E. Picard, 'La vie et l'oeuvre de Pierre Duhem' (see note 53 to Ch. 7), pp. 40-41. The friend's identity was not disclosed by Picard. The letter must have been written after 1906 because it contains a reference to *La théorie physique*.

quality is part of Duhem's dissent is better suggested by the fact that during his career as a physicist he had to dissociate himself, for one and the same reason, from two successive consensus. One was the consent which mechanistic physics was able to command, apparently in the name of common sense, even during its last two decades, the period coinciding with the first two decades of Duhem's career. The other was the increasingly noticeable impact made during Duhem's last ten years by relativity and atomic physics, both of which were markedly defiant of common sense in their origin and development.

To dissent from mechanistic physics in the name of common sense demanded much more than commonly attributed to it. That physical processes were so many impacts of moving bodies on one another seemed to be in full conformity with that common sense which merely demands that one may visualize what takes place. Descartes, who put so heavy a mark on French intellectuality, claimed common sense to his rationalism precisely because his physics could be readily imagined.² Nor was Newton's dissent from Cartesianism a serious threat to the role of imagination. While the *Principia* contained no references to mechanical models, the physical interactions dealt with there were not necessarily beyond the confines of common sense taken for visualizability. At any rate, the *Queries of the Opticks* were teeming with graphic descriptions of a wide variety of physical processes, including gravitation. This explains in part the fact that although the great tradition of French mathematical physics, from d'Alembert through Laplace to Fresnel, represented a shift of allegiance from Descartes to Newton, it never implied a strict disavowal of mechanical models. The warnings which Rankine, Kirchoff, and Mach gave in the 1870s about the fundamental weaknesses of mechanistic assumptions were not broadly appreciated prior to the turn of the century. The science of mechanics had by then become the ideal which other sciences were supposed to emulate.³ T. H. Huxley, who spoke of 'trained and organized common sense' as being science itself,⁴ was an advocate of a strictly mechanistic biology.

Duhem's early and thorough exposure to the young science of thermodynamics did not trigger in him an immediate break with mechanistic physics as an ideal. Whatever the non-mechanistic framework in which thermodynamics, especially its second law, had originally been cast, by the 1880s there was emerging a mechanistic reinterpretation of it in terms of the kinetic theory of gases. Yet the fact that thermodynamics could deal with a vast range of phenomena without having recourse to assumptions about underlying mechanisms, was of no small significance. Duhem indeed attributed a crucial role in his formation as a physicist to two monographs he read, under Moutier's guidance, during his last year at Stanislas, in both of which such assumptions were conspicuously absent.

2. And his mathematics too, as argued by P. Boutroux, *L'imagination et les mathématiques selon Descartes* (Paris: Félix Alcan, 1900).

3. The extent to which this became true for biology and psychology is discussed in my *The Relevance of Physics* (Chicago: University of Chicago Press, 1966) ch. 7, and *Brain, Mind and Computers* (1969; South Bend, IN: Gateway, 1978), ch. 3.

4. 'On the Educational Value of the Natural History Sciences,' in T. H. Huxley, *Science and Education. Essays* (London: Macmillan, 1899), p. 45.

That the shorter of the two, Helmholtz's memoir 'Zur Thermodynamik chemischer Vorgänge,' was immediately brought to Duhem's attention, tells as much of Moutier's being abreast with the best in the latest as of his pupil's capacity for it. Within twenty years the memoir became a small volume in *Ostwald's Klassiker der exakten Wissenschaften* with a commentary by M. Planck who spoke of it as the 'pioneering start of the development of pure thermodynamics, that is, the development of those theories of heat which disregard special kinetic hypotheses and confine themselves to the application of both of its two main laws.'⁵ The other and much larger monograph, *Etudes sur les équilibres chimiques*, was the work of Georges Lemoine, professor of chemistry at the Institut Catholique in Paris, who had just been called to a chair in the Ecole Polytechnique. The monograph was part of an almost thousand-page-long volume, the second in a vast chemical encyclopedia published between 1882 and 1905 under the editorship of E. Frémy, but available as a separate volume already in 1881.⁶ Moutier himself contributed to that second volume and so did Berthelot, who offered a 68-page-long summary of the two volumes of his *Essai de mécanique chimique fondée sur la thermochimie*.⁷ The chemical mechanics as set forth by Berthelot contained no assumptions about the mechanism of molecular interactions. He merely aimed at establishing the validity of the first law of thermodynamics in chemical processes measured on the macroscopic level. Such was an antimechanistic position insofar as it explicitly disregarded the question of the existence of atoms and of their machine-like characteristics. Not even that much was implied about mechanism in Moutier's contribution on 'some relations of physics and chemistry.'⁸ The physics Moutier had in mind was restricted to the two laws of thermodynamics. Lemoine's large monograph, in which the question of underlying mechanisms was equally disregarded, came to a close with a summary of Gibbs' theory of dissociation and with a report on Moutier's finding the temperature independence of dissociation in gaseous systems. There too references to mechanisms were absent.

Such were in their contexts the two works which, to quote Duhem's words, 'showed us the course which we have followed ever since never to depart from it.' But this statement, the end of the first paragraph of the eighty printed pages in which in the spring of 1913 he summed up, at the request of the Académie des Sciences, his researches as a physicist,¹⁰ was preceded by a bow to Jules Moutier. The bow, conspicuous as it was, meant more than gratitude to a beloved teacher.

5. M. Planck (ed.), *Hermann von Helmholtz. Abhandlungen zur Thermodynamik* (Leipzig: W. von Engelmann, 1902), p. 73.

6. G. Lemoine, *Etudes sur les équilibres chimiques* (Paris: Dunod, 1881), Tome I, Fasc. 2 in *L'Encyclopédie chimique*, dirigée par E. Frémy (Paris: Dunod, 1882-1905), pp. 69-380.

7. *Ibid.*, pp. 1-68. The summary was, of course, that of the first edition (1979).

8. *Ibid.*, pp. 387-431, followed by Moutier's report on the allotropic transformation of phosphorus (pp. 437A-G).

9. *Ibid.*, pp. 361-67 and 367-78. Duhem, who by then more than suspected the slighting of Moutier by officialdom, must have been pleased by the recognition given by Lemoine to Moutier's theoretical studies on dissociation (p. 367).

10. *Notice sur . . . Pierre Duhem*, 1913 (1), p. 36.

Duhem also wanted to remind the French scientific world of its rank failure to recognize and even to remember Moutier, by then long dead.¹¹ For as Duhem put it at the outset, Moutier, who made him love theoretical physics, not only initiated him into the applications of thermodynamics to chemical mechanics, a very new field in the late 1870s, but had to his credit the first of those applications to which he added several important ones.

In speaking of his own initiation Duhem must have had in mind his many private meetings with Moutier, because Moutier's textbook of physics, which formed the basis of his instruction of students, who at Stanislas prepared for the Polytechnique or the Ecole Normale, did not contain, for all its vastness,¹² more theory than could be carried by elementary calculus. Even Moutier's *Thermodynamique*,¹³ a vast advance over his *Eléments de thermodynamique*,¹⁴ was no match in theoretical thrust to the two monographs mentioned above by Duhem. Only through private meetings with Moutier could young Duhem have been exposed to Moutier's vast researches which were summarized by Moutier in a *Notice*, a booklet of 48 quarto pages published in 1881,¹⁵ when Duhem still had one more year to spend at Stanislas, not any more as a student but as an assistant teacher. In the *Notice* Moutier, then fifty-one, gave a topical account of 138 published articles, notes, and memoirs under the following headings: heat, hydrostatics and capillarity, electricity and magnetism, acoustics, and optics. Of these headings, heat and electricity included the vast majority of Moutier's researches. That this was to some extent true of Duhem's researches as well, should indicate something of Moutier's share in the making of Duhem the physicist. Duhem readily acknowledged that the orientation of his first tendencies was in the direction of Moutier's own preferences,¹⁶ a fact strongly intimated by some of the subheadings under which Moutier grouped

11. Moutier must have died in 1897 or before, because his son, A. Moutier, a physician in Paris, thanked Duhem, in a letter of January 22, 1898, for a copy of Duhem's 'Thermochimie' and above all for 'what you have done there on behalf of my revered and beloved father.' The reference was to the first volume of Duhem's *Traité élémentaire de mécanique chimique*, 1897 (1), in which Moutier's work is extolled on pp. 187-93. No biographical information on Moutier is available in the library and archives of the Ecole Polytechnique in spite of Moutier's connections there as an alumnus and as a répétiteur.

12. J. Moutier, *Cours de physique comprenant les matières d'enseignement de la classe des mathématiques spéciales* (Paris: Dunod) of which the second volume (640 pp) dealing mostly with heat was published in 1884. The first volume (922 pp) dealt with hydrostatics, electricity, and optics, and appeared a year later. Both volumes first appeared in fascicules.

13. J. Moutier, *La thermodynamique et ses principales applications* (Paris: Gauthier-Villars, 1885), 568 pp.

14. J. Moutier, *Eléments de thermodynamique* (Paris: Gauthier-Villars, 1872), 163 pp.

15. *Notice des travaux scientifiques de M. J. Moutier* (Paris: Gauthier-Villars, 1881). It is indicative of Moutier's ability as a researcher that all those publications appeared within twelve years (1869-1881). According to the title page Moutier was inspector of the telegraphic services before he joined the faculties of the Polytechnique, Stanislas, and Ste Barbe.

16. *Notice sur . . . Pierre Duhem*, p. 36.

his publications on heat and electricity.¹⁷ They also reveal Moutier's close attachment to the work done in the chemical laboratories of the Ecole Normale since 1851 when Henri Sainte-Claire Deville took there the chair of chemistry. The work largely centered on Deville's finding in 1857, of the phenomenon he called dissociation.¹⁸ The finding, which showed that a limited and reversible chemical reaction could be produced by the mere application of heat, signalled the beginning of the field later called physical chemistry.¹⁹ Originally spoken of as chemical mechanics, the new field posed a major challenge to the principles of thermochemistry, a science initiated by the Danish chemist J. Thomsen and avidly cultivated in France by M. Berthelot. Through Moutier young Duhem became familiar with the growing conflict between the chemists, such as Debray, Troost, and Hautefeuille, working at the Ecole under Deville's leadership, and the ones grouping around Berthelot who kept adding political clout to his scientific renown. Since Moutier was heavily involved in the theoretical justification of the work done on dissociation, young Duhem could not help sensing that the sacred cause of truth was at stake, a cause which at the same time appeared patriotic as well. While the cause could freely advance abroad through the work of Gibbs, Maxwell, and Helmholtz, France seemed to be deprived of truth through Berthelot's influence.²⁰ The prospect of helping to reverse that trend could but appeal to a young patriot like Duhem.

Moutier was not however a partisan spirit. Duhem imbued ample critical sense from Moutier, whom he described as 'an ingenious theorist whose critical sense, ever alert and extremely perspicacious, distinguished with sure accuracy the weak point of many a system which others accepted without dispute.'²¹ Young Duhem certainly followed Moutier in the advocacy of mechanism, an advocacy all the more appealing as it was judicious:

Although Moutier appealed in his investigations to the most diverse methods, one after another it was to the mechanical attempts at explanation that he returned most often with a sort of predilection. Like most of the theorists of his time he saw the ideal of physics in an explanation of the material universe constructed in the manner of the atomists and the Cartesians . . . Being a disciple of Moutier, it was as a convinced partisan of mechanism that we approached the courses in physics taught at the Ecole Normale.²²

17. No less revealing are the titles of Moutier's papers relating to hydrostatics and capillarity. The last of them, on the motion of bodies floating on the surface of liquids, is an application of Gauss' theorem (see *Notices des travaux scientifiques de M. J. Moutier*, p. 30) which obviously influenced Duhem.

18. The subheading, 'Applications à la chimie' (ibid., pp. 23-26), begins with a reference to Sainte-Claire Deville who is repeatedly mentioned thereafter.

19. As emphatically noted in the chapter, 'Les sciences physiques et chimiques,' by Brunhes, Duhem's successor in Lille, in *Un Siècle: Mouvement du monde de 1800 à 1900* (Paris: Librairie H. Oudin, 1900, p. 463), a topical evaluation of the 19th century, published by a committee under the presidency of Msgr. Péchenard. Its almost thirty contributors surveyed the 19th century under three headings: politico-economical, intellectual, and religious.

20. That history is still to be written. There is not a hint of it in M. P. Crosland's article, 'Berthelot,' *Dictionary of Scientific Biography*, 2: 63-72.

21. 'Physics of a Believer,' in 1954 (3), p. 275.

22. Ibid., p. 276.

Those courses and the courses in chemistry as well were taught in a decidedly anti-mechanistic sense, that is, with a marked diffidence about hypotheses concerning the ultimate constitution of matter. Those who gave those courses were, in Duhem's words, 'past masters in experimental manipulation, they saw in experiment the only source of truth; when they accepted physical theory it was on condition that it rest entirely on laws drawn from observation.'²³ Such an acceptance of physical theory meant for all practical purposes little or no theory at all and invited a neglect of casting experimental results into an elaborate and rigorous mathematical framework. Herein lay an irony, unnoticed by Duhem, who described his teachers of physics and chemistry as 'rivalling one another in praising the method that Newton had formulated at the end of his *Principia*.'²⁴ Whatever the true merits, unsuspected by Duhem, of Newton's protestations against making hypotheses, Newton's method certainly demanded a vast role for mathematics in physics. Those articulating that role were few and far between in France in the 1880s. Compared with the vigor which theoretical physics displayed in France during the first three decades of the century through the work of Laplace, Lagrange, and Fresnel, the situation during the following two generations represented a 'certain fatigue.' Biot, Arago, and Lamé may have been the target of this remark with which Lucien Poincaré, a physicist by training and a high official in the French educational system, introduced his survey of French physics during the period 1870-1915. He understated the case. No less an understatement was his other remark that 'one has to admit in all frankness that French physics ceased being the sole and the great initiator.'²⁵ France could boast around 1880 of only two major physicists, Fizeau and Regnault, both experimentalists. Mathieu, an outstanding theoretician, was languishing in the provinces. Henri Poincaré was still to give new luster to theoretical physics in France by extending the scope of his lectures at the Sorbonne where he arrived in 1881, at the age of twenty-seven, with the reputation of a genius. As was already noted,²⁶ Duhem startled his fellow students specializing in mathematics at the Ecole Normale by his grasp of Poincaré's work. Poincaré was a great admirer of Hermite, who had already made a deep impression on Duhem the student at Stanislas.

Had young Duhem not been possessed by an unusual interest in physical theory insofar as it implied a heavy reliance on mathematics, he would not have found special stimulus in his teachers of mathematics at the Ecole, especially Jules Tannery. Thus, although theirs was the interest of pure mathematicians, they could but propel the development of a born theoretical physicist like Duhem as 'they worked to develop and sharpen in us a critical sense and to make our reason infinitely difficult to satisfy when it had to judge the rigor of a demonstration.'²⁷

23. Ibid.

24. Ibid.

25. See *Un demi-siècle de civilisation française (1870-1915)* by B. Baillaud and more than twenty other contributors (Paris: Hachette, 1916), p. 325.

26. See Ch. 2, pp. 43-44.

27. 'Physics of a Believer,' p. 276.

In fact an 'ingenious theory of Moutier' became one of the first victims of young Duhem's quest for complete rigor.²⁸ The simultaneous impact on him of the teaching of single-minded experimentalists and of no less single-minded mathematicians was all that was needed in the way of external stimulus to carry toward completion the making of Duhem the physicist while still at the Ecole. This was true in a general as well as in a special sense, though not in that sense of unrestricted consistency which ultimately marked Duhem's efforts as a theoretical physicist. Yet even in that latter respect the full formation of Duhem the physicist was not long in the making.

The general sense related to his viewing the ideal theory 'as resting solidly on laws verified by experiment and completely exempt from hypotheses about the structure of matter . . . and at the same time . . . constructed with that logical rigor which the algebraists had taught us to admire.' He was clearly in the grip of that view already in his last years at the Ecole. Otherwise he would not have stated that 'we tried hard to make our lessons conform [to that view] when we were given the first opportunity to teach' in Lille.²⁹ Well before taking up his first teaching post there, Duhem had articulated that general idea in a specific sense. He seized in particular on the analogies between certain formulas of thermodynamics and mechanics. His reading of Gibbs, of Maxwell, and of Helmholtz acquainted him with the analogy between the notion of potential in mechanics and the function which Gibbs and Maxwell called 'available energy' and Helmholtz called 'free energy' in chemical reactions. 'To treat the theories of thermodynamical statics by methods very similar in form to those in which, since Lagrange, mechanical statics is treated, such was the lasting concern of Gibbs and Helmholtz. The desire to set forth even more forcefully, if possible, the analogy guided our first researches.'³⁰ By these first researches Duhem obviously meant his rejected doctoral dissertation on thermodynamic potential and the papers leading to it.

Duhem's years in Lille completed his making as a physicist in two respects. First, under the impact of the searching questions of his students — 'an elite audience,' to recall his glowing praise of them — he realized how difficult it was to live up with unrestricted consistency to the program of eliminating all mechanical hypotheses about the constitution of matter. Their 'requests for clarification and embarrassing objections indefatigably indicated the paradoxes and vicious circles which kept reappearing despite our care.'³¹ Revealingly, the most effective aspect of their quest for full clarity derived from their dissatisfaction with current treatises on thermodynamics. Little did Duhem suspect what was in store for him as he acceded to their request to put together a 'small treatise on the foundations of that science'³²

28. *Introduction à la mécanique chimique*, 1893 (1), pp. 159-61.

29. 'Physics of a Believer,' pp. 276-7.

30. *Notice sur . . . Pierre Duhem*, p. 37.

31. 'Physics of a Believer,' p. 277.

32. Not unexpectedly, the 'small treatise' grew into a vast memoir, the 'Commentaire aux principes de la thermodynamique,' 1892 (9), 1893 (11), and 1894 (2).

if it was to embody a complete absence of mechanistic assumptions, the invariable source of self-defeating paradoxes and inconsistencies. Complete success demanded nothing less than giving up the notion of physical method as an inductive procedure and as an explanation. Rather, physical theory, if fully conformed to logical rigor, was to become equivalent 'to an artificial construction manufactured with the aid of mathematical magnitudes; . . . a kind of synoptic painting or schematic sketch suited to summarize and classify the laws of observation.'³³ Observations once stripped of any interpretative detail concerning the structure of matter, had to become statements about physical motion taken in the most general sense of any physical change. Herein lay the foundation of the kind of physics which Duhem later developed under the name of Energetics and which ultimately became the hallmark of his work in physics.

The second respect in which the making of Duhem the physicist was complete by the time he reached the mid-point of his stay in Lille was the progress of his first researches which, as he stated, 'very soon suggested to us a much broader idea.'³⁴ The latter consisted in a theory which may underlie two analogous domains, mechanical statics and physico-chemical statics. To look for such a theory meant a procedure much more steeped in the exigencies of rigor than would have been the case with a mere attempt to reduce mechanics to thermodynamics. The theory in question implied a generalized notion applicable to any and all physical change. The main laws of that theory had therefore 'to combine in a more conveniently generalized form the axioms of the old mechanics and the axioms of more recent thermodynamics.' The prospects of the task beckoned to Duhem as a supreme challenge and a call. Or as he reminisced: 'The formulation of such a science *very soon* appeared to us an objective so worthy that our life should be consecrated to its cultivation however imperfectly we may implement it'³⁵ (Italics added).

Whatever its breadth and depth, the validity of this notion of physics depended also on a sustained attention to the wide variety of experimental details. An early illustration of such attention was Duhem's rejected doctoral dissertation which would have deserved acceptance even if it contained nothing else but that theoretical gem which later became a byword among physical chemists as the Gibbs-Duhem equation. Long before Duhem reached this point in his *Potentiel thermodynamique*,³⁶ he had already offered a vast analysis of the ability of thermodynamic potential to account for the shape of curves established for vapor pressure in saline solutions. As to the equation in question, its formulation was preceded by a lengthy comparison of experimental data gathered during the previous two decades with two theories. One was Gibbs' theory of dissociation in homogeneous and non-homogeneous substances, the other was Helmholtz's theory of heat produced in a voltaic pile. In fact, the equation, developed in the strictly theoretical chapter of

33. 'Physics of a Believer,' p. 277.

34. *Notice sur . . . Pierre Duhem*, p. 37.

35. *Ibid.*, p. 38.

36. *Le potentiel thermodynamique*, 1886 (1), p. 141, where its derivation is based on Euler's theorem on homogeneous functions.

the dissertation, served only to extend the range of experimental application of the thermodynamic potential. The extended range related to the problem presented by the combined etherification of more than two substances and to the problem of solubility of salt mixtures, exempt from double decomposition as well as subject to it. The heavy presence of experimental data in the third part of the dissertation was amply suggested by its caption: "Some applications of thermodynamic potential to electrical phenomena."³⁷ Not that all those data demanded the thermodynamic potential as a solution. In many cases, that is, in sufficiently energetic processes, its predictions were not significantly better than the ones provided by the maximum work principle. Yet, against such background one could sense all the more keenly the significance of a small group of data with which that principle could not cope.

Setting forth the theoretical significance of a novel approach in physics demanded then as now a mathematical articulation. The extent to which Duhem was able to do this already in his years of formation could be seen in his second or successful dissertation. In essence its subject was still the thermodynamic potential, although as related to magnetic induction.³⁸ This new viewpoint allowed for a heavy recourse to mathematical analysis which was also dictated by the practical consideration of making Duhem eligible to the only doctor's degree still accessible to him, the degree in the mathematical sciences. Duhem's starting point was his conclusion at the end of a vast historical survey of the topic that the absence of complete rigor in Poisson's mathematical treatment of magnetic induction had not been remedied by any subsequent study. He therefore derived the differential equation with partial derivatives which were required by the limiting conditions of the problem. He then showed that for magnetic bodies there existed one and only one solution for magnetization and that it corresponded to a state of stable equilibrium. Concerning diamagnetic bodies Duhem's mathematical analysis showed that if for such a body there existed a state of magnetic equilibrium, that is, a minimum of thermodynamic potential, then either that potential would present an infinity of other minima or there would exist a finite or an infinite number of unlimited and continuous series of magnetic distributions such that along each of them the potential in question always decreased. Paradoxical as such a result could appear, it provided a solution to some recent experiments.³⁹ Mathematical analysis led also to a conclusion opposite to a law stated by Faraday, a law which provided a distinction between magnetic and diamagnetic bodies. To provide a new basis for

37. *Ibid.*, pp. 191-240.

38. 1888 (1).

39. It shows something of the paucity of experiments which Duhem's physics called for that the experimental evidence he referred to was by 1913 a quarter of a century old. In fact, it was obtained during the very winter of 1887-88 when Duhem expected a decision on his second doctoral dissertation. Not that the evidence was not valuable. Paul Joubin, a year Duhem's junior and a fellow Normalien, was a préparateur at the Collège de France when he arrived at his results ('Sur la mesure des champs magnétiques par les corps magnétiques,' *CR* 106 [12 mars 1888]: 735) without knowing of Duhem's theory, a fact to which Duhem made a pointed reference in the printed form of his dissertation, 1888 (1), pp. 52-3. Duhem's theory was not subjected to further tests by Joubin whose career eventually shifted to administrative posts.

their distinctness, Duhem had to make further mathematical recourse to the thermodynamic potential. For the case of two bodies, one very slightly magnetic, another very slightly diamagnetic, he could show that what was stable equilibrium for one, was unstable equilibrium for the other. While the answer was rigorous, it meant a drastic limitation of phenomena under consideration, a procedure also characteristic of the work of Duhem the physicist beyond his formative period. That in the same dissertation Duhem also considered the applicability of his main thesis to a broad variety of fields — thermic phenomena produced by magnetization, and to the behavior of crystallized bodies in magnetic fields — anticipated another feature of Duhem's subsequent work in physics.

The physicist as seen by himself

Duhem saw his work in physics as an advance which had to be along a broad front with repeated returns to the same topics. The reason for this lay in the need to formulate theorems about the generalized notion of movement applicable to all branches of physics: 'Only a large number of confrontations between those theorems and experimental physics could guarantee that the theory had acquired all the generality and precision desirable.' Progress therefore meant 'a series of tries and retouches' and the realization that 'it was necessary to be satisfied with sketches, guesses, frequent reworkings and at the same time to forget about beautiful treatises setting forth the definitive truth in all its purity.'⁴⁰ While the 'final word' in physics was not the direct aim of that advance, it was to provide the basis of a consistent organization of all branches of physics, a precondition of approaching however remotely the definitive truth about the physical universe.

In 1913, when Duhem gave this characterization of his work as a physicist, he could look back on almost three decades of relentless research which certainly showed a unity of purpose and method. It was no exaggeration on his part to say that the only change in that research related to its label. What he first called 'thermodynamique générale,' or generalized thermodynamics, he later spoke of as 'énergétique.'⁴¹ Behind Duhem's care to recall Rankine as the one who coined that word,⁴² there lay more than his bent on recognizing priority. Well before 1897, when Rankine was first recalled by Duhem in such a connection,⁴³ he must have

40. *Notice sur . . . Pierre Duhem*, p. 41.

41. See note 78 to Ch. 6.

42. Duhem, always quick to acknowledge priority and provenance, hardly knew of this before 1896.

43. Duhem did so in the preface to the first volume of his *Traité élémentaire de mécanique chimique*, 1897 (1), p. vi. Rankine first used the word energetics in his paper 'Outline of the Science of Energetics' (1885): see pp. 209-28 in his *Miscellaneous Scientific Papers*, ed. J. W. Millar (London: Charles Griffin, 1891).

seen the word in its German variant, *Energetik*, in the writings of Ostwald.⁴⁴ The latter's grafting on the word a quasi-metaphysical nuance could hardly endear it to Duhem whatever Ostwald's interest in a generalized thermodynamics. Indeed, Duhem never dignified Ostwald's 'Energetik' by so much as a mere reference. In Rankine's use of the word Duhem could, however, find the intimation of a thermodynamics germane to his own approach to physical theory.⁴⁵ He could in fact show in his *Notice* with a long quotation from his commentaries on thermodynamics, published in the early 1890s, or years before he became familiar with Rankine's paper, that he had by then a clear notion of thermodynamics as distinct from its mechanical interpretation and also from its definition as a strictly separate branch of physics.⁴⁶ Such a notion of thermodynamics did not have for its foundation, and not even for its starting point, hypotheses about the structure of matter, but abstract and formalistic axioms analogous to the ones on which Lagrange based his purely analytical mechanics.

The commentaries on thermodynamics were one of the five monumental studies representing the first phase in that advance along a broad front. The other four were studies relating to hydrodynamics, elasticity, chemical solutions, and electro-dynamics, comprising in all half a dozen volumes, each covering almost 500 pages and published within four years (1891-94). The chief parts in the second phase were a four-volume treatise on physical chemistry, and another series on hydro-dynamical researches and elasticity. It was during that phase of about six years (1897-1903) that Duhem guided to successful conclusion half a dozen doctoral researches. The extensive analysis in them of experimental data was aimed at bringing further support to Duhem's theoretical approach. The third phase (1910-1916) was largely represented by the two volumes of the *Traité d'énergétique*, a vast broadening of his commentaries on thermodynamics, and by a series of memoirs and notes on electro-dynamics.

44. First in the article, 'Studien zur Energetik,' which Ostwald published in 1892 in his *Zeitschrift für physikalische Chemie* (9:563-78 and 10:363-86). Rankine was not mentioned either in this article or in the publications cited below. Three years later Ostwald regaled the French public with an article on energetics which in its German original had the revealing title, 'Die Überwindung des wissenschaftlichen Materialismus,' a title toned down by the French editor to 'La dérouté de l'atomisme contemporain' (*RGS CPA* 6 [1895]:953-58). The same paper was read by Ostwald next year at the meeting of the German scientists in Lübeck. The subsequent major steps of the transformation by Ostwald of his *Energetik* into a monistic or panspsychistic *Weltanschauung* were his *Vorlesungen über Naturphilosophie* (1902), 'The Modern Theory of Energetics' (*The Monist* 17 [1907]:481-515), and *Der energetische Imperativ* (1912). The difference between Ostwald's and Duhem's notion of energetics is emphatically noted by R. Dugas in his posthumous work *La théorie physique au sens de Boltzmann et ses prolongements modernes* (Neuchâtel: Du Griffon, 1959), pp. 88-90.

45. As is very clear from Duhem's discussion of Rankine's 'energetics' in *La théorie physique*. See its English translation, 1954 (3), pp. 52-53, where Duhem's sole criticism concerns Rankine's advocacy of the usefulness of starting with mechanistic hypothesis on the route toward a fully abstract theory.

46. *Notice sur . . . Pierre Duhem*, pp. 38-39. The quotation consisted of the concluding paragraph.

Since these three major phases were a variation on the same theme, Duhem could readily dispense with the historical perspective in summarizing his achievements as a physicist. His account, written mainly for the members of the Académie des Sciences, was topical. More significantly, the account was interrupted only now and then by a brief mathematical formula and a very elementary one at that. This markedly non-mathematical account could seem surprising in view of the heavy presence of mathematics in most of Duhem's publications on theoretical physics. No less a mathematician than Hadamard spoke of Duhem's *Leçons sur hydrodynamique* as a source where he and other pure mathematicians had found powerful stimuli.⁴⁷ No wonder. According to Hadamard, Duhem was fully conversant, already when at the Ecole Normale, with the latest and best in mathematics offered by a Hermite and a Poincaré.⁴⁸ Complete mastery of all the mathematical tools helpful to the physicist was for Duhem a professional requirement to be taken for granted. It would have been inconceivable for him to rely on a hired mathematician as was the case with Einstein, who came to regret keenly his erstwhile neglect of mathematical studies. Duhem's abstaining from mathematics in his *Notice* to the Académie des Sciences was not primarily dictated by the practical consideration that many of its members would not have otherwise been able to peruse the eighty or so pages he devoted in that *Notice* to his work in physics. Far more decisive should seem in that respect Duhem's notion of common sense as a foundation of physics. It implied the translatability into ordinary language of physics, be it cast into the most esoteric mathematical moulds. The same translatability, it is well to recall, was upheld decades later by Einstein, Heisenberg, and Bohr,⁴⁹ who did so in connection with a physics far more removed from common sense than the physics done by Duhem. At any rate, his detailed account of himself as a physicist should seem to have interest of its own and all the more so because few if any other major physicists produced a similar document.

As could be expected from a thinker like Duhem, bent on rigor and logic, his first topic, or Section I of Part I of the *Notice* dealing with his work in physics, was the codification of the principles of energetics. Within the perspective of energetics motion in space (locomotion) could not be treated as a form of change simpler than

47. J. Hadamard, 'L'oeuvre de Pierre Duhem dans son aspect mathématique,' in *L'oeuvre scientifique de Pierre Duhem* (Paris: A. Blanchard, 1928), p. 472. Hadamard mentioned Volterra, and the Abbé Coulon, a doctoral student around 1896 at the University of Bordeaux.

48. *Ibid.*, p. 467.

49. According to Einstein, reliance on 'the connection of the elementary concepts of everyday thinking with complexes of sense experiences . . . is the only thing which differentiates the great building which is science from a logical but empty scheme of concepts' (*Out of My Later Years* [New York: Philosophical Library, 1950], p. 61). Heisenberg acknowledged that 'even for the physicist the description in plain language will be a criterion of the degree of understanding that has been reached' (*Physics and Philosophy* [New York: Harper Torchbook, 1962], p. 168). Heisenberg reported Bohr as having stated that 'if we want to say anything at all about nature – and what else does science try to do? – we must somehow pass from mathematical to everyday language' (*Physics and Beyond* [New York: Harper Torchbook, 1972], p. 135).

any other change. All changes were on equal footing, they all were but modifications of systems. The notion of work too had to be much broader than the one issuing in locomotion. The concept of force, which in its Newtonian definition also related to spatial categories, namely, to the acceleration of moving bodies, had to yield to the concept of action. The notion of work thus broadened made possible a new definition of the quantity of heat, which in Duhem's eyes was 'one of the principal innovations' of the doctrine of energetics.⁵⁰ The new notion was to forestall any possibility, however subconscious, to define measurements of temperature in terms of hypotheses, however disguised, about the nature of heat.⁵¹

No such hypotheses seemed to be involved if the quantity of heat was defined so as to make the equivalence of heat and work its immediate consequence. This meant that classical mechanics, for which temperature changes were irrelevant, had to be viewed as a special or non-normal case of energetics. The normal case was constituted by systems capable of temperature change, that is, having calorific capacity. The absorption of heat became thereby a mere rise in temperature which obtained its absolute scale through Carnot's principle. While in statics the specification of temperature entailed no unusual consequences, the case was different for dynamics for the very reason that it could not be built as a mere amplification of d'Alembert's principle, that is, as a generalization of the principle of virtual work of inertial actions. In addition, the principle of the virtual work of passive resistances or actions of viscosity had to be brought in because 'those actions do not simply depend on the state of the system but also on its velocities [including] the velocities by which vary its most diverse properties, chemical, electrical, magnetic etc.'⁵²

A science of dynamics thus constituted had two limiting cases. One was Newtonian dynamics, corresponding to situations where viscosity played a negligible part. There acceleration was proportional to force. The other case was largely the realm of chemical reactions where the velocity of change was proportional to the action (or the product of force and time) producing it and therefore 'reminds one of the old dynamics of Aristotle.'⁵³ One of the primary tasks of this new dynamics was the demonstration of the inequalities of Clausius, a particularly difficult task

50. *Notice sur . . . Pierre Duhem*, p. 42.

51. Duhem saw an evidence of the subtle presence of mechanical notions of heat in the endless efforts to submit measurements of heat to a great variety of corrections and asked: 'Will these hypotheses become truly banished from science until there is on hand a notion of the quantity of heat, a definition so clear and general, that it implies no implicit and surreptitious appeal to assumptions which today are considered doubtful and even condemned?' (*ibid.*, p. 44).

52. *Ibid.*, p. 46. All these velocities, Duhem added, 'are marked by one characteristic: in any real modification the work effected by them is positive.'

53. *Ibid.*, p. 47. This and other statements of Duhem about energetics as 'analogous' to Aristotelian dynamics became, as will be seen, so many pretexts in the hands of some for a thorough misrepresentation of his thought as if he had advocated a return to Aristotle's physics.

when parts of a system were at different temperatures.⁵⁴ Even more difficulties were presented by the isothermo-isentropic systems as they could be treated only with the help of postulates extraneous to energetics. In singling out the problem of thermal conductivity in this connection, Duhem certainly showed keen awareness of the imperfections of his energetics. A chief of them was the constraint imposed on its cultivator to ignore deliberately areas of research teeming with unexpected advances and discoveries. In making this admission, both admirable and revealing, Duhem must have thought of radioactivity, spectroscopy, photoelectricity, and black-body radiation. They all called for methods which assumed those very discontinuities that could not be considered in his energetics even as mere hypotheses.

Energetics was also an imperfect science because of the magnitude of problems which in principle could be treated by it. A principal area of such problems was the mechanics of fluids and elastic bodies, a topic which took up almost one third (Sections II and III) of the summary of his work as a physicist and was a signal evidence of his courage to remain in the grip of most arduous problems. The unsatisfactory character of most propositions in Book II of the *Principia*, where Newton largely dealt with fluid mechanics, was symbolic of many subsequent efforts even with respect to the relatively simple case represented by homogenous and compressible fluids. Unlike in Newtonian mechanics, which made the interaction between two parts of such fluids a function of their masses, in generalized mechanics (a branch of energetics) the interaction became a function of their masses as well as of their densities. Duhem's first effort to make use of this idea in a memoir on the thermodynamic potential and hydrostatic pressure made him all too aware of 'complications previously unsuspected.' His subsequent efforts made him recognize that 'while energetics brings new insights to hydrodynamics, they mostly make obvious the extreme difficulties of the theory.'⁵⁵

In his work on the mechanics of non-viscous bodies Duhem made much of the supposition of 'very small motions' though he did so with mixed feelings. He saw in it mere intuition which, however helpful, 'deprived of the characteristic of infallible rigor all demonstrations which make use of it.'⁵⁶ The supposition made possible further studies of the stability of floating bodies in which he relied heavily on the criticism to which R. Clebsch, who ended his brief career as professor of mathematics in Göttingen, subjected, around 1850, the metacenter rule, first proposed by Bouguer and later improved by Euler. Next came studies on floating bodies loaded with liquid because the 'problem presented to energetics an opportunity to test its methods.' If however, the problem was 'not to remain a mere offshoot of the old mechanics, it had to be generalized,' which in part was done through the introduction of the notion of associated displacement. Thus the diffi-

54. *Ibid.*, p. 48. Here Duhem devoted much attention to the conductibility of heat and to the studies of Jouguet which 'gave us an abundance of fruitful suggestions and profitable criticisms.'

55. *Ibid.*, p. 52.

56. *Ibid.*, p. 54.

culty which Clebsch pointed out with respect to the metacenter rule could be resolved though only with a sixth-degree equation, which showed that, when all its roots were positive, the equilibrium of a body oscillating on a compressible fluid was stable.⁵⁷

While the complications of the hydrodynamics of non-viscous fluids appeared 'frightening,' those of viscous fluids seemed to Duhem 'almost a cause for despair.'⁵⁸ He felt his work could alleviate but slightly the difficulties and described in detail only his work on the effects of viscosity within a fluid whose state hardly differed from the critical state. The area of hydrodynamics where Duhem found matters relatively easy was the propagation of waves. Before him studies were restricted to the limiting cases of isothermic and adiabatic propagations. Since the intermediary cases remained unexplored, the method of energetics, Duhem remarked characteristically, 'demanded that not the least lacuna be left in the series of cases to be explored.'⁵⁹ A particular area never studied before was the propagation of waves in viscous media. His principal finding was that in such media no waves could be propagated. Rigor therefore forced him to conclude that since air was a medium, however slightly viscous, sound waves were not real waves but quasi-waves, that is, a sequence of very thin layers across which the partial derivatives of velocity varied rapidly though without discontinuity. In commenting on this he gave a revealing glimpse of the physics he was doing:

The study of the propagation of sound has so much imbued physicists with the notion of wave and its velocity of propagation that this kind of propagation appeared alone possible to them. They found it repugnant to admit that certain properties, such as temperature in a heat-conducting medium, could exclusively depend on the analytic functions of the co-ordinates [of space and of time] in such a way that in this kind of propagation there should be neither wave nor velocity. It is teasing to recognize that this is precisely the kind of propagation which applies to the motion of sound in air and that in the same case the existence of waves and the existence of a velocity of propagation are merely appearances and approximations.⁶⁰

Concerning the mechanics of elastic bodies Duhem found that the dynamics of such bodies presented far greater opportunities to him than their statics. The equations he obtained for the laws of viscosity within an elastic medium in motion allowed him the study of wave propagation in vitrous media with results analogous to the ones obtained for fluids. In a vitrous but non-viscous medium with small deformations mathematical analysis predicted the separation of waves into a longitudinal and a transversal perturbation whose velocities were not the same. From the same equations, insofar as they governed the finite motions of elastic

57. *Ibid.*, p. 56.

58. *Ibid.* 'All those,' he quoted from his communication made in 1902 (11) to the Académie, 'who observed in a fluid the streaks and tracks which develop near the critical state, [and] who also observed the movements which are produced in the dissolution of hardly uniform concentrations, could note the extreme similarity of these two phenomena' (*ibid.*, p. 57).

59. *Ibid.*, p. 58.

60. *Ibid.*, p. 61.

bodies, Duhem derived both rigorously and approximately valid propositions concerning states of equilibria. The subject matter demanded a sharp narrowing of the aspects under which it could be investigated, so that the results might be specific such as the inevitable instability of a medium in the case when an imaginary number represented the velocity with which an infinitely small perturbation moved within it.

The same subject allowed not only the refinement of previous studies but also the exploration of previously untouched fields. Among these was the motion of waves within elastic and viscous media affected by finite deformations. The impact of mathematical rigor was once more in full evidence as it predicted the breaking of waves in such media into eddies which, unlike ordinary eddies, could not slide past one another. Duhem's work on such eddies (*ondes-cloison*) was quickly verified by physicists, chemists, geologists, and astronomers. He viewed the outcome as a 'valuable confirmation of one of the most general theorems formulated by mechanics based on energetics.'⁶¹ The method of energetics, a mathematical treatment of macrophysical transformations, however slight, of continua, was certainly germane to the theory of small movements of elastic bodies, a study initiated by Clebsch to whom Duhem often referred. For the same reason Duhem was attracted to Kirchoff's theory of diffraction which in addition appeared to Duhem to be in need of a more rigorous formulation. The apparent disparity between the latter subject and the former posed no problem for energetics because its method barred concern about underlying mechanisms. On working with Clebsch's theorem Duhem found close similarity among the statics of a flexible filament, the determination of the brachistochronous trajectory of a material point subject to a given potential function, and the route traced by a light ray in isotropic homogeneous media. 'The analogies,' wrote Duhem, 'which are tied to this last problem, led us to discuss the stability of a flexible and inextensible fluid.'⁶²

An area most suited to the method of energetics was chemical mechanics (Section IV). In many works Duhem tried to organize fully the entire field by taking his lead from Gibbs' memoir 'On the Equilibrium of Heterogeneous Substances.' In addition to rendering 'irreproachable' the formulation of the phase rule, Duhem also wanted to make it as general as possible through five propositions based on two postulates. One asserted the stable equilibrium of the homogeneous mixture of any number of fluids whose composition and temperature were variable, and which was under uniform and constant pressure. The other made the equilibrium of the mixture of any number of fluids the function of homogeneity, on the condition that the temperature and pressure remained the same. These postulates supported the general theorem: 'If the temperature, pressure, and masses of independent components are given, and if these data are compatible with an

61. *Ibid.*, p. 67. Duhem was also pleased to note that the same kind of approach was used with respect to the mechanics of filaments and flexible membranes by L. Roy and Jouguet. Owing to their contributions, Duhem added, 'this chapter of physical mechanics offers today a definitive, well-rounded character.'

62. *Ibid.*, p. 70.

equilibrium state of this system, the composition of each of those phases, within the system in equilibrium, is determined without any ambiguity.⁶³ The consequence that no unstable chemical equilibrium was possible at a constant temperature, illustrated for Duhem a principal claim of energetics, namely, the absence of a rigid line of demarcation between physics and chemical mechanics.

The foregoing consequence concerning equilibria was found by Duhem particularly relevant for the study of mixed fluids, of their internal and external motions (Section V). He felt that unlike the kinetic theory of gases, which provided equations for particular cases, such as the diffusion of perfect gases into one another, 'energetics provided a regular and general method for establishing the theory of motion of any number of mixed fluids.' Generality meant no rigidity. In that sense Duhem could say that 'energetics is not an exact science, [although] all theorems stated in it are subject to well-defined conditions. Does a material system not fulfill one of these conditions? The corresponding theorem must not then be applied.'⁶⁴ Such was Duhem's introduction to his summary of his researches relating to friction and false equilibria (Section VI). Phenomena belonging under this head could not be handled by Carnot's principle, a point acknowledged by Gibbs whom Duhem quoted at length. Therefore, in Duhem's view, there was a need of a 'new energetics.' 'Old energetics' (hardly two decades old yet) sufficed with a new chapter containing the doctrine of false equilibria, a doctrine which, as will be seen, did not elicit notable assent. Duhem's study of a wave of first order with respect to the velocity with which chemical reaction propagates in a medium at the limit of false equilibrium was, however, recognized by some as a particular case of the propagation of an explosive impact or more generally of a shock wave. Duhem made particular mention of his work on the applicability of false equilibria to some electric phenomena. The reason for this was the affirmative answer which his last doctoral student obtained in 1908 to his suggestion made in 1896 that the decrease of electric charge brought about by exposure to ultraviolet light might be analogous to the decrease of viscosity under similar exposure.⁶⁵

The answer was both a registering of facts and their systematization in terms of energetics, which had to be stretched beyond its normal framework also in connection with some facts relating to permanent modification through magnetic hysteresis, the subject of Section VII of Duhem's account of his physics. To cope with those facts, energetics had to be made more complete by adding one more variable to the equation governing thermodynamic equilibrium. One such fact closely investigated by Duhem, in part through the doctoral dissertation of Marchis, was represented by the behavior of what metallurgists called 'hammered wire.' Yet, a more 'complete energetics' could relieve a sense of chaos only to the extent of providing a 'qualitative agreement' between facts and theory.⁶⁶ By putting this admission in *Italics* Duhem served signal evidence how alien to him was any intention of concealing the shortcomings of his work.

63. *Ibid.*, pp. 74-75.

64. *Ibid.*, p. 78.

65. *Ibid.*, p. 84. The author of the dissertation was Mme H. Baudeuf; see Ch. 6.

66. *Ibid.*, p. 87.

Energetics could appear even more imperfect in respect to the magnetization of bodies (Section VIII). Imperfection meant that very often an extra term, which Duhem called electro-kinetic energy, had to be added to the purely potential and kinetic energies which alone were assumed in ordinary energetics. The latter seemed to suffice in studying thermoelectric currents, a topic which early attracted Duhem's attention. He was pleased to recall Poincaré's qualification of his work as the one 'which among all such works leaves the least to desire.'⁶⁷ Duhem also recalled his generalization of Lord Kelvin's study of the problem known as Mahomet's coffin, that is, the question whether a piece of soft iron could be made to float in air by fashioning appropriately the magnetic field around it. The question was that of stable equilibrium and Duhem's answer was, on the basis of energetics, negative. Again, Duhem's answer was negative with respect to the analogy often assumed between magnetized and dielectric bodies. He insisted that the distribution of electric and dielectric charge on a conducting body immersed in a dielectric medium implied a fictitious coefficient of polarisation in excess of the real coefficient. Maxwell's use of one single rule in both cases prompted Duhem to considerable criticism. While algebraically rigorous, Maxwell's procedure seemed to Duhem to do violence to the principles of mechanics and call 'for the reconsideration of the problem by using in a possibly most exact manner the methods justified in energetics through the rigorous application of the principle of virtual displacements.'⁶⁸ The problem was also that of electrostatic pressure which Duhem investigated in detail. His solution, however praised, did not supplant 'the paradoxical and indefensible theory of Maxwell,' so Duhem mused by giving to Pascal's dictum the variation: 'Fashion has its reason which reason does not know.'⁶⁹ If failure to acknowledge priority was not so frequent in science as to constitute a fashion, it could happen time and again. An illustration of this was, according to Duhem, his account of pyro-electric and piezo-electric phenomena, and he quoted, somewhat philosophically, Lamé: 'Those who first pointed out these new procedures are no longer alive and will be wholly forgotten unless an archeologist-mathematician will eventually revive their names.' So be it, Duhem added, 'what alone should matter is that science progressed.'⁷⁰

The longest of the Sections was the ninth and the last in which Duhem summed up his extensive studies on electrodynamics and electromagnetism. He made it clear from the outset that his originality did not consist primarily in tracing all electrodynamics to virtual displacements. But unlike Helmholtz, who first noted this possibility and introduced electrodynamic energy as a postulate, Duhem called for a full justification of it: 'The mind has the right to request . . . that it be not shocked by unexpected postulates as the laws of electrodynamics are successively

67. *Ibid.*, p. 88. On Poincaré's remark see p. 280 below.

68. *Ibid.*, p. 91.

69. *Ibid.*, p. 92.

70. *Ibid.*, p. 93. Lamé's statement concluded his *Leçons sur les coordonnées curvilignes et leurs diverses applications* (Paris: Mallet-Bachelier, 1859), p. 368.

obtained.⁷¹ To satisfy this requirement Duhem took his starting point in E. Betti's theorem on the connectivity of space.⁷² A consequence of this procedure was a reinterpretation of the rotation of a magnet under the action of a current. What actually happened was rather to be seen as the impact exercised by currents and magnets on a mobile segment of a current which was linear. There followed the extension of the argument to conducting bodies of any dimension, by the dielectric or magnetic, where again Helmholtz was Duhem's guide. One of his chief concerns was to determine the role of the constant, which Helmholtz denoted with K , in the case when magnetic and dielectric bodies were present. Equilibrium was assured when K was positive or zero. What would happen, Duhem asked, 'if K was negative? Would it then be allowed to state that on an immobile conductor the electric equilibrium was unstable?'⁷³ On finding an answer, which appeared to him rigorous because of its purely algebraic structure, Duhem noticed its close similarity to the procedure he had used concerning the initial stability of an isotropic elastic medium. As could be expected, the fact that the same mathematical formalism covered two physical situations, which appeared drastically different to common sense, further confirmed Duhem in his conviction that the method of mathematical physics revealed nothing about the nature of reality.

While Duhem's work in electromagnetics witnessed repeated reversals on particulars, such as the existence of diamagnetic bodies, the principal thrust of that work, a further articulation of Helmholtz's theories, remained unchanged. Not only were those theories, in Duhem's eyes, in agreement with all experimental data, but were also developed according to the dictates of the 'most severe logic.'⁷⁴ Maxwell's electromagnetic theory, illogical in Duhem's opinion on several accounts, became therefore the target of his relentless criticism. Duhem felt that only Helmholtz's theory, which admitted not only transverse but also longitudinal flux, both in conducting bodies and in dielectric media, could rigorously account for the waves first detected by Hertz. The chief bone of contention was the so-called displacement current which Maxwell postulated and which provoked the criticism of many prominent physicists, among them Poincaré, as being an *ad hoc* postulate and not a factor imposed by consistent logic. The explanation given by Maxwell's supporters to Hertz's experiments had to rest on the displacement current because the transverse flux had to be seen by them as localised largely in the region near the surface of a conductor placed in a field where the electric field oscillated in very short periods. In the theory given by Helmholtz, the longitudinal flux could function as the explanation, and all the more so as in Duhem's belief the existence of that flux

71. *Notice sur . . . Pierre Duhem*, p. 94.

72. E. Betti (1823-1892) was professor of physics and mathematics at the University of Pisa since 1859. Duhem's reference to Betti's paper on spaces of any number of dimensions in *Annali di matematica pure ed applicata* (4 [1871]:140-58) gives a glimpse of Duhem's familiarity with Riemann's work.

73. *Notice sur . . . Pierre Duhem*, p. 97.

74. *Ibid.*, p. 105.

had received experimental confirmation through the experiments of Blondlot and also of Turpain, Duhem's doctoral student.

Duhem recalled his criticism of Maxwell's theory and turned it into the climax of his account of his own work in physics because he could thereby restate the ideal of physics he believed in. According to Duhem the principal advantage of Helmholtz's theory was its rigorously logical character. Quite different appeared to Duhem Maxwell's work both in its genesis and development: 'At the moment when logic suggested to Maxwell an order not to be transgressed, he overcame the inconveniencing obstacle by a flagrant default in reasoning or in calculus, convinced as he was that the target he wanted to reach was truth itself.' That Maxwell was a genius was not questioned by Duhem: 'The spectacle of those perilous jumps that led Maxwell to the target by defying rules, according to which the reasoning of ordinary humans is bound to proceed, reveals to our stupefied admiration the very being of a genius.' According to Duhem there were two ways of honoring such geniuses. One was a redoing of their work in terms 'of the universal laws of logic,' that is, 'to trace out to the summit . . . a safe route whose edges avoid the precipices which geniuses cross by a jump.'⁷⁵ Such was the way Helmholtz honored Maxwell. The other way was of those who believed themselves to have been better disciples of Maxwell by not looking into the meaning of his equations. Such disciples were Hertz, Cohn, Heaviside, and Boltzmann. Their attitude was expressed in Hertz's famed dictum: 'Maxwell's theory is Maxwell's system of equations.'⁷⁶ The defiance vis-à-vis difficulties, as expressed in that dictum, proved hollow, so Duhem argued, through the readiness of Hertz and Boltzmann to downplay the shortcomings in Maxwell's reasonings. Maxwell's theory had the even more serious difficulty of being in conflict with obvious facts. According to Duhem, Maxwell's theory made impossible by definition the existence of such obvious bodies as magnets, because in that theory the magnetization of an isotropic body had to be a vector pointing in the same direction as the magnetic field.

The ultimate issue in physics was therefore a matter of attitude toward common sense evidence. Should a physicist start with facts provided by that evidence or by theories which, however successful, are burdened with an implicit denial of facts evidenced by common sense? Did not the slavish disciples of Maxwell act with respect to magnets, which they did not want to see, in much the same way as did Cremonini who declined to see the sunspots through the telescope so as not to jeopardize Aristotelian physics? Duhem's own relentless logic could indeed prompt sweeping comparisons while it motivated unswerving dedication to a cause. His own relentless criticism of Maxwell's theory was dictated, Duhem remarked, by the fact that 'he did not want to renounce either the evidence of the senses or the laws of

75. Ibid.

76. By 1913 this famous dictum of Hertz was over twenty years old. It first appeared in Hertz's introduction to his collection of papers on the detection of electromagnetic waves, *Untersuchungen über die Ausbreitung der elektrischen Kraft* (1892); see English translation by D. E. Jones, *Electric Waves: Being Researches on the Propagation of Electric Action with Finite Velocity through Space* (1893; New York: Dover, 1962), p. 21.

reason.’ Duhem’s consistent approach to problems of physics certainly supported his claim that all his intellectual career was meant to be an apostleship on behalf of common sense. That the case was more complex than seen by Duhem was unwittingly implied in his acknowledgment that his criticism of Maxwell prompted no major response. He felt victimized by disinterest in rigorous argumentation: ‘No reasoning can engage those unconcerned whether they are right or wrong.’⁷⁷ They were the physicists for whom it did not matter whether a theory was logical or absurd, and who asked of a theory only that, rightly or wrongly, it suggested new experiments.

Had this attitude become ‘general and final,’ Duhem would have had no choice but to consider his own life as a ‘signal waste.’ His confidence to the contrary was rooted in his trust in common sense claiming consistency. According to it, physical theory did not have for its unique role, not even for its principal role, the suggesting of new experiments. Its overriding role was ‘to classify and coordinate the chaos of facts revealed by experience.’ There was logic in this, and ‘since logic was eternal, it could be patient.’⁷⁸ Such was Duhem’s concluding remark on his work as a physicist. He felt no doubt that in the long run his work in physics would be given justice because of its logical consistency which, however, was above all residing mainly in its mathematical aspect. In 1913 Duhem was writing long memoirs devoted to the vindication of his electromagnetics.⁷⁹ As will be seen, within two years, and only one year before his death, he perceived a major logical fault in his work on electricity and magnetism. The outcome was not, as he seemed to believe, dictated by logic alone, but also by the evidence of senses, that is, facts, which ultimately prevail over logic, however rigorous. This turn came too late to be a part of the reaction by Duhem’s peers to his immense output in physics.

The physicist and his peers

‘Mr. Duhem combines two qualities which often exclude one another: a great erudition and a very systematic mind. These qualities, to which one should add a rare talent for presentation, are evident in all his publications which by now form a considerable amount.’ So Jules Tannery introduced his review, conspicuous by its length, of Duhem’s *Hydrodynamique, Élasticité, Acoustique* in the *Bulletin des sciences mathématiques*. Thoroughly familiar with his former student’s way of thinking, Tannery gave an accurate portrait of what in terms of method the two large volumes meant to convey. Although mathematics was preponderant in both, they were ‘very much the work of a physicist who always has reality in mind,’ and, consequently, whose concern was not the complexity of mathematics but its ability to reveal about facts that unity which mere experience could not unfold: ‘To draw all logical consequences from a very general principle, to show clearly what it contains and what it does not, and to specify the points where experiments

77. *Notice sur . . . Pierre Duhem*, p. 107.

78. *Ibid.*

79. See the memoirs 1913 (12), 1914 (6), and above all 1916 (11). The printing of the latter, submitted for the volume 1914 of *AFScT* was delayed by two years.

must intervene to bring in something really new, such is the aim he pursues and undoubtedly he will thus contribute in a large measure to the organization of current science.⁸⁰ By 'current science,' which Duhem aimed at organizing, Tannery may have meant not only an up-to-date hydrodynamics, viscosity, and acoustics but all branches of physics with their latest advances. If such was in 1893 Tannery's notion, it would have anticipated, as will be seen, the central problem of Duhem's work in physics.

For the time being the prospects for the organization of all 'current science' could appear promising to a sympathetic reader of Duhem's publications. One of them was Painlevé who contributed also in 1893 to the same *Bulletin* a dozen-page-long review of the three volumes of Duhem's treatise on electricity. Painlevé, who like Tannery, wrote about Duhem on the basis of personal acquaintance and esteem, began with a reference to the 'innumerable treatises' of very unequal merit which since Poisson had been written on electrical theory. To separate from that welter of material 'the elements that had already become part of science and to fuse them into a single body of doctrine, is the daring enterprise which Duhem is not afraid to undertake.'⁸¹ Indeed, the appearance on the scene of a powerful systematizer was conjured up in Painlevé's remark that the same thermodynamic potential, which in Duhem's hands had already given a new unity to hydrodynamics, viscosity, vaporization, and dissociation, was now performing the same role with respect to electricity. Few physicists at that time, or at any other time, could expect the encomium which Duhem received from Painlevé: 'The invariably analytical method adopted by Duhem gives to his book truly the character of power and unity.'⁸²

A signal recognition of Duhem's excellence as a physicist came a year earlier from none other than Henri Poincaré. Only five years after he had approved Duhem's doctoral dissertation, Poincaré made it clear enough that the former student was now his peer. The introduction of Poincaré's lectures on thermodynamics came to a close with the paragraph: 'Twice in the book I happened to be in disagreement with Mr. Duhem. He might wonder that I cite him only to combat him. I would be saddened if he thought of any ill will. I hope he will not suppose that I ignore the services he had rendered to science. I have only thought to be more useful by insisting on points where his results seemed to me to deserve complementing rather than on those points where I could but repeat him.'⁸³ The two points related to Duhem's theory of dissociation and to his theory of the relation between the electromotive force at any given point and the heat developed there, and formed two sections in a book which Poincaré's reputation carried far and wide. Poincaré submitted the second of those theories to a detailed and devastating criticism ('Duhem's theory becomes illusory'), because 'it is the one which

80. *BScM* 17 (1893):221-22. The review was of 1891 (2).

81. *BScM* 17 (1893):5. The review was of 1891 (1) and 1892 (1).

82. *Ibid.*, p. 15.

83. H. Poincaré, *Thermodynamique. Leçons professées pendant le premier semestre 1888-89*, rédigées par J. Blondin (Paris: Georges Carré, 1892), p. xix.

leaves the least to desire.⁸⁴ About the first theory Poincaré's final dictum was 'We can therefore admit Duhem's hypothesis and accept Gibbs' theory.'⁸⁵

Duhem's reputation quickly spread across the Atlantic. W. D. Bancroft and E. Trevor, both professors at Cornell University, asked him to contribute to their newly founded *Journal of Physical Chemistry*. In its first volume Trevor introduced his review of Duhem's *Traité élémentaire de mécanique chimique* 'as one of the most notable publications of the year.' Trevor found it difficult to 'name anyone who is better qualified to give a connected and well-rounded treatment of the subject than the famous theoretical physicist of the Bordeaux university.'⁸⁶ Six years later, in 1902, Duhem was spoken of in the same periodical as 'the celebrated French physicist' in a review of his *Thermodynamique et chimie*.⁸⁷ In the *American Chemical Journal* the same book was reviewed also in 1902 by Harry C. Jones, associate professor of chemistry at Johns Hopkins University, whose *The Elements of Physical Chemistry* was much in use during the first two decades of the century. Jones began his review with a reference to Duhem's authority as 'well recognized.'⁸⁸ Two years later the English translation of Duhem's book was greeted by Jones as 'a sign of the times and an indication of what the chemistry of the future will be.'⁸⁹

Such was a prophecy which Jones himself was not eager at all to implement. In the four revised and enlarged editions of his book, published between 1902 and 1915, Jones never referred to Duhem, an omission all the more ironic because in 1915 Jones saw the reason for the wide and constant demand for his book in a quality which after all was very Duhemian, namely, in its help 'to transform chemistry from empiricism . . . into science.'⁹⁰ Equally inconsistent with his enthusiasm for Duhem was Bancroft in his monograph on phase rule in which Duhem appeared only in a critical footnote.⁹¹ The American physicist who at that time truly lived up to his high regard for Duhem was E. Buckingham, professor of physics and physical chemistry at Bryn Mawr College. In his *An Outline of the Theory of Thermodynamics* Buckingham not only devoted a special chapter to Duhem's theory of thermodynamic potential but also praised Duhem's four-

84. *Ibid.*, p. 366.

85. *Ibid.*, p. 338.

86. *JPhCH* 1 (1896-97):427.

87. *JPhCh* 6 (1902):193. The reviewer was H. R. Carveth.

88. *American Chemical Journal* 28 (1902):242. Jones, however, took Duhem to task for not recognizing the largely erroneous theoretical derivations which Henri Sainte-Claire Deville built upon his experiments.

89. *American Chemical Journal* 31 (1904):302.

90. H. C. Jones, *The Elements of Physical Chemistry* (4th revised ed.; New York: Macmillan, 1915), preface. Jones did not find it necessary to add Duhem's name to those of L. Meyer, Ostwald, Nernst, and Van't Hoff, whose great textbooks were listed in the preface to the first edition as his principal guides.

91. W. D. Bancroft, *The Phase Rule* (Ithaca N.Y.: The Journal of Physical Chemistry, 1897), p. 22. The criticism concerned Duhem's putting in the class of 'labile equilibrium' a mixture of hydrogen and oxygen.

volume treatise on chemical mechanics as a work 'which makes a new volume of applications superfluous for the present.'⁹²

The spreading of Duhem's renown owed much to the attention given to his publications in the *Zeitschrift für physikalische Chemie* which Ostwald and Van't Hoff launched in 1887. Soon the leading periodical in the field, the *Zeitschrift* regularly carried reviews, most often by Ostwald himself, of Duhem's books and major articles. Ostwald greeted the "Commentaires sur les principes de thermodynamique" as a work whose sole defect was the absence in its title of the word 'energetics', which he had been advocating since 1891.⁹³ In 1896 Ostwald announced the reprinting of the *Potentiel thermodynamique* as a work which 'played an important and influential role in the rapid development of the application of thermodynamics to the phenomena connected with physical and chemical equilibria.' The book appeared to Ostwald as having by then a largely historical significance precisely because, as he put it, 'the subject had meanwhile taken on a very different aspect in no small part through the indefatigable researches of the famed author.'⁹⁴ The appearance in 1899 of the fourth volume of the *Mécanique chimique* was described by Ostwald as 'another monument to the famed author's brilliant methods.'⁹⁵

Naturally, Duhem was championed in Germany by G. F. Helm, professor of physics at the Technical Institute in Dresden, who unlike Ostwald did not fuse pseudo-metaphysics into physics conceived as generalized thermodynamics or energetics. In a book on the mathematical principles of chemical change, which soon appeared in English translation as well, Helm spoke in 1894 of 'the numerous and careful investigations of Duhem,' which showed the usefulness of the thermodynamic potential for the mathematical treatment of chemical processes.⁹⁶ Three years later Helm described in his *Energetik* Duhem as 'the first to recognize and thoroughly explore in an analytical perspective the great significance of Helmholtz's method of using thermodynamics on the free energy function.' Helm also gave proper credit to the *Potentiel thermodynamique* and to Duhem's subsequent researches: 'Since the publication of his book on thermodynamic potential this French investigator has reworked with rare incisiveness the entire field of theoretical science in order to subordinate it to this concept with ever increasing analytical

92. E. Buckingham, *An Outline of the Theory of Thermodynamics* (New York: Macmillan, 1900), p. v. Of the twenty-five principal books pertaining to the subject listed by Buckingham four were by Duhem.

93. *ZPhCh* 16 (1895):571. Ostwald's 'Studien zur Energetik' (see note 44 above) was a rather elementary restatement of the fact that energy was the common feature of all branches of physics and no match either in extent or in depth to Duhem's 'Commentaires.'

94. *ZPhCh* 19 (1896):518.

95. *ZPhCh* 30 (1899):183.

96. G. F. Helm, *Grundzüge der mathematischen Chemie: Energetik der chemischen Erscheinungen* (Leipzig: Engelmann, 1894); see English translation by J. Livingston R. Morgan, *The Principles of Mathematical Chemistry: The Energetics of Chemical Phenomena* (New York: J. Wiley, 1897), p. 74. In the same context Helm declared that Berthelot's principle of maximum work 'has no theoretical foundation.'

rigor.⁹⁷ Duhem must have been even more satisfied on seeing a few years earlier in Ladenburg's massive dictionary of chemistry a long article by Planck who listed there four all-important consequences drawn from the entropy function: two by Gibbs, one by Helmholtz, and one by him, namely, his thermodynamic potential as a magnitude that decreases in reactions taking place at constant temperature and pressure.⁹⁸ Since many of the papers of L. Natanson, professor of physics in Cracow, were published in German, his sustained references to the importance of Duhem's thermodynamics attested in a sense to his renown in German scientific ambience.⁹⁹

Quite different was the situation in France. Had Tannery not been co-editor of the *Bulletin des sciences mathématiques*, Duhem's books on hydrodynamics and electricity might not have been reviewed there. Such a guess is almost imposed by that general silence which greeted in France Duhem's three-volume *Traité* on electromagnetic theory, a silence baffling in more than one sense. After all, what Duhem implemented there in a systematic way was that critical attitude with which French physicists had already greeted Maxwell's electromagnetic theory. The French translation of Maxwell's classic work carried notes, more often critical than explanatory, by such leading French physicists as Cornu, Sarrau, and Potier.¹⁰⁰ The French reader was warned against "circularity in reasoning," against 'definitions introduced in surreptitious ways which anyone not too familiar with the subject will but find absolutely arbitrary,' against Maxwell's mathematical use of the word induction which is 'evidently inadequate and presented in an artificial manner,' and against Maxwell's "briskly passing from one concept of electricity to another.' By the time the reader reached the second volume, where the sting of these remarks was dampened by a suggestion about their merely 'didactic' character,¹⁰¹ he must have already been negatively disposed also by the repeated references to the absence of empirical evidence on behalf of not a few of Maxwell's inferences.

97. G. F. Helm, *Die Energetik nach ihrer geschichtlichen Entwicklung* (Leipzig: Verlag von Veit, 1898), p. 181.

98. M. Planck, 'Thermochemie,' in *Handwörterbuch der Chemie*, edited by A. Ladenburg (Breslau: E. Trewendt, 1882-95), vol. XI (1893), pp. 566-646; on Duhem see p. 633. Planck's article appeared also as a separate monograph under the title, *Grundriss der allgemeinen Thermochemie* (Breslau: E. Trewendt, 1893); for reference to Duhem, see p. 117). Two years earlier, in a speech given at the meeting of *Deutsche Naturforscher und Ärzte* in Halle, Duhem's thermodynamic potential was listed by Planck as one of the important feats which assured the superiority of generalized thermodynamics (energetics) over kinetic theory. The text of Planck's lecture, 'Allgemeines zur neueren Entwicklung der Wärmetheorie,' was immediately printed in *ZPhCh* 8 (1891):647-56.

99. See, for instance, L. Natanson, 'Ueber thermodynamische Potentiale,' *ZPhCh* 10 (1892): 740; 'Studien sur Theorie der Lösungen,' *ZPhCh* 10 (1892):748; 'Ueber Zustandänderungen in einem von Bewegung begriffenen System,' *ZPhCh* 26 (1898): 286, 289, 294 (an article which in a sense was a summary of Duhem's work); and 'Ueber die Fortpflanzung einer kleinen Bewegung in einer kleinen Flüssigkeit mit innerer Reibung,' *ZPhCh* 40 (1902):584, 590.

100. J. Clerk Maxwell, *Traité de'électricité et de magnétisme*, traduit de l'anglais sur la deuxième édition par G. Seligman-Lui, avec notes et éclaircissement par Cornu, Potier, et Sarrau (Paris: Gauthier-Villars et Fils, 1885-89), 2 vols.

101. *Ibid.*, vol. 1, pp. 36, 53, 91, 106 and vol. 2, p. 148.

No small credit should have therefore been given to a work, like Duhem's *Traité*, which carried rigor and completeness as its hallmark. At any rate, even on a mere inspection, Duhem's work must have appeared superior to other major French monographs published previously on the subject in France by such notables as J. Bertrand¹⁰² and H. Poincaré,¹⁰³ both members of the Académie des Sciences. Although Duhem's *Traité* did impress Picard, he did not go public with his encomiums expressed in a letter to Duhem.¹⁰⁴ Somewhat understandable was the omission of Duhem in the second revised and enlarged edition of the lectures on electricity by Poincaré, an author never generous with references.¹⁰⁵ Such an excuse is not, however, applicable to E. Mascart who like Bertrand was professor at the Collège de France and published a much enlarged version, four years after Duhem's *Traité* appeared, of his two-volume textbook on electromagnetic theory.¹⁰⁶ The same may be said of the lectures which Brillouin gave on the propagation of electromagnetic effects in the Collège de France in 1901-02.¹⁰⁷

If silence during the 1890s on Duhem in major French publications concerning electromagnetic theory was symptomatic, the silent treatment accorded to his work in thermodynamics makes it inevitable to assume that more than professional jealousy, unwilling to recognize the merit of potential competitors, was at play. The extra factor was academic politics, quietly orchestrated from behind the scenes. This should seem obvious in view of what had been privately reported to Duhem about the intimidation which even some of his best and well-positioned friends felt on the part of Berthelot. Absence of any reference to Duhem in the course given by H. Pellat on thermodynamics at the Sorbonne in 1985-96 could perhaps be

102. J. Bertrand, *Leçons sur la théorie mathématique de l'électricité* (Paris: Gauthier-Villars, 1890). Bertrand claimed in the preface that it was legitimate to ignore, say, complicated multiple integrals, to which electrical theory led, whenever they did not appear to suggest experiments. Hardly a policy, Duhem might have said, appropriate to the highest level of scientific instruction in France.

103. H. Poincaré, *Electricité et optique. I. Les théories de Maxwell et la théorie électromagnétique de la lumière*. Leçons professées à la Sorbonne en 1888-89 et rédigées par J. Blondin (Paris: Georges Carré, 1890).

104. A letter quoted in Ch. 5.

105. H. Poincaré, *Electricité et optique. La lumière et les théories électrodynamiques*. Leçons professées à la Sorbonne en 1888, 1890, et 1899. Deuxième édition, revue et complétée par J. Blondin et E. Néculcéa (Paris: Georges Carré et C. Naud, 1901).

106. *Leçons sur l'électricité et le magnétisme de E. Mascart et J. Joubert*. Deuxième édition entièrement refondue par E. Mascart (Paris: Masson, 1896-97). It must be noted that the two massive volumes of this work contained far more detailed information on experimental data and procedures than Duhem's *Traité*. The first volume of the first edition was published in 1882 and served for young Duhem as introduction to the subject. By 1886, when the second volume was published, Duhem's grasp of electromagnetic theory was far superior to what was contained there.

107. M. Brillouin, *Propagation de l'électricité: Histoire et théorie* (Paris: A. Hermann, 1904). Duhem's omission in a book in which history and theory were treated together speaks for itself.

excused by its elementary character.¹⁰⁸ No such explanation is possible à propos the introduction which Le Chatelier wrote to his translation of the first part of Gibbs' memoir on the equilibria of homogeneous systems. Le Chatelier began with a reference to Sainte-Claire Deville's work on dissociation as the research which provided the most fertile terrain where Gibbs' ideas could show their fruitfulness. Any fairly well informed reader could then expect a reference to Duhem, and all the more so because Le Chatelier was not forgetful of Duhem's teacher, Moutier! Instead, Le Chatelier singled out, in 1899, a Schreinemakers, a Stortenbeker, a Mouret, and a Peslin – mostly unknown entities today even to a specialist historian – as chief implementers of Gibbs' ideas, in addition to Roozeboom and Van't Hoff,¹⁰⁹ as if Duhem himself had not written twelve years earlier the first critical study of Gibbs' theories!

Possibly Le Chatelier, already a professor at the Collège de France, repaid some debt to Berthelot who indeed must have been grateful to Le Chatelier for his rear-guard defense of the maximum work principle.¹¹⁰ This may also have been the case with Bernard Brunhes who in 1895, at twenty-eight, obtained a chair of physics at the University of Dijon and in 1900 at the University of Clermont Ferrand where he also took the post of director of the Observatory of Puy de Dôme. In an article, which he contributed to a book on the 19th century, Brunhes made much of the significance of thermodynamics in general and energetics in particular. He then deplored, though fleetingly, the fact that the new science of physical chemistry developed in the United States, Germany, and the Netherlands, while in France 'an incorrect thermochemistry held all attention.'¹¹¹ Of the role of Duhem in reversing that situation he could not be unaware, as he served two years in Lille as Duhem's immediate successor. By the time Brunhes made up for his slighting of Duhem,¹¹² a young physicist, H. Bouasse, to be known for the rest of

108. H. Pellat, *Thermodynamique. Leçons professées à la Sorbonne en 1895-96*, rédigées par Duperray & Goisot (Paris: G. Carre et C. Naud, 1897). The state of the art of teaching thermodynamics at the Sorbonne was well attested by the reprinting, without any change, in 1905, of Lippmann's *Thermodynamique* (Paris: A. Hermann), which, already when first published in 1888, was distinctly inferior to *Thermodynamique* by J. Bertrand (Paris: Gauthier-Villars, 1887).

109. J. W. Gibbs, *Equilibre des systèmes chimiques*, tr. H. Le Chatelier (Paris: G. Carre & C. Naud, 1899); see especially pp. x-xi.

110. A strange defense indeed! Le Chatelier ignored the theoretical falsity of the maximum work principle and denied that there had been any development from Mathieu's characteristic functions to Duhem's thermodynamic potential! See H. Le Chatelier, 'Les principes fondamentaux de l'énergetique et leur application aux phénomènes chimiques,' *Journal de physique* 3 (1894):289-306 and 352-71, especially p. 291, and also the summaries there (p. 381) of his communications to the Académie des Sciences on that principle.

111. B. Brunhes, 'Les sciences physiques et chimiques,' in *Un siècle: Mouvement du monde de 1800 à 1900* (see note 19 above), pp. 440-70; for quotation, see p. 465.

112. Brunhes did so in his introduction to the translation by L. Roy of Gibbs' memoir, *Diagrammes et surfaces thermodynamiques*, a booklet (Nr 22) in the series *Scientia* (Paris: Gauthier-Villars, 1903), where he stated that Duhem with his work on thermodynamic potential 'brilliantly inaugurated a vast series of publications by which he made classic in France the new thermodynamics' (p. 7).

his long life for his courage and outspokenness, broke the French silence on Duhem in a rather noteworthy context, the section on the history and philosophy of science in the International Congress for Philosophy held in Paris in 1900. There Bouasse brought his paper on the historical evolution of the principles of thermodynamics to a close with a glowing reference to 'the admirable *Traité de mécanique chimique* by Duhem.'¹¹³

Such courage hardly appealed to those making up an academic establishment which Berthelot helped to shape to an oppressive extent. Henri Moissan, professor of chemistry at the Sorbonne, had already taken prominent part in the celebration of the 50th anniversary of Berthelot's doctorate by setting forth his accomplishments in chemistry,¹¹⁴ before he was invited to the Congress on Sciences and the Arts at the St. Louis World Fair in 1904. He was hardly the one to add Duhem's name to those of Ostwald, Arrhenius, Gibbs, Van't Hoff, Berthelot, and Thomsen as he surveyed the development of physical chemistry. French glory had to yield if Berthelot's glory was at stake, the obvious reason why Duhem was asked to play but a secondary role in the International Congress of Physics in Paris in 1900, a role which he rightly declined in the name of French glory. Personal glory seems to have been at stake when in his two-volume monograph on elasticity Brillouin found no room for a single mention of Duhem's name.¹¹⁵ Duhem's contribution to that field was much too well known to give Brillouin the possible excuse that his book was already in press when there appeared in 1906 in the *Journal de chimie physique* the lines: 'Duhem's *Recherches sur l'élasticité* is an altogether original book in which the author gives for the first time the theory of elasticity in viscous media void of hysteresis. The book will retain all the more readily the attention of the scientific world because Duhem's great competence to take up such a topic is well known. One cannot in fact find a more reliable guide to study the fundamental topics treated in that book.'¹¹⁶

A year earlier, in late 1905, there occurred possibly the most glaring instance of the silent treatment meted out to Duhem by a French physicist, since Berthelot avoided mentioning Duhem's name in 1894 while trying to refute his criticism of the principle of maximum work. The occasion was the meeting of the Société française de philosophie on November 26, where Jean Perrin provided the subject of discussion with a paper on the essential contents of the principles of thermo-

113. H. Bouasse, 'Sur l'histoire des principes de la thermodynamique,' in *Bibliothèque du Congrès International de Philosophie, III. Logique et Histoire des Sciences* (Paris: Armand Colin, 1901), p. 131.

114. H. Moissan, 'Inorganic Chemistry: Its Relation with the other Sciences,' in *Congress of Arts and Sciences: Universal Exposition St Louis, 1904*, vol. IV. *Physics, Chemistry, Astronomy, Sciences of the Earth*, edited by H. J. Rogers (Boston: Houghton, Mifflin, 1906), pp. 243-57.

115. M. Brillouin, *Leçons sur la viscosité des liquides et des gaz* (Paris: Gauthier-Villars, 1907). Brillouin's lectures were, of course, based exclusively on the kinetic theory of gases.

116. *JChPh* 4 (1906):576. The unsigned review was written most likely by the editor, Philippe A. Guye, professor of chemistry at the University of Geneva and safely outside of Berthelot's principate.

dynamics. Present at the meeting were such prominent figures as Brunschvicg, Delbos, Lachelier, Laberthonnière, Le Roy, Lévy-Bruhl, Parodi, Painlevé, Sorel, and Jules Tannery. At the outset Perrin contrasted atomism and energetics and specified the latter, which he equated with thermodynamics, as the sole subject of his presentation. Actually, his chief concern was a vindication of atomism taken for a proof of materialism. The first half of Perrin's lecture was reserved for the definition of the first and second laws which he gave so meticulously that those in the know, such as Painlevé and Tannery, could but think of Duhem, who was not mentioned by that very same Perrin who half a dozen years earlier had written to Duhem in order to learn from him, a principal authority in the field.

By 1905 Perrin felt no need for a contact with Duhem who could hardly be in sympathy with the thrust of Perrin's lecture. At its midpoint Perrin turned to the question whether the second law, or the increase of entropy, was an absolute law or a mere statement of probability. Perrin was not, of course, the first advocate of a thoroughgoing materialism who tried to escape the vista of a cosmic end (and a cosmic beginning) which the law of entropy conjured up from the moment it was formulated by Clausius in 1873. The inexorable decrease of available energy clearly rendered meaningless any adherence to the eternity of a matter forever active about which no less an antimetaphysician than E. Littré reminded in the the early 1870s Frenchmen and others that it was the basic axiom of materialism.¹¹⁸ In fact, the second part of the discussion, which followed Perrin's lecture, centered on that cosmological problem. The first part of the discussion was largely a long restatement of the topic by Painlevé, who declared that Perrin provided 'the best, if not the very best, presentation so far of the principles of energetics.'¹¹⁹ If such was Painlevé's way of reminding the audience of Duhem, it was a very covert way indeed. It may have given Duhem serious misgivings about Painlevé's trustworthiness as a friend, who as a member since 1900 of the Académie des Sciences, would have had nothing to fear had he not aspired to political glory as well. Whatever the merit of a very covert way of salvaging truth, it would have been called for also in connection with Perrin's statement that the non-atomistic interpretation of the second law had Lippmann for its chief spokesman in France!¹²⁰

While Perrin's straight silence about Duhem could easily betray itself, recognition of Duhem could be given in such a way as to amount to rank slighting. A good example of this was provided by Perrin's treatise on physical chemistry.¹²¹ Not only was it acknowledged there that Duhem gave the first rigorous definition of reversible transformations but also that he was correct to look at utilizable

117. The text of Perrin's presentation and of the discussion are given in full in *Bulletin de la Société française de philosophie* 6 (1906):81-111.

118. E. Littré, *La science au point de vue philosophique* (Paris: Didier, 1873), p. 322. A successor of Comte as unofficial pontiff of the positivist church, Littré added condescendingly that 'there was a time when one believed in the creation and destruction of substances.'

119. *Bulletin de la Société française de philosophie* 6 (1906):105.

120. *Ibid.*, p. 96.

121. J. Perrin, *Traité de chimie physique. Les principes* (Paris: Gauthier-Villars, 1903).

energy as a thermodynamic potential.¹²² Yet no sooner had Perrin stated that Duhem was right in claiming that the thermodynamic potential at constant pressure and volume provided a rigorous definition for stability, he continued with an encomium on the practical criterium of stability, which he identified of all things as the maximum work principle, stated by Thomsen and ‘independently formulated by Berthelot in 1864.’ The rest of the paragraph was a classic in talking away the issue and truth as well, and treating its sole and courageous champion as a non-entity:

But the statement, rather obscure and too general, which Berthelot proposed, soon gave rise to violent polemics, and had to be restricted and specified. According to the ideas, which Berthelot himself reached in the end, the law of maximum work does not pretend any longer to dominate the entire physical chemistry. It leads to consequences which, though never exact, are all the less certain the higher is the temperature. However, the principle remains valuable, and I repeat, it forms actually the only practical criterium of stability.¹²³

Perrin, who after graduating from the Ecole Normale in 1893 was only offered a post in a lycée which he had refused, was still a mere chargé de cours, though at the Collège de France, under the tutelage of Brillouin. For his own advancement in Paris he had to bend truth, theoretical and historical, in favor of Berthelot. Part of the policy was to leave Duhem unmentioned at the crucial juncture. Not surprisingly, in the preface of his book Perrin attacked energetics together with its ‘theological obscurities,’¹²⁴ without making clear that he did not mean to implicate Duhem, the chief advocate of energetics in France, whose writings on the subject, unlike those of Ostwald, remained strictly scientific.

Not that Perrin, whose confidence in the victory of atomism could not have been greater, had been overly concerned about energetics. Duhem and his energetics left just as unimpressed other French physicists who at that time championed the cause of atomism. At most they dignified Duhem by voicing their disagreement with him. When Duhem wanted to obtain Brillouin as member of the jury examining Marchis’ thesis, Brillouin finally refused by stating that in his view all of Marchis’ experiments were a waste of time.¹²⁵ About the same time Brillouin expressed agreement only in a letter to Duhem with the scientific truth of the latter’s criti-

122. *Ibid.*, pp. 135 and 197. Yet Perrin did not mention Duhem at all in the long chapter, ‘Le potentiel chimique’ (pp. 228-64)!

123. *Ibid.*, p. 198. Naturally, Duhem was ignored in the works of other spirited defenders of the maximum work principle, such as *Les théories physico-chimiques* (2d ed.; Paris: A. Hermann, 1901) by A. Reychler, professor at the University of Bruxelles, and *Introduction à l’étude de thermodynamique* (2d ed.; Paris: Gauthier-Villars, 1909) by R. Blondlot, professor at the University of Nancy.

124. Perrin, *Traité de chimie physique*, p. xiii.

125. ‘C’est un travail considérable et qu’il me serait agréable de louer, si je ne trouvais qu’il pêche par la base même, et si je n’étais convaincu que tout ce soin, toutes ces heures et années de travail sont comme nuls et non avenus, et que de tout cela il ne restera rien’ (letter to Duhem, Febr. 22, 1898).

cism of Berthelot.¹²⁶ In early January 1902, in thanking Duhem for a copy of his book on Maxwell's electromagnetic theories, Pierre Curie made it clear that whatever the shortcomings of Maxwell's theory, he did not find useful Duhem's warnings against it. 'I think it would be a good idea that our physicists display in Maxwell's style an *unheard imprudence*,' the very thing Duhem decried. 'By what to replace Maxwell's way of reasoning?' asked Curie, who voiced his repugnance 'to go back to purely mathematical formulas which represented nothing physically.' After listing several disagreements between Maxwell's theory and experiment, Curie told Duhem: 'I am in complete disagreement with you concerning magnetism.'¹²⁷ And so was, of course, in physical chemistry, Le Chatelier, whose antagonism toward Duhem's work lingered on for long among his disciples.¹²⁸

The only French physicist to take issue openly with Duhem was Paul Langevin, who did so in a speech delivered on February 18, 1904, at a symposium on the teaching of physics and mathematics held at the Musée de pédagogie.¹²⁹ A brilliant graduate of the Ecole Normale and a fellow in J. J. Thomson's laboratory at Cambridge, Langevin was, with Perrin, a protégé of Brillouin, before Mascart asked him in 1902 to give a course at the Collège de France where he took Mascart's chair in 1909. Whatever his fascination with the various new advances of corpuscular physics, Langevin, as will be seen shortly, did not remain even within one single speech consistent with his advice for keeping a balance between a mechanistic and a non-mechanistic (thermodynamical) approach in physical method. Balance was indeed rudely upset when in praising the thermodynamical approach Langevin had place for Duhem only as the representative of an 'energetics' hardly different from that pseudo-religion into which Ostwald had transformed it. It was a rude misstatement on Langevin's part that Duhem simply advocated a return to Aristotelian physics of qualities, as if Duhem had not made it all too clear that his energetics included only such qualities that could be handled quantitatively. While Langevin

126. Letter of Nov 29, 1897, in which Brillouin declared himself a 'defender of Berthelot' on the ground that he was always on the side of those 'violently attacked.' Brillouin sensed nothing of the violence of the quiet attack with which Berthelot kept scuttling Duhem's career.

127. This letter has been published by P. Brouzeng in his 'Magnétisme et énergétique. La méthode de Duhem. À propos d'une lettre inédite de Pierre Curie,' *Revue d'histoire des sciences* 31 (1978):333-44.

128. In acknowledging the receipt of a complimentary copy of Duhem's *Thermodynamique et chimie*, Le Chatelier politely made it clear that he considered the book worthless (letter of March 9, 1902). As to the attitude of Le Chatelier's students, the letter which R. Piontelli, professor of physical chemistry at the Politecnico of Milan, wrote to D. G. Miller on Jan 25, 1962, is bluntly revealing: 'As far as Duhem's enemies are concerned, in my opinion, one of the most severe has been Le Chatelier, whose pupils are still in predominating places in the French scientific world. Their attitude in respect to Duhem's contributions is very cold, as I had the opportunity of ascertaining.'

129. The text of the lecture, 'L'esprit de l'enseignement scientifique,' was reprinted in P. Langevin, *La physique depuis vingt ans* (Paris: Librairie Octave Doin, 1923), pp. 424-53. Only the pages relating to Duhem are reproduced in *Paul Langevin: La pensée et l'action*, textes recueillis et présentés par P. Laberrenne, préfaces de Frédéric Joliot-Curie et Georges Cogniot (Paris: Editions Sociales, 1946), pp. 60-63, where Lenin's criticism of Duhem was eagerly recalled!

could plausibly argue that Duhem's system could not do justice to new phenomena in physics about which, it may be noted, few had at that time in France a more up-to-date knowledge than Langevin, he charged unjustly that in Duhem's system 'the physicist declares himself satisfied when complex and new phenomena are represented by new terms in the equations, terms whose arbitrary form is indicated only too well by superficial analogies.' Objectivity was further honored in the breach when Langevin stated that Duhem's method was a 'peevish tendency to limit the field of investigation' and a resolve 'to declare satisfactory and final a general and superficial knowledge of things, and to forbid ourselves a deeper investigation because a first success yielded some of the more general laws.' Langevin had no justification for saying that Duhem's method was equivalent to 'raising a barrier to knowledge' and 'a declaration of frontiers set by the unknowable, a declaration made perhaps in the fear about what may lie beyond.' At any rate, Duhem was not to be impressed with some good points in a reasoning at the basis of which was a definition of science as an urge to penetrate nature, an urge having its origin 'in our obscure instincts out of which arises a sentiment of identity and communion with the entire nature.'¹³⁰ Langevin clearly endorsed that aspiration of mechanistic physics which aimed at unveiling the nature of things in terms of atoms. Whatever the merits of atomism, it did not require the garb of a pseudometaphysical evolutionism, especially when atoms themselves could not be pictured as products of an evolutionary process, though at the same time they were taken for that device which alone could restore man's faith in reality.¹³¹

While Langevin's speech was undoubtedly prompted by Duhem's articles on the evolution of mechanics published the previous year, concern on Langevin's part about the impact of those articles was unfounded. Duhem was languishing in the provinces and deprived of doctoral students, while the atomists, well entrenched in Paris, had around them the best young talent. They were riding more and more visibly on the crest of a triumphant wave which was their making. Of this they were fully aware, and Langevin certainly was. Confidence and assurance exuded from his lecture on the physics of electrons which he delivered at the International Congress of Sciences and Arts at the St. Louis World Fair in September 1904, the text of which became widely available in France the following spring. The new results, Langevin concluded, 'go to the very heart of physics, overthrow old notions in order to arrive at a systematization which one foresees as simple, harmonious, and fruitful.'¹³² In her opening lecture as a newly-appointed lecturer at the Sorbonne, Madame Curie in 1906 surveyed with complete confidence in atomism the modern theories of electricity and matter.¹³³ The publication in 1909 of Perrin's memoir

130. *La physique depuis vingt ans*, pp. 435-36.

131. The same ideological ambience had a few years later Pierre Delbet, professor at the Faculty of Medicine in the Sorbonne, for its spokesman with his *La science et la réalité* (Paris: Flammarion, 1913), where he declared at the outset that science, through the sighting of atoms, has acquired 'a knowledge of absolute nature concerning matter.'

132. P. Langevin, 'La physique des électrons,' *RGS&PA* 16 (1905):257-76.

133. M. Curie, 'Les théories modernes relatives à l'électricité et à la matière,' *RSc* 44 (1906): 609-16 and 651-54.

on molecular reality on the basis of Brownian motion was for atomism in France a document of victory which could easily dispense with a declaration of surrender from its opponents.¹³⁴ The victors – Brillouin, Mme Curie, Langevin, Perrin – were the uncontested representatives of French physics at the Solvay conference of 1911. As their opponents were dwindling in numbers, demand was soaring for Perrin's *Les atomes*, once it was published in 1913,¹³⁵ the year of Duhem's election to the Académie.

By then a good deal of Duhem's interest and energies had for almost ten years shifted from physics to its history. At the same time his physics too was increasingly turning into a historic relic which found fewer and fewer investigators. Not that it was not worth investigating and would not have deserved emphatic mention. The postscript which the Austrian physicist, Max Margules, added on February 18, 1896, to his long paper, already in press, on the composition of saturated vapors of mixtures should have set a pattern for the future: 'Only a short while ago I had the opportunity to peruse Duhem's treatise and I regret not having known it earlier. Many of the relations derived above are contained in that treatise [of Duhem] published in 1894.'¹³⁶ Years later the most important of those relations became known as the Duhem-Margules equation.

Unlike Margules, the French physicist and mathematician, G. Robin, kept silent on his indebtedness to Duhem in a course on thermodynamics given at the Sorbonne in 1896-7, the text of which was published only posthumously in 1901.¹³⁷ Always keen on recognizing the contributions of others, including the very few made by Robin,¹³⁸ Duhem could but feel chagrined on seeing many of his results and pivotal definitions reappear, with no reference to him, in Robin's course. Robin spoke disparagingly of the thermodynamic potential as 'a hardly significant epithet' grafted on what Helmholtz called 'free energy.'¹³⁹ Even more offensive was the remark of L. Raffy, who published the text of Robin's courses, that Robin 'presented the basic principles and general equations of thermodynamics under an absolutely new form.'¹⁴⁰ Duhem's reaction was quick and sharp: 'There is not a single topic in this book on general thermodynamics,' he wrote in a long review of Robin's book,

134. Its importance was amply proven by its immediate translation by F. Soddy into English in booklet form, *Brownian Movement and Molecular Reality* (London: Taylor and Francis, 1910), 93 pp.

135. Within a year the book was in its fifth edition.

136. M. Margules, 'Über die Zusammensetzung der gesättigten Dämpfe von Mischungen,' *Sitzb. d. mathem. naturw. Cl.* (Wien) Bd. 104, Abth. IIa (1895), pp. 1243-78.

137. G. Robin, *Thermodynamique générale*, vol. 2, pt. 2 in *Oeuvres scientifiques*, collected and edited by L. Raffy (Paris: Gauthier-Villars, 1901). Robin (1855-97), the son of Charles-Pierre Robin, a strongly anticlerical senator who as a biologist held various chairs in Paris and became in 1866 member of the Académie des Sciences, published only a few short papers, all around 1880 and long before his having been invited in 1895 to initiate the teaching of physical chemistry at the Sorbonne.

138. See, for instance, the section 'Loi de Robin' in *Thermodynamique et chimie*, 1902 (1), pp. 179-80.

139. Robin, *Thermodynamique générale*, p. 59.

140. *Ibid.*, p. vi.

'to which I had not devoted some publications, and several of those topics had previously been a virgin field.'¹⁴¹

Duhem, had the matter been brought to his attention, would have found reasons for cutting comments about the definition of reversible processes proposed in 1909 by C. Carathéodory, at that time professor at Göttingen and also a member of the Société scientifique de Bruxelles. Of course Carathéodory, who referred at the outset of his often quoted paper¹⁴² to Perrin's discourse in 1906 on the essential contents of the principles of thermodynamics, could not learn from it about Duhem. Carathéodory's apparent unfamiliarity with Perrin's *Traité de chimie physique*, where emphatic priority was given to Duhem's rigorous definition of reversible processes, though with no reference to any publication of Duhem, was more difficult to explain. Matters should seem even more perplexing in view of Carathéodory's quoting Bryan's *Thermodynamics* in which Duhem was amply recognized. At any rate, any avid reader, like Carathéodory, of the mathematical literature, could be expected to scan the volumes of such prominent serials as the *Bulletin des sciences mathématiques* or the *Journal des mathématiques pures et appliquées*. In a paper published in 1887 in the former on Gibbs' theorems Duhem emphasized that the reversible process between two thermodynamic states A and B of a system was an unrealizable limiting process, to which he gave the name quasi-static.¹⁴³ Five years later, Duhem pointed out in the second of his commentaries on thermodynamics that in the case of hysteresis the limiting set of equilibrium states was not identical in both directions between A and B.¹⁴⁴ This meant that an irreversible process, which was still quasi-static, was possible, a point which Carathéodory presented as a novel conclusion. Fifteen years later Carathéodory was still seen as a pioneer in that respect by Max Born.¹⁴⁵

Another telling oversight of Duhem's work was provided in a major memoir which G. Jaumann, member of the Vienna Academy of Sciences, presented on March 2, 1911. The seventh or concluding part of the memoir, which aimed at giving a systematization of differential equations used in physics and chemistry, dealt to a large extent with thermodynamics. Massieu, Gibbs, Helmholtz, thermodynamic potential, the case of partial pressures in mixtures, were all there, except

141. The review, 1901 (12), covered 30 pages in the November 1901 issue of *BScM*; for quotation see p. 176.

142. C. Carathéodory, 'Untersuchungen über die Grundlagen der Thermodynamik,' *Mathematische Annalen* 67 (1909):355-86.

143. 'Etudes sur les travaux thermodynamiques de M. J. Willard Gibbs,' 1887 (16), see especially pp. 132-34. Duhem's anticipation of Carathéodory was pointed out by D. G. Miller, 'Duhem,' *Dictionary of Scientific Biography*, 4:229.

144. According to Miller, *ibid.* A better reference would have been to Duhem's second memoir on permanent deformations and hysteresis, 1896 (5), p. 27.

145. M. Born, 'Kritische Betrachtungen zur traditionellen Darstellung der Thermodynamik,' *Physik. Zeitschr.* 22 (1921):218-24, 249-54, 282-86; see especially pp. 219 and 221. Some justice was given to Duhem's definition five years later by C. N. Hinshelwood in his *Thermodynamics for Students of Chemistry* (London: Methuen, 1926), p. 20.

the name of Duhem.¹⁴⁶ Duhem, of course, could be mentioned in such a way as to distract attention from the importance of his work. After a page full of equations on saturated vapors of mixtures there followed in 1897 in the second edition of W. Nernst's famed textbook on theoretical chemistry the following remark in small print: 'A series of further conclusions can be found in Duhem's monographs, *Trav. Mém. Lille*, 12 and 13; furthermore especially in the memoir of Margules who among other things calculated a number of important cases.'¹⁴⁷ Such reporting, unchanged in another ten editions, was at variance not only with Margules' postscript quoted above but also with the appreciation given to Duhem in the textbook on chemical thermodynamics by W. Voigt whom Nernst had for a senior colleague while at Göttingen.¹⁴⁸ Perhaps if Helmholtz had not expressed himself negatively on the concept of thermodynamic potential¹⁴⁹ as soon as it had been proposed by Duhem, Van't Hoff, Helmholtz's colleague in Berlin, to whom Duhem always referred with effusive admiration, might have been more appreciative.¹⁵⁰ While the absence of kinetic interpretation of thermodynamics was understandable, Boltzmann battled energetics by concentrating on Helm's freshly published book without

146. G. Jaumann, 'Geschlossenes System physikalischer und chemischer Differential-gesetze,' *Sitzb. d. mathem-naturw. Cl. (Wien)* Bd. 120. Abth. II a (1911), pp. 385-528; see especially pp. 511-14.

147. W. Nernst, *Theoretische Chemie vom Standpunkte der Avogadro'schen Regel und der Thermodynamik* (2d ed.; Stuttgart: Ferdinand Encke, 1898), p. 118. Duhem was not mentioned in Nernst's discussion of thermodynamic potential (*ibid.*, pp. 562-63) which was attributed by the latter to Planck and Riecke. See also the English translation by L. W. Codd from the tenth German edition (1921), *Theoretical Chemistry from the Standpoint of Avogadro's Rule and Thermodynamics* (London: Macmillan, 1923), pp. 124 and 767.

148. Voigt began his *Thermisch-Chemische Umsetzungen* (Part II of Vol. II of his *Thermodynamik*) (Leipzig: G. J. Göschensche Verlagsbuchhandlung, 1904) by pointing out that the general theory given by Gibbs was worked out in detail by Planck, Duhem, Riecke, and Nernst. Immediate reference was also given to Duhem's *Potentiel thermodynamique* and his monographs in the *Travaux et Mémoires de Lille*.

149. H. von Helmholtz, 'Ueber die physikalische Bedeutung des Princips der kleinsten Wirkung,' (1886), in *Wissenschaftliche Abhandlungen*, Bd. III (Leipzig: Barth, 1895), p. 205.

150. Absence of any reference to Duhem was all the more baffling in the three volumes of J. H. Van't Hoff's *Vorlesungen über theoretische und physikalische Chemie* (Braunschweig: F. Vieweg und Sohn, 1898-1900), of which the first and second dealt with chemical dynamics and statics respectively, as Pélabon's experiments were discussed there in detail (1:207-08). The book was immediately translated into French by A. Corvisy under the title, *Leçons de chimie physique* (Paris: Hermann, 1898-1900). Earlier, in dismissing the maximum work principle in his *Studies in Chemical Dynamics* (revised and enlarged by E. Cohen, translated by T. Ewan [Amsterdam: Frederik Müller; London: Williams & Norgate, 1896]) Van't Hoff ignored Duhem (pp. 224-26). In his lecture series on physical chemistry, given in June 1901 at the University of Chicago, Van't Hoff mentioned Duhem only as one of those who go so far as to see in physical chemistry a branch of science on the same rank with physics and chemistry (see J. H. Van't Hoff, *Acht Vorträge über physikalische Chemie* [Braunschweig: Friedrich Vieweg und Sohn, 1902], p. 3). Van't Hoff based this somewhat exaggerated judgment on Duhem's 'Une science nouvelle: La chimie physique' 1899 (13).

mentioning Duhem, Helm's hero.¹⁵¹ The hero vanished by 1904 in Helm's survey of theories of electrodynamics, a fact all the more telling because the survey contained a chapter on the 'image-free description of the electrotonic state.'¹⁵²

A narrowing advance

The foregoing oversights of Duhem's work should not however be construed as a general lack of appreciation on the part of German scientists. In physical chemistry Duhem's work was closely followed not only by Ostwald in Leipzig but also by Gustav Tamman who held the chair of chemistry in Göttingen since 1892. Yet, that interest considerably diminished by the time there appeared in 1910 the enlarged and revised form of Duhem's *Thermodynamique et chimie*. In reviewing it Ostwald began with the remark that the first edition published eight years earlier 'did not exercise [even] in French-speaking lands the same influence as the corresponding English or German textbooks did, although this would have been justified by the book's methodical exactness of presentation and clarity of analysis.' The reason for this lay, according to Ostwald, 'in the outspoken one-sidedness of the famous author in selecting what is necessary in an introductory work.' The register of names told the story. Many names occur very often in Duhem's work, Ostwald remarked, 'which mean little or nothing to us, whereas many names we hold important are not found there.'¹⁵³ In particular, Ostwald deplored the complete exclusion by Duhem of electrochemical phenomena. This, of course, was no accident as precisely those phenomena, growing in number at an accelerated rate, suggested forcefully the atomicity of matter which Duhem wanted to keep out of sight.

Ostwald could have named other areas as well. The frontiers of physics were expanding with increasing rapidity which imposed an almost inevitable narrowing of the horizon of any physicist even when, unlike Duhem, he did not methodically restrict his chief interest to a specific field. The field was in Duhem's case the mechanics of continua, the field where he did not allow himself to fall behind. As a result, his great monographs on hydrodynamics, viscosity, and energetics were prominently listed at the head of several monographs contributed to the volumes on mechanics in the *Encyklopädie der mathematischen Wissenschaften* sponsored by the Academies of Sciences in Göttingen, Leipzig, Munich, and Vienna.¹⁵⁴ The incisiveness of Duhem's potential function was emphatically noted by Th. von Karman, then at the University of Aachen, in his monograph on the physical bases of theories on stability.¹⁵⁵ The same was true in the monograph on the general

151. Boltzmann did so in a speech to the 70th meeting of German scientists and physicians in Düsseldorf, 1898; see *Wissenschaftliche Abhandlungen, Band III, 1882-1905*, ed. F. Hasenöhr (Leipzig: Barth, 1909), p. 638.

152. G. Helm, *Die Theorien der Elektrodynamik nach ihrer geschichtlichen Entwicklung* (Leipzig: Veit, 1904), pp. 152-55.

153. *ZPhCh* 77 (1911):121-22.

154. See *Mechanik*, Band IV, Teilband 4 (Leipzig: B. G. Teubner, 1907-14), pp. 2 and 216.

155. *Ibid.*, p. 743.

theses of the mechanics of continua written by E. Hellinger of the University of Marburg.¹⁵⁶ Prof. P. Stäckel of Hanover gave a brief discussion of Duhem's work on the stability of floating bodies,¹⁵⁷ whereas Prof. G. Zemplen of Budapest went into considerable detail in reporting the main results of Duhem's studies on the propagation of disturbances in viscous fluids.¹⁵⁸

The *Encyklopädie's* volumes on mechanics, written and published prior to 1914, certainly attested the appreciation of Duhem the physicist by his peers. Most parts of the volumes on physics, which dealt with other non-atomistic and non-relativistic topics, saw print also during Duhem's life, but there Duhem did not fare nearly as well. H. Lorentz referred in his monograph on electromagnetics only to Duhem's polemical work against Maxwell but not to his three-volume treatise.¹⁵⁹ Prof. W. Wien of Würzburg ignored Duhem as he discussed Helmholtz's electromagnetic theory. In the monograph on thermodynamics Prof. G. H. Bryan of Wales gave, however, a conspicuous place to Duhem's thermodynamic potential and his theory of false equilibria.¹⁶⁰

Bryan, who had shown an early interest in Duhem by visiting him in Bordeaux in 1900, found no emulators in England. Love's neglect of Duhem's hydrodynamics was paralleled also in thermodynamics. Thus, while Duhem's *Traité de mécanique chimique* and *Potentiel thermodynamique* were listed in the bibliography, which Sir Joseph Larmor added to his article 'Energetics' in the 11th edition of the *Encyclopedia Britannica*, Duhem was not mentioned in the article itself.¹⁶¹ The same was true in the article 'Thermochemistry' written by Prof. J. Walker of Edinburgh for the same *Encyclopedia*, although the rise and fall of the principle of maximum work was emphatically noted there.¹⁶² It was from the younger that came that appreciation of Duhem which made his name a textbook feature. J. R. Partington was just appointed lecturer at the University of Manchester when he published, in 1913, his introduction to thermodynamics in which there appeared for the first time 'the Duhem-Margules equation.'¹⁶³ No immediate notice of this was taken on the transatlantic side of the Anglo-Saxon world. Prof. Jones, who once described Duhem's textbook on physical chemistry as the shape of the future, brought out there in 1915 a considerably enlarged form of his *Elements of Physical Chemistry* in which Duhem was still non-existent.¹⁶⁴ Nor did Jones notice the

156. *Ibid.*, p. 665.

157. *Mechanik*, Band IV, Teilband 3 (Leipzig: B. G. Teubner, 1901-08), p. 659.

158. *Ibid.*, p. 294 and 320-23. Surprisingly, Prof. A. E. O. Love made no mention whatever of Duhem in his monograph on hydrodynamics.

159. *Physik*, Band V, Teilband 2 (Leipzig: B. G. Teubner, 1909-26), pp. 63 and 133-34.

160. G. H. Bryan, *Thermodynamics: An Introductory Treatise Dealing Mainly with First Principles and Their Direct Applications* (Leipzig: B. G. Teubner, 1907), pp. 95 and 193-94.

161. *The Encyclopaedia Britannica*. Eleventh Edition. Volume XXVI (New York: The Encyclopaedia Britannica Company, 1911), pp. 390-98.

162. *Ibid.*, pp. 804-08.

163. J. R. Partington, *A Text-Book of Thermodynamics (with Special Reference to Chemistry)* (New York: D. Van Nostrand, 1913), pp. 395-98.

164. See note 89 above.

emphatic reference which a young American physicist, H. A. Perkins, had made in his textbook two years earlier to Duhem's notion of thermodynamic potential.¹⁶⁵

In Duhem's own country the publication between 1912 and 1916, with the collaboration of a large number of French physicists, of the French version of the *Encyclopédie der mathematischen Wissenschaften* provided an opportunity for a vindication of the value of Duhem's hydrodynamics. To Prof. Love's monograph there was added an account of Duhem's contribution which began with the statement: 'It is impossible to end this study without giving a very special place to Duhem's works on the general hydrodynamics of viscous and non-viscous media or fluids. This author, after having given to rational mechanics a new and much more general form than was customary until then, went on to revising the principles of hydrodynamics which led him to the formulation of new and most important theories.' The essence of Duhem's contributions was seen in the fact that the general equations of classical hydrodynamics 'enter into Duhem's equations only as particular cases.'¹⁶⁶

To make the existing theories more general was indeed Duhem's chief ambition. It must have been gratifying to him to see Hadamard emphatically recognize his derivation of the basic laws of hydrodynamics from the thermodynamic potential.¹⁶⁷ The latter was given 'official' acceptance by the Sorbonne through the thesis, which L. Roy, a student of Boussinesq, defended there in 1910. The thesis, which dealt with the thermomechanical properties of solids, gave, in terms of the thermodynamic potential, an analysis of a slightly deformed plaque and a shaft.¹⁶⁸ Clearly, even though French physicists hardly discussed Duhem's ideas in detail, they were widely known, as shown also by the emphasis which the Cosserat brothers gave in 1909 to Duhem's definitions of reversible transformation and isolated systems in the preface to their book on the theory of deformable bodies.¹⁶⁹ Interest in Duhem was also attested by the demand for a second enlarged edition of his textbook on physical chemistry, published in 1910. It was in fact that enlarged

165. H. A. Perkins, *An Introduction to General Thermodynamics* (New York: John Wiley, 1912), p. 61.

166. *Encyclopédie des sciences mathématiques pures et appliquées . . . Edition française*, ed. J. Molk and P. Appell; Tome IV, Volume 5, *Systèmes déformables*, ed. H. Beghin and H. Villat (Paris: Gauthier-Villars, 1914), pp. 206-08; see also pp. 81 and 146. In Volume 1, *Généralités historiques* (Paris, 1915), of Tome IV Duhem's contributions with his energetics to the foundations of mechanics were repeatedly noted by E. and F. Cosserat in their French version of Voss' monograph of the principles of theoretical mechanics (see pp. 3, 175, 179-80).

167. Hadamard did so in his *Leçons sur la propagation des ondes et les équations de l'hydrodynamique* (Paris: A. Hermann, 1903), pp. 132-33. By then Duhem's had been conspicuously ignored by H. Poincaré in his *Cinématique et mécanisme potentiel et mécanique des fluides*, rédigé par A. Guillet (Paris: Georges Carré et C. Naud, 1899) and even by Duhem's friend, P. Painlevé, *Leçons sur le frottement* (Paris: Hermann, 1895). Painlevé, a newly appointed maître de conférences at the Sorbonne, very likely did not wish to endanger his career.

168. L. Roy, *Recherches sur les propriétés thermodynamiques des corps solides* (Paris: Gauthier-Villars, 1910).

169. E. Cosserat and F. Cosserat, *Théorie des corps déformables* (Paris: A. Hermann, 1909), pp. 4-5.

edition which prompted a lengthy critique of Duhem's notion of false equilibria by E. Ariès, a French army engineer, whose two monographs on thermodynamics were crowned by the Académie des Sciences with the Prix Hugues in 1904.¹⁷⁰ Perhaps to make all of Duhem's friends aware of his thorough disagreement with that notion, a favorite point in Duhem's thermodynamics, Ariès published his criticism in the *Annales* of the Société scientifique de Bruxelles, of which he had been a member since 1906. Ariès was all too aware of Duhem's thorough familiarity with a vast field: 'If the learned Professor of Bordeaux has written much, he also has read much and one remains astonished by the power of assimilation which enabled him to add to his theories examples drawn from the researches of the great chemists of all lands We must therefore have a conviction no less profound of the meager solidity of that theory [of false equilibria] in order to combat it, in the hope that out of the discussion there may arise some light on a doctrine which appears to us to have been accepted too readily.'¹⁷¹ The almost 60-page-long article, much of it devoted to the dissecting of Pélabon's experiments, ended with the devastating statement:

In spite of the reasons which should have opposed the spreading of that doctrine, it was destined to infiltrate and dominate minds not well versed in thermodynamics. It is to those that we wanted to address ourselves, and would be all too happy if by this discussion we could have liberated them of a belief which we consider a true scientific heresy.¹⁷²

Three years later, two months after Duhem's death, Ariès was elected corresponding member of the Académie des Sciences in that very same section of mechanics which received Duhem as its correspondent sixteen years earlier.

Ariès' criticism of Duhem, which appeared a few months before Duhem's election to the Académie, made little difference in professional estimates of him in France. To his opponents he had long ceased to be someone to reckon with. Most of his admirers were more interested in repairing the harm done to his career by officialdom than in discussing his theorems and conclusions. How his opponents could keep ignoring him was best illustrated by the glaring omission of Duhem's name in the introduction to volume VI in *Les classiques de la science* (a series coedited by H. Le Chatelier), containing eight memoirs on dissociation, as if Duhem had not been the most sedulous and authoritative interpreter of papers written on that topic by Sainte-Claire Deville and his followers.¹⁷³ Duhem was practically

170. They were *Chaleur & énergie* (Paris: Gauthier-Villars, 1896), 167 pp, and *La statique chimique basée sur les deux principes fondamentaux de la thermodynamique* (Paris: A. Hermann, 1901), 251 pp.

171. E. Ariès, 'Les faux équilibres chimiques et la thermodynamique classique,' *Annales de la Société scientifique de Bruxelles* 37 (1912-13):229-84; for quotation see pp. 229-30.

172. *Ibid.*, p. 284. There was no reference to Duhem in Ariès' *Thermodynamique: Propriétés générales des fluides* (Paris: Hermann, 1920).

173. *Fusion du platine et dissociation* (Paris: Armand Colin, 1914). The memoirs were by Sainte-Claire Deville, Debray, Troost, Hautefeuille, Isambert, Ditte, Joannis, and Joly, whose names were constantly occurring in Duhem's writings on physical chemistry. It was also Duhem who had Sainte-Claire Deville's memoir reprinted in 1899 with a long introduction.

ignored in the articles 'Physique' and 'Chimie' in a government-sponsored survey of French intellectual achievements for the San Francisco Universal Exhibition in 1915.¹⁷⁴ Duhem's reputation was, however, great enough by then to prevent an invariable recurrence of this pattern. In the article, 'La physique,' which L. Poincaré contributed in 1916 to a vindication of French culture against German claims, Duhem was recalled as one who 'through a long series of studies, remarkable for their science as well as philosophical depth, showed how one can construct physics with no reference to hypotheses about the constitution of matter,' and as one through whom French science 'has been given counsels of wisdom and prudence to all.'¹⁷⁵ A modest though distinct recognition of Duhem the physicist appeared also in the massive illustrated volume which Larousse published in 1916 on contemporary French history.¹⁷⁶

For a physicist, reputation, however widespread, is far less important than the amount of actual work done by his peers on his ideas. Not counting Duhem's doctoral students, who, with the exception of Pélabon, soon turned to topics never touched by Duhem,¹⁷⁷ the number of physicists and chemists, who paid sustained attention to Duhem's work in order to find there themes worthy of further development, was very small indeed. One of the few was E. Jouguet (1871–1943), professor of mechanics at the Ecole des Mines and of mathematics at the Polytechnique, whose interest and expertise were rather similar to those of Duhem.¹⁷⁸ Duhem did not live long enough to see the longer instalments of studies on his electrodynamic theories by L. Roy¹⁷⁹ who, at the age of 37, became professor of physics at the University of Toulouse. As to Henri Bouasse, a legendary teacher of

174. *La science française* (Paris: Larousse, 1915). In the article 'La Chimie' written by A. Job not one work of Duhem was among the dozen listed since 1900. Job glossed over the opposition between Sainte-Claire Deville and Berthelot, and singled out Le Chatelier as the chief interpreter of Gibbs in France (1:158-59). E. Bouty, author of the article 'La physique,' mentioned Duhem only in a list of twelve names (*ibid.*, p. 146) and found not one work of Duhem worth quoting in a long bibliography. In the article 'Les sciences chimiques' by G. Lemoine, Duhem was only one of six to be mentioned in connection with the principle of maximum work (*ibid.*, p. 214).

175. *Un demi-siècle de civilisation française (1870-1915)* by MM. Baillaud, Boutroux *et al* (Paris: Hachette, 1916), p. 346.

176. *Histoire de France contemporaine de 1871 à 1913* (Paris: Larousse, 1916), pp. 401 and 405, where in a note of eight lines a summary of Duhem's work in physics is given with emphasis on his formulation of the thermodynamic potential. Two pages later, however, Duhem was not mentioned in connection with Berthelot's maximum work principle.

177. Marchis turned toward engineering physics, Turpain to practical questions of telegraphy, Manville to ionization and other topics related to modern physics, while Saurel specialized in mathematics.

178. Jouguet did considerable work on shock waves along the lines followed by Duhem, and also published a two-volume monograph on mechanics in which the method of historical presentation was followed with ample quotations of original texts; for further details see Ch. 10.

179. Roy was a student of Boussinesq whose rigorous and analytical thinking is reflected in the three volumes of Roy's *Cours de mécanique rationnelle* (see note 210 below). Prior to taking the chair in Toulouse in 1919, Roy taught at the Ecole Supérieure de l'Electricité. He began to publish on the Helmholtz-Duhem electrodynamics shortly before Duhem died. His most important publication on that subject is listed in note 202 below.

physics at the same university from 1896 until 1935, he kept Duhem in focus with glowing references to him in the invariably peppery prefaces to his textbooks which dominated physics instruction in France for decades. In the introduction to his textbook on thermodynamics Bouasse wrote: 'To fulfill certain duties of gratitude is a joy. This book would not exist without the works of Duhem with which it is wholly permeated. One honors oneself by declaring himself a disciple of such a master.'¹⁸⁰ Bouasse was also Duhem's disciple in outspokenness: In the introduction to his textbook on electricity and magnetism Bouasse decried mechanistic theories with a reference to the 'admirable *Théorie physique* in which the matter was settled and which I recommend to philosophers for meditation No less than Duhem I detest nonsense; experience shows that nothing is more akin to nonsense than the use of mechanistic models.'¹⁸¹ Duhem amply reciprocated by greeting with a long essay-review the publication in 1910 of a book by Bouasse as a work of revolutionary significance with respect to teaching physics in French universities.¹⁸² The simultaneous treatment by Bouasse of the analytical and experimental aspects of mechanics broke with a century-long French tradition symbolized by the fact that the chair of mechanics was part of the department of mathematics. Courses in mechanics became therefore for the most part courses in pure mathematics, whereas courses in other branches of physics turned into recitations of experiments and measurements severed from that physical theory which cannot exist without mathematical formalism. Such a compartmentalization of physics seemed to Duhem a rank anachronism at a time when not only the various branches of physics were drawing ever closer to one another but so were all major branches of all the natural sciences as well:

Once distinct, mechanics and physics are being fused into one another; through the discovery of chemical mechanics they both are welded to chemistry; through syntheses organic and mineral chemistry are united in a single science. Geometrical through its study of symmetries, physical through all it borrows from the theories of electricity and magnetism, and especially from optics, chemical when it wants to figure out and repro-

180. H. Bouasse, *Cours de thermodynamique. Tome deuxième du Cours de physique* Paris: C. Delagrave, 1910), p. xxiii. Bouasse completed in 1931, five years before his retirement at the age of 70, a colossal and meticulous survey of physics, consisting of 45 volumes, each at least 600 pages, under the general title: 'Bibliothèque scientifique de l'ingénieur et du physicien.' Bouasse, whose first year at the Ecole Normale coincided with Duhem's last year there (1886-87), resembled Duhem not only in his prodigious productivity, pedagogical finesse, fondness for excursions, but also in his outspokenness in matters of scientific method and instruction. Some of his books carried prefaces with titles, 'Science et professorat' – 'Conseils aux savants qui veulent être lus' – 'Des principes, de leur emploi, et de la nature de leur certitude,' which spoke for themselves. Yet, beneath this outward combativeness there lay, as in Duhem's case, a withdrawing personality whose kindness could easily be taken for timidity.

181. H. Bouasse, *Cours de magnétisme et d'électricité. Tome troisième du Cours de physique* (Paris: C. Delagrave, 190), pp. xvi-xvii.

182. H. Bouasse, *Cours de mécanique rationnelle et expérimentale, spécialement écrit pour les physiciens et les ingénieurs, conforme au programme du certificat de mécanique rationnelle* (Paris: C. Delagrave, 1910). This book of 692 large octavo pages was reviewed by Duhem; see 1910 (8).

duce the conditions under which the minerals and rocks were formed, mineralogy is now at the basis even of geology. Owing to paleontology, who can say where geology ends and botany and zoology begin? Between these two last sciences who could put a line of separation since Claude Bernard taught us to see the phenomena of life as common to animals and plants? And if physiology thus finds itself special to these two fields, is not there then, through the mediation of biological chemistry, a continuity between physiology and organic chemistry? Our ancestors could think that science was an archipelago where the islands would forever remain separated by stretches of sea that cannot be crossed. We see there now a continent of perfect continuity.¹⁸³

Behind the uniting by Bouasse of experimental and theoretical mechanics there lay much more than a grandiose view of the unity of all sciences. That unity, if it was to be truly such, required a revolution in the concept of mechanics itself in terms of energetics, on behalf of which Duhem had by then been crusading for two decades. In fact he opened his review of Bouasse's book with an animated recount of the failures of a mechanics conceived in a Cartesian spirit. The rise of thermodynamics not only made those failures glaring, but also suggested a wider concept of motion, the basis of energetics. Not that Duhem saw any promise in a frontal attack on the citadel of Cartesian mechanics whose defenders stubbornly maintained the possibility of an eventual reduction of all physical phenomena to local motion: 'The place is so well guarded that it has defied until now the most violent assaults. Are we sure that it is not truly impregnable?' Duhem suggested therefore another strategy: 'Let us not tarry by holding that place under siege. The countryside is wide open. Let us direct our army of occupation to invade it at forced march!'¹⁸⁴

To call to arms, in 1910, well founded as it was by Duhem's display of great intellectual force in his *Energétique* to be published soon, could easily make the impression of an ineffective trumpet. A realm of physics was opening up increasingly wide; the invasion into that realm by Duhem's energetics could appear but a very narrow affair indeed. Not that the breadth and width of a basic strategy was to be measured by the immediate implementation of it by its author. This point was intimated in the review in the *Journal de chimie physique* of the first volume of *Energétique* as the accomplishment of a task of 'absolute necessity.'¹⁸⁵ The reason for this was, in the words of the anonymous reviewer, the increasing application of the fundamental principles of thermodynamics not only in mechanics and chemistry but also in the biological and social sciences. 'It is in fact more necessary today than ever to take an exact account of the conventions on which those fundamental principles rest and the restrictions which they imply.' Yet for all that praise, the short review made it clear that the import of the book was restricted: 'It will be highly appreciated by those who are interested in the problems of scientific philosophy and by all those who are led by their researches to the application of the methods and principles of energetics.' By 1911 the number of these physicists was

183. *Ibid.*, p. 176.

184. *Ibid.*, p. 146.

185. *JChPh* 9 (1911):777. The anonymous review may have been written by the editor; see note 116 above.

very small, unlike the number of those for whom the introductory or fairly philosophical first chapter of the book would have had an appeal. Apart from that chapter the two volumes of *Energétique* were physics – rigorous, abstract, painstaking – but a physics rarely concerned with current problems. Such a physics needed some defense, which in fact was the tone of the opening of a review by E. Jouguet, possibly among Duhem's contemporaries the most familiar with his work as a physicist. The defense was necessitated by the fact that, as Jouguet put it, 'the study of electricity and radiations led modern physicists to propose profound modifications of the traditional concepts which form the basis of our science of the motion of bodies.' Yet radically different as could be those modifications and the new physics they gave rise to, the latter in its first approximations 'must remain identical to classical mechanics in order to remain viable.' Therefore the physics which studies the motion of bodies in their normal, that is, macroscopic conditions, retains an enduring validity. When motion in turn is understood also in a sense that satisfies thermodynamics, 'a body of doctrine will be constituted which includes the motion of solid bodies, elastic bodies, and liquids, also the transformations which one has become wont to call chemical mechanics.'¹⁸⁶

Such was an accurate listing of the main topics of the *Energétique*. The absence in it of electrodynamics may have been dictated by consideration of space. Duhem soon began to put together long memoirs on electrodynamics of which the last started with the same strictures of the illogical character of Maxwell's theory as the ones bringing to a close his *Notice*. But by the time he had read the proofs he found essential faults in the consideration on the basis of which he kept postulating the existence of longitudinal waves inadmissible in Maxwell's theory. Many though not all aspects of his work in electromagnetics appeared now as having no relevance for physics.¹⁸⁷ At any rate, his interest in electromagnetics always related strictly to what might be termed its part whose cultivation did not require any consideration of electrons. While that part was modernity itself when constructed by Maxwell and refined by Helmholtz between 1860 and 1885, it became within a short generation a part that could be called 'classical,' that is, a thing of the past,

186. *RGS&PA* 24 (1913):276. A much longer review of the *Energétique* was the one by the mathematician, H. Vergne, in *BScM* 37 (1913):10-32. Even more than Vergne, Bouasse restricted himself to the philosophical foundations of the *Energétique* in his review of it in *Cosmos* (29 avril 1912, pp. 465-8). Such neglect of the physics of *Energétique* undoubtedly chagrined Duhem.

187. See 'Remarque finale' added in press to 1916 (11), pp. 299-300. The basis was a total electric field which did not derive from an electrostatic and an electrodynamic field as separate entities. Only such a total field implied the existence of longitudinal waves. When he started that memoir Duhem still saw in Blondlot's experiments an indication of the existence of such waves and planned on the subject a long memoir which was never written. The seven short communications, 1916 (4-10), which he sent to the Académie des Sciences between February and May, give a glimpse of the direction in which he sought a way out of the impasse expressed in the concluding phrase of that 'Remarque finale': 'Thus the theory of electrical resonance given in this memoir is deprived of any bearing on physics. It is but an exercise in mathematics, though it seems to deserve the name exercise in that it prepares the more complex theory of effects truly observed by the physicist.'

however indispensable. A parallel development took place in respect to energetics. If the actuality of a subject is measured by the intensity of debates about it, energetics too became for most physicists a thing of the past by the turn of the century.¹⁸⁸ The predicament of Duhem, the physicist, could resemble the shunting into a stockyard of a huge locomotive with a long train of wagons meticulously built and assembled over years

whilst somewhere further up the line a small train edged out of a siding onto the main line, and grew gradually in size and power as it accelerated down the track of history, taking on board all those passengers, waiting and arriving at the stations ahead, whom Duhem's mighty express had expected to carry to their destinations.¹⁸⁹

As all graphic similes, this too makes its very valid point – the quick turning of Duhem's physics into a historical display – with that emphasis which unwittingly does injustice to no less valid points. While the main line was vastly extended by innovative engineers, its solvency was assured by the vast crowd of ordinary passengers. More importantly, a main line, if it was truly such, had to be continuity between past and future. True solutions, Duhem kept stressing, were never lost as science moved on. Not a few solutions he had worked out came, as time went on, into ever wider use. Again, not all physicists, who did valuable work after the age of atom arrived, were 'atomic' physicists. The realm of continua experienced by common sense kept posing to macroscopic physics endless questions which not only called for an approach represented by Duhem but to some of which, as will be seen, he anticipated an answer.

The physicist and posterity

Scarcely a decade had elapsed after Duhem's death when his physics began to be spoken of as a mere historic monument. Ironically, this was first done in that survey of the history of physics in France which he declined to write for the multi-volume *Histoire de la nation française*, directed by Gabriel Hanotaux. Charles Fabry, professor of physics at the Sorbonne and author of that survey, presented Duhem as the leader of a cause, antiatomism, which had been lost once and for all. If he was to be remembered, it was only because he represented that cause most systematically and with the greatest philosophical depth.¹⁹⁰ This was the kind of characterization which, on account of its generality bordering on vagueness, could only make a monument look more curious than instructive as time went on. It certainly kept under cover the fact that Duhem's 'antiatomism' was a vast positive

188. This was well illustrated by the gap of ten years between the last entry in the literature on debates about energetics in the survey of A. Voss of the principles of theoretical mechanics and the appearance of Duhem's *Energétique*, which E. Cosserat and F. Cosserat added to their French version of Voss' survey; see *Encyclopédie des sciences mathématiques pures et appliquées* Tome IV, volume 1, fascicule 1 (Paris: Gauthier-Villars, 1915), pp. 3 and 179-80.

189. As put by the translator, M. Cole, of Duhem's *The Evolution of Mechanics*, 1980 (1), p. xxxviii.

190. C. Fabry, 'Histoire de la physique,' in *Histoire de la nation française* Vol. XIV, *Histoire des sciences en France* (Paris: Plon-Nourrit, 1924), p. 392.

work dealing with a broad range of problems relating to physical continua. Lasting value could appear to be denied to any aspect of that work by a generic reference to it. Such was the impression to be gained in the passing mention of Duhem's work on elasticity and viscosity, his only achievement which was found worth recalling in the long essay by H. Andoyer and P. Humbert on the history of astronomy and mechanics for the same *Histoire*.¹⁹¹ Duhem became even more a vague and small monument in the history of chemistry written by A. Colson, professor at the Polytechnique. He saw Duhem as one who attached 'in a general form' to Moutier's and Robin's findings 'the famed theory of equilibrium which Gibbs conjured up and which carries the names of Le Chatelier and Van't Hoff.'¹⁹² In the section on thermochemistry Colson did not even let Duhem appear on the scene as a mere adjunct to a monument.¹⁹³ The pages were all Berthelot as if he had not given to all his work a wholly erroneous interpretation meekly accepted by the establishment. The fact that in that history Duhem accomplished the undoing of a monument with no foundation could not be mentioned without some risk even in an enterprise directed by Hanotaux, though few pieces of that monument were by then still visible.

Historiography quickly creates its easy clichés to be sedulously repeated with a verbal skill which covers up the lack of original research, a fact well illustrated a decade later à propos Duhem in the two large volumes on science which Larousse published with customarily lavish illustrations. Duhem was recalled there as a student of viscosity, and later as one of four Frenchmen who, together with savants from other nations, were the chief artisans of thermodynamics.¹⁹⁴ The sole reference to him in the second volume dealing with 20th century science not only turned him into mere history but was outright misleading. In the section on atomism, written by Marcel Boll, it was claimed that "scientists who were most hostile to molecular theory, such as Pierre Duhem and Wilhelm Ostwald, had to lay down their arms."¹⁹⁵ Duhem, as will be seen, never surrendered nor did he have to. Boll could do much worse. In 1936 he ignored Duhem while he cited everybody from Sainte-Claire Deville to Nernst and beyond in an article on thermodynamics and chemistry written for a wide audience. He even spoke of a Gibbs-Helmholtz equation.¹⁹⁶ Such was a deliberate slighting of Duhem, though perfectly understandable on the part of an ardent spokesman of the scientism of the Front Populaire. Actually, French science was slighted. Abroad, as will be seen, the

191. H. Andoyer et P. Humbert, 'Histoire des mathématiques, de la mécanique et de l'astronomie,' *ibid.*, p. 156.

192. A. Colson, 'Histoire de la chimie,' *ibid.*, p. 555.

193. *Ibid.*, pp. 558-61.

194. *La science, ses progrès, ses applications*, ouvrage publié sous la direction de MM G. Urbain et M. Boll, *Tome Premier. La science jusqu'à la fin du XIX^e siècle* (Paris: Larousse, 1933), pp. 138 and 222.

195. *Tome Second. Les applications et les théories actuelles*, p. 368.

196. M. Boll, 'Thermodynamique et chimie,' in *Les nouvelles littéraires, artistiques et scientifiques* (Paris), 2 février, 1936, p. 7.

expression 'Gibbs-Duhem equation' had for over a decade been spoken of with increasing frequency.

Ideological animosities were instrumental in the pulping, about that time, of all remaining copies of the *Energétique*.¹⁹⁷ Duhem as a physicist ceased to exist to the editors and contributors of two volumes, the second and twelfth, which dealt respectively with physics and chemistry among the 21 volumes composing the *Encyclopédie française* published between 1935 and 1966.¹⁹⁸ It was indeed curious that the vast spaces of the publication could not accommodate a brief statement, such as 'in the domain of mathematical physics all these questions occasioned Duhem's profound studies,' for which a place was available in a small volume on the development of French science since the 17th century which saw print twice during the same period.¹⁹⁹ Since reference to those profound studies was in a context dealing with thermodynamics and chemistry in France in the second half of the 19th century, one wonders why Duhem's name was omitted in a section on 'thermochemistry and energetics' in a vast historical survey of 19th-century-science written by French contributors, including several French scientists.²⁰⁰

The latter could hardly be unaware of Duhem as his research found distinguished continuators. E. Jouguet, who became a member in the section of mechanics of the Académie des Sciences in 1930, made time and again unabashed acknowledgments of his indebtedness to Duhem's researches.²⁰¹ L. Roy, who became in 1927 a corresponding member in the same section, championed in the early 1920s the Helmholtz-Duhem electromagnetic theory in several memoirs. He did so in full awareness of the fact that around 1923 he might be considered to be 'thirty years behind the times.' His answer to this likely objection was quite Duhemian: 'One is never behind as long as one seeks to bring a little logic and clarity to questions where these qualities are missing.' And he maintained, in concluding, that since the Helmholtz-Duhem theory 'has the advantage to proceed along an impeccable logic,

197. Dr. D. G. Miller, my source of information on this point, referred to his conversations with Hélène Duhem. She put the blame on the strongly leftist sentiments of J. Hermann, who kept nothing of his father's admiration for Duhem as a man and as a savant.

198. The omission of Duhem's name was particularly glaring in the chapter, 'Energétique chimique,' which G. Allard contributed to *Tome II. Physique* (Paris: Société Nouvelle de l'Encyclopédie Française, 1955, pp. 4-7 of section 56 of that volume), where the Gibbs-Helmholtz equation (without being called such) was discussed. In *Tome XII. Chimie* (1958) Duhem was recalled only as the one who accurately described the nature of atomistic and non-atomistic hypotheses; see p. 4 of section 04.

199. M. Caullery, *La science française depuis le xvii^e siècle* (Paris: A. Colin, 1933), p. 131; also in the 2d rev. edition, 1948.

200. R. Taton (ed.), *History of Science. Vol. III. Science in the Nineteenth Century*, A. J. Pomerans (New York: Basic Books, 1965), p. 298.

201. 'It could be foreseen a priori,' Jouguet remarked à propos the analogy which his equations of shock waves in solid bodies showed with Duhem's equations of shock waves in viscous fluids (see *CR* 171 (1920):464). Jouguet ended his study of the variation of entropy in shock waves in solids with a reference to the Hadamard-Duhem ellipsoid of polarization (*CR* 171 [1920]:791). Three years earlier, in his *Mécanique des explosifs: études de dynamique chimique* (Paris: O. Doin et Fils, 1917), Jouguet credited Duhem with 'having laid the theory of explosives on especially solid foundations' (p. xviii).

without breaking the tradition and being applicable both to permanent magnetics and perfectly soft magnets, it constitutes the only true demonstration given so far of Maxwell's equations.²⁰²

These statements were noteworthy on two counts. First, they were from a memoir which, as one in a series of monographs on the latest scientific issues, saw a wide distribution. Second, in the same monograph there appeared for the first time an account of the errors made by Duhem on that topic and of the reason why the Helmholtz-Duhem theory should nevertheless be considered as the 'only true demonstration of Maxwell's equations.' According to Roy the errors made by Duhem were the same kind of inconsistency for which he kept denouncing Maxwell. In both cases the inconsistency was the result of constructing a theory over a long period. Thus Duhem, who in 1896 declared unacceptable any electromagnetic theory which would not admit two fundamental constants, one for currents of conduction, another for currents of displacement, fell back later on the identity of them. Nor were the champions of Maxwell's theory, which lead inconsistently to equations in full agreement with experiments, as inconsistent as Duhem kept claiming. Apart from Blondlot's doubtful experiments there were no data suggesting that the additional constant, which most conspicuously made Helmholtz's theory different from that of Maxwell, should be different from zero. If however the value of that constant was zero, then the Helmholtz-Duhem theory was in its conclusions equivalent to Maxwell's equations, if not to Maxwell's theory. The sole advantage of the former theory over the latter was its rigorously logical character which however could be offset, to quote Roy, 'by its complicated appearance.'²⁰³

Not of course to those concerned with rigor and consistency. A. Liénard, future director of the Ecole des Mines in Paris and a colleague of Jouguet there, added, in 1923, in his great memoir on electromagnetic theory, to his criticisms of Duhem's work the statement: 'Having made these remarks, I am bound to recognize that the careful study of [Duhem's] *Leçons sur l'électricité* suggested to me the idea of the present memoir as well as the method employed in it.'²⁰⁴ Liénard's memoir was found to be the best statement of classical electromagnetic theory by the Irish physicist A. O'Rahilly, author of a still unsurpassed monograph on its development.²⁰⁵ His chapter on the Helmholtz-Duhem theory is illuminating both for his defense of its logical purity and also for his account of the thorough dissatisfaction which a Lorentz and a Jeans expressed à propos Maxwell's theory. In the country

202. L. Roy, *L'électrodynamique des milieux isotropes en repos d'après Helmholtz et Duhem* (Paris: Gauthier-Villars, 1923), pp. 5 and 87. The book was Nr. 40 in the series *Scientia*.

203. *Ibid.*, p. 10. Other studies of Duhem's electromagnetics by Roy are listed in his 'Sur l'électrodynamique des milieux en mouvement,' *AFScT* 15 (1923):199-240.

204. A. Liénard, 'Equilibre et déformation des systèmes de conducteurs traversés par des courants et des corps magnétiques sans hystérésis,' *Annales de physique* 20 (1923):249-360 and 3 (1925):145-60.; for quotation see p. 257. Both the opening and the closing sections of Liénard's memoir showed a heavy reliance on Duhem's thermodynamic potential.

205. A. O'Rahilly, *Electromagnetics: A Discussion of Fundamentals* (London: Longmans, Green and Co., 1938), pp. 161-80. It was reprinted as *Electromagnetic Theory: A Critical Examination of Fundamentals* (New York: Dover, 1965).

of logic leading physicists were not so outspoken perhaps because in remembering Poincaré's strictures of Maxwell, they should have recalled Duhem's perspicacity as well. Omission of Duhem's electromagnetic theory was glaring indeed in a large book on the topic by L. Bloch, in 1919 still an assistant preparator at the Sorbonne, who referred to Poincaré's treatise as one of his guides.²⁰⁶ When the subject was physical chemistry,²⁰⁷ or even hydrodynamics,²⁰⁸ omission of Duhem's name could evidence itself in no less glaring manner. His remark to his daughter about his having been buried alive by his fellow physicists had forecast a situation which was to prevail for decades at least in Paris.

French reminders of Duhem came mostly from the provinces. One of them was the publication in 1926, through the efforts of A. Boutaric, professor of chemistry at the University of Dijon, of an updated version of Duhem's textbook on physical chemistry.²⁰⁹ Another reminder came two years later from Bordeaux through a large memorial volume on Duhem in which over four hundred pages were taken up by the study of O. Manville, professor of physics there, of Duhem's physics,²¹⁰ an account which might have gained much in incisiveness had Roy's collaboration been asked. Roy himself made much of Duhem's hydrodynamics in the third volume of his analytical mechanics.²¹¹ The most frequent and most widely read reminders about Duhem came from Toulouse in the prefaces which gave additional appeal to H. Bouasse's famed series of textbooks. One example, the preface to Bouasse's general thermodynamics, may suffice. There Bouasse, in reminding his readers of a truth which 'Aristotle had already known and Adam himself may have suspected,' namely, that one does not demonstrate anything by postulates because one can

206. L. Bloch, *Précis d'électricité théorique* (Paris: Gauthier-Villars, 1919). Silence on Duhem in G. Bruhat's *Cours d'électricité* (Paris: Masson, 1924; 3d rev. ed. 1934), a book based on a course given in Lille in 1922-23, may have been motivated by its author impending promotion to the Sorbonne.

207. A. Kirrmann was agrégé préparateur at the Ecole Normale when he wrote *La chimie d'hier et d'aujourd'hui* (Paris: Gauthier-Villars, 1928) in which Berthelot was extolled for his researches in thermochemistry!

208. See, for instance, P. Painlevé's *Leçons sur la résistance des fluides non-visqueux* (Paris: Gauthier-Villars, 1930), a work on a most Duhemien topic, in which emphasis was given to the theories of Lagrange and Helmholtz (pp. 175-6) though with a complete silence on Duhem, and the *Leçons sur l'hydrodynamique* (Paris: Gauthier-Villars, 1929) by H. Villat, professor at the Sorbonne, who referred even to Roy!

209. A. Boutaric, *Thermodynamique et chimie d'après la deuxième édition de l'ouvrage de Pierre Duhem* (Paris: J. Hermann, 1926). Less significant was the publication, next year, of A. Turpain's *Éléments de thermodynamique* (Paris: Gauthier-Villars, 1927) partly because of its shortness (168 pp) and partly because of its introductory character. Turpain's admiration for his master was attested not only by his specification of Duhem's contributions to the notion of thermodynamic potential and to the theory of triple point (pp. 62-70) and by a brief summary of Duhem's career (p. 70 note), but also by a pointed reminder of Thomsen's priority over Berthelot as set forth by Duhem (p. 68).

210. O. Manville, 'La physique de Pierre Duhem,' in *L'oeuvre scientifique de Pierre Duhem* (see note 67 to Ch. 7), pp. 1-435.

211. L. Roy, *Cours de mécanique rationnelle*, 3 vols (Paris: Gauthier-Villars, 1944-45); see especially 1:14 and 3:vii.

only look in them for what they contain, Bouasse referred to Duhem's *Energétique* as a work in full conformity with that elementary truth. Another barb of Bouasse was directed at professors of physics in France:

For God's sake, teach physics to your students! French science is not so brilliant that it would be judicious to waste their time and yours in discussions dangerous to your as well as to their mental health. At any rate, you are not paid for that. Even if the very titles of your chairs authorize you not to worry about the masses of students and even if you have the right to act like philosophers, do so in the manner of Duhem in the *Energétique* rather than in the style of Plotinus or Polichinelle.²¹²

Such was a sharp warning though also pointless. While the frequent and facile changes of one's principles (symbolized by 'Polichinelle,' a marionette-figure with faces in the front and the back) deserved strictures, strict consistency with one's principles was no more a stance deserving unqualified approval. No less decisive was the intrinsic merit of the principle itself. Duhem's resolute turning away from any and all physical phenomena which suggested basic discontinuities was a principle on which physics teaching could not be based around 1930 and even two or three decades earlier. Equally inadequate was the opposite stance which meant a practically exclusive attention to discontinuities which multiplied as fast as the realm of atoms was opening up. The realm of the continuum, or the realm directly accessible to sensory perception (and thereby to common-sense judgments) not only remained the starting point on the road to the microscopic or atomic level but was also a level of reality that represented much more than a mere summation of imperceptibly small entities and interactions.

Duhem's physics retained therefore an intrinsic interest which was less recognized in France than abroad. Contrary to A. Boutaric, who registered 'profound sadness' over the fact that 'Duhem's name could hardly be found cited, and even not cited at all, in the great treatises published abroad recently,'²¹³ it was abroad that the Duhem-Margules equation made its first printed appearance and had become a

212. H. Bouasse, *Thermodynamique générale: Gaz et vapeurs* (Paris: Delagrave, 1932), pp. viii-ix and xvi.

213. A. Boutaric, *Thermodynamique et chimie*, pp. v-vi. Boutaric should have rather been saddened by the fact that Duhem was ignored two years earlier by A. Leduc, professor at the Sorbonne, in his *Thermodynamique. Energétique. Théorie cinétique des gaz* (Paris: Gaston Dion, 1924). That the book carried the word 'énergétique' in its title made matters even more glaring. Astonishingly, Duhem's name occurred nowhere in the 150 or so pages which Boutaric contributed on the main achievements in physics and chemistry during the first 30 years of this century, although he found ample place for the work done by Berthelot on organic synthesis! See his 'Les sciences physico-chimiques' (pp. 327-494) in P. Sergescu, J. Rostand, A. Boutaric, *Les Sciences* (Paris: Denoel et Steele, 1933) or vol. II of *Tableau du XX^e siècle 1900-1933*. Duhem's name figured prominently in Sergescu's contribution 'Les sciences mathématiques' (pp. 5-182) for his work done in mechanics and in the philosophy and history of science! Rostand's contribution was on the biological sciences.

staple feature in treatises and textbooks on physical chemistry.²¹⁴ The same is true of the phrase ‘Gibbs-Duhem equation,’ which made its first formal appearance also outside France²¹⁵ and had been a standard feature in books written by Belgian, American, and British authors long before the French followed suit.²¹⁶ Again, it was outside France, in Belgium, that Duhem’s macroscopic thermodynamics was keenly remembered by such eminent savants as Th. De Donder²¹⁷ and his erstwhile

214. The permanence of the phrase was secured when J. R. Partington made it again the title of a section in his *Chemical Thermodynamics: An Introduction to General Thermodynamics and its Applications to Chemistry* (London: Constable, 1924; see pp. 178-83), which on account of its small format saw an even larger circulation than the first edition, *Text-book of Thermodynamics* (1913), quoted in note 163 above. In the United States the first discussion of the Duhem-Margules equation came in *Thermodynamics and Chemistry* by F. H. Macdougall, professor of physical chemistry at the University of Minnesota (New York: John Wiley and Sons, 1921, pp. 156-66 and 190-96); also in the 2d edition (1926, pp. 165 and 190), and the 3d edition (1939, pp. 156 and 183). The ‘Duhem-Margulesche Gleichung’ appeared as par. 219 in *Lehrbuch der chemischen Physik* (Leipzig: Akademische Verlagsgesellschaft, 1930) by A. Encken, professor at the University of Breslau.

215. The spark was provided by the reference to the ‘equation originally derived independently by Gibbs and Duhem’ in the widely used *Treatise on Physical Chemistry: A Cooperative Effort by a Group of Physical Chemists*, edited by H. S. Taylor (New York: Van Nostrand, 1929), 1:775. Further impetus was given in *Modern Thermodynamics by the Methods of Willard Gibbs* (London: Methuen, 1933, pp. 14-15) by E. A. Guggenheim. In 1936 Th. De Donder and P. Van Rysselberghe spoke of ‘Gibbs-Duhem formulas’ in their *Thermodynamic Theory of Affinity: A Book of Principles* (Stanford: University Press, 1936, pp. 37-39). The Gibbs-Duhem equation was mentioned in a matter-of-fact manner by J. A. V. Butler in *A Commentary on the Scientific Writings of J. Willard Gibbs*, edited by F. G. Donnan and A. Haas (New Haven: Yale University Press, 1936), 1:134. The Danish original, published in 1936, of *Physical Chemistry* by J. N. Brønsted, professor at the University of Copenhagen (tr. R. P. Bell; London: W. Heinemann, 1937, for the discussion of the Gibbs-Duhem equation see pp. 99-100) was not available to me. In 1939 Macdougall made room for the Gibbs-Duhem equation in the third edition of his *Thermodynamics and Chemistry* (see note 214 above, p. 147).

216. Y. Rocard, professor at the Sorbonne and director of the physical laboratories at the Ecole Normale Supérieure, seems to have been the first French author to refer in print to the ‘equation assez fondamentale dite Gibbs-Duhem’ in his *Thermodynamique* (Paris: Masson, 1952), p. 52. Among Anglo-Saxon authors, who shortly before Rocard had spoken of the Gibbs-Duhem equation, are J. R. Partington, *An Advanced Treatise on Physical Chemistry. Vol. I. Fundamental Principles. The Properties of Gases.* (London: Longmans, Green and Co., 1949, p. 210), and M. A. Paul, *Principles of Chemical Thermodynamics* (New York: McGraw Hill, 1951, p. 77), a volume in the International Chemical Series. Debates about the proper derivation of the Gibbs-Duhem equation, which saw print in the section ‘Textbook Errors’ of *Journal of Chemical Education* in 1962 and 1963 (39:527-28 and 40:225-28), prompted D. G. Miller’s note ‘Duhem and the Gibbs-Duhem equation’ (*ibid.*, 40:648-49) in which Duhem’s derivation of the equation was reproduced with appropriate comments and references. Perhaps the foregoing data provide the resolution of the uncertainty expressed by Miller: ‘I am not as yet sure when or by whom Duhem’s name was added to the equation.’

217. As already referred to in note 215 above. Absence of any reference to Duhem in De Donder’s *L’Énergétique déduite de la mécanique statistique générale* (Leçons rédigées par Mlle Leuzière; Paris: Gauthier-Villars, 1939) may perhaps be explained by De Donder’s starting point, statistical mechanics, an approach never cultivated by Duhem.

student at the University of Brussels, I. Prigogine.²¹⁸ The same holds true of the revival of intense work in continuum mechanics with C. Truesdell of Johns Hopkins University as one of its most productive investigators.²¹⁹ In that field the extensive publications of Duhem, already yellowing on the shelves, if not mildewing in storage, are found to contain solutions which have been unsuspectingly reinvented half a century later.²²⁰

Yet ultimately it remains both natural and imperative that French physicists should assume the task of plumbing in depth the riches of what Duhem, the physicist, bequeathed. Their present generation is well positioned for carrying out that task. Unlike their forebears a generation or two ago, they are now helped by the liberality of insights which only the lessons of scientific (as well as philosophical and practical) developments stretching over more than half a century can provide. For if De Broglie was correct in stating that Duhem as a 'theoretical physicist bequeathed a beautiful and great work where physicists of today can still find numerous topics worthy of study and fruitful reflection,'²²¹ then more is called

218. In Prigogine's first major publication, his two-volume *Thermodynamique chimique conformément aux méthodes de Gibbs et De Donder* written with R. Defay (Tome I. Liège: Desoer, 1944, Tome II. Paris: Dunod, 1946), a special chapter is devoted to 'Duhem's theorem' which gives the number of variables, both intensive and extensive, that completely determine each phase of equilibrium of a closed system (1:299-303). In addition to an entire section on the Duhem-Margules formula (2:237-39), there is also a special section on 'Saurel's theorem' (2:384-86) developed in the latter doctoral dissertation. In his *Etude thermodynamique des phénomènes irréversibles* (Paris: Dunod, 1947), Prigogine introduced Duhem as the 'first to realize the importance of non-compensated heat and calculated, in his great work, *Energétique*, its specific value in the case of thermal conductivity and viscosity' (p. 3.) In Prigogine's *Introduction to Thermodynamics of Irreversible Processes* (1955; 3d ed.; New York: John Wiley, 1967) the *Energétique* is referred to as the work which gives 'a very thorough discussion of the first principle' (pp. 8-9 note).

219. See, for instance, Truesdell's discussion of Duhem's theorems on the effect of temperature variation, in his 'General and Exact Theory of Waves in Finite Elastic Strain,' *Archive for Rational Mechanics and Analysis* 8 (1961): 292-94, where he emphasized 'Duhem's fundamental relation between two acoustical tensors.' In his *Rational Thermodynamics* (New York: McGraw-Hill, 1969) Truesdell spoke of the 'Clausius-Duhem inequality . . . as a pillar of the mathematical theory of thermodynamics' (p. 35) and of the 'generalized Fresnel-Hadamard-Duhem theorem' for homothermal and homocaloric acoustic tensors (p. 73). *The Concepts and Logic of Classical Thermodynamics as a Theory of Heat Engines* (New York: Springer Verlag, 1977), which Truesdell co-authored with S. Bharathe, carries the dedication: 'May this tractate be received as an expression of respectful gratitude for the legacy of the great thermodynamicists CARNOT, REECH, DUHEM.'

220. 'Without ever having made a systematic or primarily historical study of Duhem's voluminous writings, we continue to find things there. For example, there is the *Traité d'Energétique*, a dense and forbidding work, but in it we found just a few years ago the basic idea of using a Liapounov function to relate dynamic stability to static stability of a deformable continuum. This idea had recently been proposed as original by one of the most eminent men in our field' (from Truesdell's letter of February 23, 1981, to the author).

221. L. De Broglie, 'Pierre Duhem, sa vie et son oeuvre,' in *Nouvelles perspectives en microphysique* (Paris: Albin Michel, 1956), p. 319. The short paragraph, which contains this statement, is omitted in the English translation of the article which forms the foreword to *The Aim and Structure of Physical Theory*, 1954 (1).

for than generic comments, however sympathetic, or even detailed analyses of this or that major feats of his.²²² What is to be done above all was intimated in the reflections prompted by the reprinting in 1961 of Duhem's *Recherches sur l'hydrodynamique*, first published in 1903.²²³ A further fortunate aspect of that undertaking was its having originated in that Lille where Duhem started his investigations on the subject. J. Kampé de Fériet, who wrote the preface to that re-edition, aptly noted that Duhem's work in the mechanics of fluids was that part of his researches which most unjustly fell into oblivion. For, as he remarked, 'whatever the successes of atomistic perspectives in physics, the mechanics of fluids, considered as continuous media, remain a science very much alive whose technical applications are numerous and important. It continues to be taught in all universities on exactly the same basis as in Duhem's times. The engineer, even if the courses in physics revealed to him the mysteries of protons, neutrons, and positrons, will adopt the viewpoint of the classical mechanics of fluids as soon as he is asked to study the shock waves produced by an airplane flying at supersonic speed.'²²⁴

Duhem in fact worked within that viewpoint with a foresight characteristic of a genius who solves problems which become of pressing interest only much later. Until the advent of supersonic flight, the mechanics of fluids was almost invariably taught in disregard of viscosity. Or, in the words of a Harvard professor, quoted by Kampé de Fériet, authors of highly regarded treatises on hydrodynamics 'spoke of a fluid, called water, without ever suggesting that [being viscous] it made things wet.'²²⁵ Such a remark was certainly not applicable to Duhem's researches on hydrodynamics whose essential feature was the study of viscosity responsible, among other things, for shock waves, that call for that thermodynamics which formed the starting point of Duhem's work in physics.

Yet, whatever the lasting value of that work, some already sighted and some still

222. Example of the former is 'Duhem physicien' by P. Lousteneau in *Les études philosophiques*, 22 (1967):433-38, who outlined the scientific background against which there emerged the notion of thermodynamic potential. The latter class is exemplified by the main part of the doctoral dissertation of P. Brouzeng, maître de conférences at the University of Bordeaux, 'L'oeuvre scientifique de Pierre Duhem et sa contribution au développement de la thermodynamique des phénomènes irréversibles' (Université de Bordeaux, 1981, No. d'ordre: 717), a photocopied typescript in two volumes. In the first volume (287 pp) a careful tracing is given of Duhem's work on the thermodynamics of irreversible processes with a comparison of it with Gibbs' researches. Preceding this is a portrayal, rather tendencious (socialist if not Marxist) of French economic, political, and academic life. The second volume (298 pp) contains documents – biographical, epistolary (letters to and from Le Chatelier, Gibbs, Van't Hoff, and Berthelot), and bibliographical. The list of Duhem's publications is, with a few exceptions, the one given by Duhem in 1913 and updated in 1917 in *L'oeuvre scientifique de Pierre Duhem*. In many cases an indication of the first pages (to say nothing of the last pages) of Duhem's articles is missing in the bibliography provided by Brouzeng. He follows Duhem even in listing his articles in groups corresponding to the periodicals in which they were published, and only within such groups in chronological order.

223. 1961 (1).

224. *Ibid.*, pp. v-vi.

225. *Ibid.*, p. vi (note). The name of the professor was not disclosed.

to be discovered, they may not seem proportionate to the intensity of his efforts, to the vastness of his output and, last but not least, to the quality of mathematical tools he employed. This lack of proportion is an aspect of Duhem's attitude to molecules, atoms, and electrons which he saw enclosed in the heavens of metaphysics, but whence they invaded, during the second part of his career, laboratories everywhere and gave physicists a new firmament. His attitude was not that of a typical dissenter. Unlike Ostwald and Mach, with whom he is often mentioned in the same breath in that respect, Duhem expressed his dissent by silence rather than by words. His article on atomic theory, written before the advent of X-rays and radioactivity, carried the story to a point which itself was history by 1892.²²⁶ A dozen or so years later, the antiatomistic remarks in his *Théorie physique* related mostly to 17th and 18th century spokesmen of the corpuscular hypothesis. By 1906 Lord Kelvin's vortex atom, which Duhem subjected there to some generic criticism,²²⁷ was also a topic belonging to history. Duhem never touched, in writing at least, on that vast technical literature which was accumulating on ions, electrons, and atoms during his last twenty years and of which a splendid collection was presented in French as early as 1905.²²⁸ In Sir Edmund Whittaker's survey, still unsurpassed for its meticulous documentation of the development of modern physics until 1925, Duhem's name occurs only once and only in connection with the classical pre-history of that story.²²⁹ Unlike Ostwald, who in 1908 admitted in a widely read context that the atomic hypothesis had risen to the 'position of a scientifically well-founded theory,'²³⁰ Duhem did not dignify the new reality of atoms to as much as a brief remark. His opposition by sheer silence to atoms was not a posture to prompt a move which, with respect to Mach, was undertaken by S. Meyer. The result was that the partly crippled Mach, on seeing the sparks induced by a grain of radium on a scintillating screen set by his bedside, uttered the words: 'I now believe in the existence of atoms,' words made public long after Mach's death.²³¹ About Duhem, who impressed as early as 1900 a visitor from

226. 1892 (7), where toward the end he passingly referred to J. J. Thomson's vortex-atom model (p. 450).

227. *The Aim and Structure of Physical Theory*, pp. 82-83.

228. *Les quantités élémentaires d'électricité. Ions, électrons, corpuscles*, Mémoires réunis et publiés par H. Abraham et P. Langevin (Paris: Gauthier-Villars, 1905), a collection of 120 articles filling 1138 pages!

229. E. Whittaker, *A History of the Theories of Aether & Electricity. Volume I The Classical Theories* (1951); New York: Harper Torchbooks, 1960), p. 252. There Duhem is quoted as a critic of the procedure by which Maxwell determined the velocity of the propagation of electric disturbances.

230. W. Ostwald, *Lehrbuch der allgemeinen Chemie* (Leipzig: Englemann, 1908, preface); English translation by W. W. Taylor *Outlines of General Chemistry* (3d ed.; London: Macmillan, 1912), p. vi, where Ostwald especially credited J. J. Thomson's researches and J. Perrin's work on Brownian motion.

231. S. Meyer, 'Die Vorgeschichte der Gründung und das erste Jahrzehnt des Institutes für Radiumforschung,' in *Sitzungsberichte der Österreichischen Akademie der Wissenschaften*, Abt. IIa, 159 (1950), Heft 1, pp. 1-26.

England by performing similar experiments in Bordeaux, no such disclosures were to be made.

About relativity, this other major domain of 20th century physical research, Duhem was even more reticent. This should seem all the more surprising as already in 1892, in his commentaries on thermodynamics, he systematically broached the question of absolute reference systems.²³² In 1908 he made it the topic of a long historical study in which, tellingly enough, the concluding chapter, 'a look at modern times,' dealt with matters not at all modern by then. The chapter was a survey of Cartesian and Kantian notions on absolute space. The only 'modern' physicists mentioned there were K. Neumann of alpha-body fame, Reech, Paul Painlevé, Jules Andrade, and the even more forgotten H. Streintz.²³³ Not a word on Poincaré, Lorentz, let alone on Einstein, who already in 1909 made a much awaited appearance before the annual congress of German scientists in Prague. There was no reference to Einstein in Duhem's *Energétique* which, as a vastly overhauled variation of Duhem's commentaries on the principles of thermodynamics, also started with a discussion of axiomatics, among them the status of absolute reference systems.²³⁴ For Duhem as a physicist, an absolute reference system was a mere convenience, an approximation always revisable, because such was in his eyes the only view permissible by logic and by observation. Duhem's sole and brief comment on Einsteinian relativity was an essentially philosophical reasoning predicated on common sense. He ascribed the growing popularity among German physicists of relativity, 'as conceived by an Abraham, an Einstein, a Minkowski, a Laue,' to the lack of sound judgment in the German frame of mind and to its disrespect of reality. According to Duhem, the only legitimate conclusion to be drawn by the 'discerning mind' (*esprit de finesse*) from the Michelson-Morley experiment was to declare all theories of optics to be in need of some retouching. Instead, led by their 'geometrical' thinking, German physicists reconciled that experiment with electron optics by contradicting the most fundamental precepts of common sense for which space and time are radically different notions. The new or relativistic physics, Duhem argued, 'equated these two notions through the so-called principle of relativity which is so completely the creation of geometrical spirit that it would be impossible to give proper account of it in ordinary language and with no recourse to algebraic formulae.'²³⁵

While Duhem's reference to ordinary language and the common sense judgments it carries is significant enough, the really revealing part of his statement resides in the expression, 'algebraic formulae.' Duhem's falling back on it raises the most

232. 1892 (9), p. 271.

233. 1909 (11), pp. 192-206. Those pages, however, have an interest of their own because of Duhem's lengthy analysis there of Kant's description, in the *Critique of Pure Reason*, of absolute space as a purely conceptual entity and because of Duhem's seeing Kant's description (which he finds fully present in Neumann's notion of alpha-body) as identical to the notion of absolute space as advocated by Simplicius, Ockham, and the Terminalists.

234. 1911 (1), 1:11-12.

235. 'Quelques réflexions sur la science allemande,' 1915 (3); see 1915 (2), p. 135.

searching question that can be asked about Duhem the physicist. His hardly concealed satisfaction that the 'geometric minds' had to resort to algebra in order to explain themselves makes one wonder whether he was as justified, as he thought he was, in terms of his own preferences, in ignoring modern physics and especially its branch dealing with atomic theory. Duhem was a convinced and committed algebraist, on whom possibly the algebraist-mathematician Hermite made the deepest imprint and who was most pleased to find that Gibbs, another hero of his, was an 'algebraist.'²³⁶ As it turned out, the fundamental problems posed by atomic physics were manageable only by algebraic formalisms of which a polynomial function, worked out by Hermite long before the advent of quantum mechanics, suited best some basic atomic discontinuities. To what extent Duhem would have been astonished by that outcome, which took place a few years after his death, is not entirely a matter of conjecture. Hadamard, who noticed the deep resonance of Duhem's thinking to Hermite's ideas, could not help musing as he recalled his many and long conversations with Duhem in Bordeaux: 'How atomistic in his very soul and in the deepest recesses of his mind was indeed the one who would be the most resolute and at times the most intransigent champion of energetics!'²³⁷

It should seem therefore legitimate to ask in a far from trivial sense the question whether the physics of Duhem might not have taken a different development. Would some deep-lying strains of Duhem's acumen have remained hidden in more propitious circumstances? Would not further impact have been made on him by teaching before an elite audience, to which he attributed a decisive role in his making of a physicist, had such an audience been available to him even after his years in Lille? Would he not, as an occupant of a chair in Paris, where an elite audience was always assured and where he would have more keenly felt the responsibility of keeping French physics on the crest of the wave, have realized the importance of doing theoretical work also on an ever vaster realm of data indicative of radical discontinuities? Would he under such circumstances have remained aloof of that very different physics which, as he prophetically remarked as early as 1903, would be ushered in by the various radiations, thermal, spectral, and radioactive?²³⁸ Is it indeed likely that, as an occupant of a chair in Paris, he would have blocked, or at least seriously retarded, the advent of modern physics in France?

Duhem was alone in France with his simultaneous command of and productivity in the 'modern' physics of the 1890s, that is, of Maxwell's electromagnetics, of Gibbs' thermodynamics, and of the new science of physical chemistry, to say nothing of his excellence in the traditional subject of fluid mechanics in which he was making strikingly novel researches. It was a grave injustice to French physics, and not only to Duhem, to keep him out of a Sorbonne enriched in the same 1890s with many new chairs and courses, including a course for physical chemistry. Although the constitutive parts of 'modern' physics rapidly changed from the early 1900s on, a chair with Duhem as its occupant would have been only one out of

236. [Etude sur l'oeuvre de Gibbs] 1907 (3), p. 10.

237. In *L'Oeuvre scientifique de Pierre Duhem* (see note 67 to Ch. 7), p. 469.

238. 'Evolution de la mécanique,' see 1980 (1), p. 185.

a dozen for physics and chemistry from which his 'traditional' view could have been readily outweighed. Duhem as a threat to progress should indeed seem a strange notion when one recalls that Le Chatelier and later Urbain, both professors of chemistry in Paris and spirited antiatomists (as was Berthelot too!), were more than welcome there. At any rate, if the hundred or so papers read at the International Congress of Physics in Paris are a proof,²³⁹ 'modern' physics had not yet by 1900 become a majority interest for physicists, French or foreign. A few years later an American physicist spending a year in Paris to find out about the latest had not heard a word about Planck's epoch-making work on black-body radiation.²⁴⁰ For all the victory of atomism by 1914, a series of interviews conducted in the pages of *Le Temps* with leading scientists on the 'revolution' taking place in science, revealed little of what by then was really revolutionary at least in retrospect.²⁴¹ As late as 1926 an Ehrenfest wondered aloud whether the victory of atomism was as secure as it appeared to be.²⁴² Indeed by then it began to dawn on the best minds that while atoms were becoming plain objects of research, atoms as pieces of mechanism, which most atomists (certainly a Langevin and a Perrin in France) saw in them, were rapidly vanishing. No sooner had quantum mechanics been formulated than it revealed its incompatibility with that very visualization in which Duhem saw the chief pitfall of mechanistic physics. As early as 1925 Bohr admitted that the 'picture in space and time on which the description of natural phenomena has hitherto been based' were an essential failure as far as quantum theory was concerned.²⁴³ Ten years later Dirac noted that for the new physics the question 'whether a *picture* exists or not is a matter of only secondary importance. In the case of atomic phenomena no picture can be expected to exist in the usual sense of the word 'picture' by which is meant a model functioning essentially on classical [mechanist] lines.'²⁴⁴

239. Listed in *Travaux du Congrès International de Physique réuni à Paris sous les auspices de la Société Française de Physique*, edited by Ch.-Ed. Guillaume et L. Poincaré, Tome IV (Paris: Gauthier-Villars, 1901), pp. 617-19.

240. Professor E. B. Wilson of Yale. For further details on the delay of Planck's achievement entering into general awareness, see my *The Relevance of Physics* (Chicago: University of Chicago Press, 1966), p. 586 note 14. In fact, Planck's article was not printed in the collection cited in note 228 above!

241. In the ten reports published between December 30 and April 14 and based on interviews with about thirty leading scientists from all fields, there was no mention of relativity, of Einstein, of Planck, let alone of Bohr. E. Borel did not speak of quanta while pointing at the statistical method needed to interpret radioactivity (17 février 1914, p. 5). The overthrow of the belief in the immutability of atoms passed for the most revolutionary outcome (2-2 janvier 1914, p. 3.) among remarks of that type.

242. In a speech delivered at the dedication of Mach's bust in Vienna in September 1926. For passages translated from the German, see G. Holton, *The Scientific Imagination: Case Studies* (Cambridge: Cambridge University Press, 1978), pp. 80-81.

243. N. Bohr, 'Atomic Theory and Mechanics,' in *Atomic Theory and the Description of Nature* (Cambridge: Cambridge University Press, 1934), pp. 34-35.

244. P. A. M. Dirac, *The Principles of Quantum Mechanics* (2d ed.; Oxford: Clarendon Press, 1935), p. 12.

No wonder that a rigorous methodology of quantum mechanics, such as the one formulated by Dirac, who steered clear more successfully than did the representatives of the Copenhagen school of the temptation of tying it to spurious philosophies, could easily appear as a vindication of the method which Duhem had advocated for physics. Such was the considered impression of R. Dugas as he 'reread Duhem with the eyes of the quantists.'²⁴⁵ As one might expect, he first noted Duhem's abdication of reliance on visual images and the always abstract sense which Duhem assigned to 'representation.' Duhem found this necessary in order to avoid contradictions. Quite similarly, contradictions arose unless waves and particles, whose simultaneous or complementary use is indispensable in quantum mechanics, were taken for more than abstract mathematical formalisms. The impossibility of ever reducing waves to particles or vice versa was again anticipated by Duhem's insistence on the impossibility of performing a *crucial* experiment. What was true of light waves, became true of matter as well. Physics could not decide whether matter was a bundle of waves or a stream of particles. A further vindication of Duhem's ideal of physics was exemplified, according to Dugas, by a simultaneous development of two trends within modern physics. One was the proliferation of elementary particles, the other was the unification of radiation and matter through the recognition that matter could be 'annihilated' into energy and energy could 'materialize.' In Duhem's rendering, the evolution of physics was a permanent tension between two trends: the discovery of many new entities through experiments and their fusion by theory into a small number of classes.

Duhem's claim that physical theory was not an explanation, found a telling illustration, according to Dugas, in Dirac's algebra of states and observables, a construct as abstract as could be imagined. The algebra of states, corresponded to a space of states, that is, Hilbert's space, a far cry from ordinary, visualizable space. The algebra of observables, a reflection of non-commutative rules, was no less removed from ordinary operations. The operators in quantum mechanics were again notions to which no physical meaning could be assigned. And since the observables themselves were not objects of common sense, that is, of direct observation, the question of objective reality remained within the domain of metaphysics in exactly the same way as legislated by Duhem's concept of the limits of the method of physics. Therefore the alleged incompatibility of quantum mechanics with common sense was shown to lack solid foundation. For, as Duhem argued, already in classical physics the axioms were not given by commonsense observation but by abstractive reasoning. In addition to these foundations of quantum mechanics, Duhem also anticipated its main conditions which, according to Dugas, were the absence of internal contradiction and global accord with experimental evidence.

245. R. Dugas, 'La méthode physique au sens de Duhem devant la mécanique des quanta,' *RFS CPA* 49 (1937):68-71; for quotation see p. 71. There is no reference to Duhem in a similar study by Dugas, *La méthode dans la mécanique des quanta (axiomatique, déterminisme et représentation)* (Paris: Hermann, 1935), 59 pp. Dugas (1898-1957) was a student of Jouguet at the Polytechnique where he graduated as a mining engineer. This explains in part Dugas' familiarity with and appreciation of Duhem's studies of the beginnings of mechanics in the Middle Ages, a point to be noted in the last Chapter.

The most remarkable parallel drawn by Dugas between quantum mechanics and Duhem's method of physics related to the conditions which Duhem specified for an inherently exact mathematics that might serve as a translation of inherently inexact physical data. Dugas, who saw no trace in the *Théorie physique* of physical determinism, could indeed say that quantum mechanics, as put in the light of Duhem's physical theory, could be found *very useful* by the physicist working in the quantum era. Duhem himself, Dugas added, 'could not pass it up today.'²⁴⁶

Whether physicists of the 1930s took quantum mechanics only as *useful*, is not a point to be discussed here. Had Duhem been alive and active around 1930, he would have certainly not taken up quantum mechanics out of fear of becoming a mere anachronism. He would have, however, eagerly noticed the strict banishing by quantum mechanics of visual mechanistic models. In that he would have stood apart from many modern physicists of whom Bridgman aptly noted in 1927: 'I believe many will discover in themselves a longing for mechanical explanation which has all the tenacity of original sin.'²⁴⁷ Such a longing was a symptom of the physicist's proneness to being inconsistent, his worst possible offense in Duhem's eyes. Yet he himself was not immune to it. As a physicist, he did not follow consistently at least one precept, the one which Dugas characterized as the global accord of theory with experiments, a precept whose fundamental importance Duhem as a philosopher of physics clearly recognized. According to that precept a good physical theory should account for all the data available. Even as a historian Duhem recognized in that precept the final justification of a theory. The heliocentric theory, while incapable of proving that the earth's motion was absolute and not merely relative, had to be preferred because, as Duhem stated at the end of his classic historical survey of the question, it saved '*all the phenomena* of the inanimate universe taken *together*.'²⁴⁸

Tellingly, the best remembered and constantly used parts of Duhem's vast work in physics were done at a time, in the late 1880s and early 1890s, when the range of his research was still fairly 'global.' At that time Duhem, who introduced Gibbs' ideas in France, was in fact very eager to reach out for the latest so as to keep abreast with the expanding frontier of research. As it happens all too often, even with the very talented, he took that 'latest,' which he encountered in his prime, for an ideal to stay indefinitely. This would not have been in itself a very mistaken policy. Had the subsequent decade or two been just another ordinary phase in the history of physics, the range of Duhem's researches would not have narrowed drastically with respect to further developments. But those decades witnessed an accelerated, nay explosive, growth. Had Duhem been born a decade or so later, his story as a physicist might now belong with those ushering in modern physics and not with those who tried to keep classical physics, however overhauled, in the center stage. Yet such a possibility should seem remote. There is a glaring discrep-

246. Ibid. Concerning Duhem's reflections on mathematics in that connection, Dugas made much of the reliance on Duhem by G. Bouligand, professor of mathematics at the University of Poitiers, in his article, 'Quelques courants d'idées géométriques,' *RGScPA* 47 (1936):581-88.

247. P. W. Bridgman, *The Logic of Modern Physics* (New York: Macmillan, 1932), p. 47.

248. 1969 (1), p. 117.

ancy between Duhem's systematic refusal to shift from classical to modern physics and the willingness of so many of his colleagues to make that shift. This refusal was rooted in his failure to see to the bottom of that common sense which he wanted to serve as its apostle. As will be seen, common sense was implied much more than would appear at first sight. Those physicists who felt the urge to venture into the unknown were not necessarily lacking common sense, unless it is equated with philistinism. Nor were those acting necessarily against the precepts of common sense who esteemed their power of imagination. Common sense could not be denied to those who saw science not only as a tool of understanding, but also as a means of achieving mastery over nature. Such traits, although not lacking in Duhem's program for doing physics, were not given an emphatic place there. Worse, Duhem did not consistently cultivate those traits even in the attenuated measure he granted to them. This is why his work as a philosopher of physics proved itself to be more 'global,' that is, well-rounded, and as a result retained more lasting interest than his work as a physicist. As to the field, history of physics, where with healthy common sense he boldly advanced into the unknown in pursuit of unsuspected facts and data, he provided the most vibrant evidences of his genius.

9. DUHEM THE PHILOSOPHER

Common sense with a realist touch

The role of common sense in Duhem's philosophy is its most pivotal, yet largely overlooked and almost invariably misconstrued aspect. The first to look in the wrong direction was Picard himself who saved for posterity Duhem's priceless self-portrayal as the apostle of common sense.¹ Picard singled out the heart, in the sense in which Pascal spoke of it, as the faculty which in Duhem's eyes was the ultimate and exclusive wellspring of common sense. Picard mentioned in the same breath Descartes' *Discours de la méthode* where common sense is presented as the liaison between thought and reality and the ultimate source of discovery and discernment.²

The putting of Pascal and Descartes in the same and all-important philosophical category would have rankled Duhem who was all too critical of Descartes and his disciples. They saw mechanism and geometry everywhere and turned both into a spurious metaphysics to which they subordinated physics. In Duhem's view Pascal had good words for Descartes only inasmuch as Descartes refused to do physics in terms of volitions.³ The context of Duhem's remark was his long review of a now completely forgotten work whose author aimed at giving a new mechanical expla-

1. E. Picard, 'La vie et l'oeuvre de Pierre Duhem' (see note 53 to Ch. 7), pp. 40-41. The passage was quoted in the preceding Chapter.

2. Duhem would have hardly agreed with Descartes who held that only his markedly mathematical method could assure proper use to common or good sense, a commodity 'of all things in the world the most equally distributed, for everybody thinks himself so abundantly provided with it, that even those most difficult to please in all other matters do not commonly desire more of it than they already possess,' and that his scientific opinions 'will be found to be so simple and so conformable to common sense, as to appear less extraordinary and less paradoxical than any others which may be held on similar subjects.' See *Discourse on the Method* in *The Philosophical Works of Descartes*, tr. E. S. Haldane and G. R. T. Ross (Cambridge University Press, 1931), 1:81 and 129.

3. 'Une nouvelle théorie du monde inorganique,' 1893 (7), p. 116.

nation of all interactions of lifeless matter.⁴ Duhem insisted that no novel garment put on mechanistic physics inaugurated by Descartes could free it from its internal contradictions. The latter had their source in the fact that Descartes (and mechanism) derived physics from philosophy, or rather from a specific form of metaphysics. The review itself was part of a broader context, a dozen or so essays on the philosophy and history of science, the first five of which Duhem wrote and published during his last two years in Lille. Many years later he emphatically made the point that he paid sustained attention to the historical and philosophical aspects of physics only because of his interest in a logically unobjectionable form of it.⁵ Only in that sense did his philosophy have a claim to completeness. In a broader sense his philosophy is deliberately incomplete and especially with respect to its foundations. This is not to suggest that Duhem failed to perceive either this incompleteness or the very nature of those foundations. They were steeped in metaphysics, and in particular in the metaphysics of a commonsense acceptance of external reality and its lawfulness. Duhem endorsed that metaphysics unreservedly and spoke of common sense and of external reality in terms which put his philosophy apart from positivism (Comte), from sensationism (Mach), and from commodism (Poincaré), to speak here only of some major trends in the philosophy of exact science in Duhem's time. Those terms, which reveal Duhem as an admirer of Aristotle, put him apart from Pascal. But Duhem was an Aristotelian only insofar as he wanted to understand and serve physics. He never discoursed at length on metaphysics, not even on logical rigor and natural classification, two topics equally Aristotelian in provenance and touchstones of truth, in Duhem's eyes, both of physics and its philosophy.

Duhem's dicta on common sense are significant both with respect to emphasis and to deliberate lack of elaboration. The emphasis came naturally and without any apology either to Humeans or Kantians. He was so little concerned about either Hume or Kant, or the whole modern fondness for epistemology, that he did not so much as hint at common sense in starting out with a statement on external reality and its lawfulness. The very beginning of his first essay on theoretical physics (the first of those essays), reveals the naturalness of a born realist who feels no need to take stock of his birthright. There is not a trace of hesitation in Duhem's opening phrase, 'The human mind, being placed in the presence of the external world in order to know it, encounters first of all the realm of facts.'⁶ Again, there is not a hint of a doubt on Duhem's part about the essential reliability of the elementary induction which carries the knower from the first level of knowledge (the level of facts) to the next which is the registering of empirical laws, that is, of class of facts. He never allows himself or any philosopher to doubt the validity of that process. All he allows them is to analyse it. He allows nothing to the Kantians, inheritors, as

4. The gist of the theory of A. Leray, physicist and theologian, as set forth in his *Essai sur la synthèse des forces physiques* (1885) and *Complément à l'essai . . .* (1892) was a complex version of Le Sage's explanation of gravitation by pressure difference in the stream of 'ethereal particles.'

5. 'Physique de croyant,' 1905 (8), and 'Notice' 1913 (1).

6. 'Quelques réflexions au sujet des théories physiques,' 1892 (6), p. 139.

he put it, of a cloudy philosophy which saw its beginnings on the no less misty shores of the Baltic.⁷

In Duhem's eyes the philosophical doubts and scepticism that had already eroded Western thought about man's ability to grasp reality and its lawfulness in a spontaneous natural way, were self-defeating to such an extent that he urged students of physics to proceed with their work without any further philosophical ado. Nor did they need any metaphysical elaboration, as he emphasized two years later, of what reality was meant by such words as body, law, extension, time, and motion. 'These notions appear to our intelligence sufficiently certain, sufficiently distinct so that we may, with no fear of confusion and error, make them operate in the experimental method.'⁸ While this distinctness did not mean absolute clarity, it constituted in his eyes a sufficiently solid ground for the working physicist. About anyone voicing such a claim, so startling when set against interminable philosophical disputes, one cannot help registering an uncommon degree of conviction. Unlike most modern philosophers, who yield to systematic doubting in their philosophical hours, Duhem never expressed doubt on a pivotal point, namely, the reliability of the human mind to notice the general in the particular and to do so with an immediacy so spontaneous as to fail time and again to become a conscious act. The generalization was a law of human thinking 'which is clear for all, philosopher or not.'⁹

The immediate perception of the general in the particular, as conceived by Duhem, was all the more a harking back to Aristotelian realism as Duhem connected that perception with the reliability of knowing things external in the same natural spontaneous way. To be sure, he did not make this connection in a philosophically systematic way. He was not and did not want to be a philosopher as such. Only inasmuch as he wanted to specify the criticism to which an experiment in physics was subject did he speak of the simple registering of facts which, as long as the observer was sane, was above criticism. For all its apparent triviality, the passage is capital:

When a sincere witness, sufficiently sober so as not to take the whims of his imagination for observation and familiar with the language he uses to express his thought clearly, affirms to have registered a fact, the fact is certain. If I declare to you that on such a day, at such an hour, in such a street of the city I saw a white horse, you must believe, unless you have reason to consider me a liar or a victim of hallucination that on that day, at that hour, in that street, there was a white horse.¹⁰

The capital importance of the passage can be perceived through the well-nigh trivial fact that Duhem does not speak of the 'sensation' of sighting a horse, nor even of the 'phenomenon' of the horse. That he does not use the word 'phenomenon' in this connection, although he uses it elsewhere in those early essays, is again very significant. Duhem speaks of the horse as an entity about which one can ascertain

7. 'Une nouvelle théorie . . .,' 1893 (7), pp. 90-1.

8. 'Physique et métaphysique,' 1893 (8), p. 62.

9. 'Quelques réflexions au sujet de la physique expérimentale,' 1894 (5), p. 215.

10. *Ibid.*, p. 207.

with obvious immediacy as having been in a particular place at a particular time. There is not a trace in his parlance of the possibility that the existence of the horse is merely an inference, let alone the function of its having been observed. Objective reality for Duhem is an unquestioned and unquestionable truth which man grasps in the very act of knowing a realm external to him, a realm in which man is placed in order that he may know it. Such a view of knowledge is comprehensible for Aristotelians and Aristotelian Thomists (to be carefully distinguished from their transcendental kind). The same view of knowledge is incomprehensible, or rather inadmissible, within practically any modern school of philosophy, and especially within that positivism where Duhem is customarily placed. Last but not least, Duhem does not predicate the existence of the horse, or of any flesh and blood reality on a fiducial principle, be it the 'heart' of which Pascal spoke. Duhem *knows* the horse to be there. He sees human knowledge as that means through which man is immediately connected to reality. Since knowledge has for centuries been severed from reality, the meaning of it as implied by Duhem's straightforward, matter-of-fact parlance, deserves attention all the more.

Duhem's foregoing words merely imply Aristotelo-Thomistic realism, and this is another indication of the drastic incompleteness of his philosophy and of its invariable subordination to his overriding concern to understand the nature of physics as a science and as a method. The subordination is all too clear in the use which Duhem immediately makes of man's certainty of ascertaining the horse and all similar objects and facts. That certainty, he warns, cannot be found in physical theory, because the physicist's discourse is not a recital of facts but 'the interpretation of those facts, that is, their transposition into the abstract symbolic world created by theories which he considers as established.'¹¹ Were the physicist to confine himself to the recital of facts, he would enunciate truths, but since he presents an interpretation of facts, he does not necessarily speak the truth. Duhem is interested in the immediate grasp of reality only as a backdrop against his concept of the never necessary and never one-to-one correspondence of physical theory with reality.

The drastic incompleteness of Duhem's philosophy is revealed right there and then. Although in the same essay Duhem speaks of common sense repeatedly,¹² he does not care to describe it philosophically. Nothing, one could argue, would have been more natural within a moderately systematic perspective than a specification of the mental organ (in this case common sense) which gives man a conscious access to reality. Duhem did not mention common sense even in the vicinity of that pivotal passage, quoted above, where he stated the knowledge of reality in a graphically matter-of-fact manner. The realist touch he gave to 'common sense' is all the more significant because he could not get it from Pascal's *Pensées* where *sens commun* denotes broadly shared erroneous views.¹³ There the expression *bon sens*

11. Ibid.

12. Ibid., pp. 186, 200, 211-17, 226.

13. See #726 and #727 in *Pensées*, in *Pascal. Oeuvres complètes*, ed. J. Chevalier (Paris: Gallimard, 1954), p. 1309.

means good faith,¹⁴ whereas with Duhem it stands for that source of discernment among principles or basic viewpoints for which Pascal uses the expression *sens droit*.¹⁵ Duhem left no indication whatever as to whether he was aware of his departure from Pascal's terminology.

A related aspect of the incompleteness of Duhem's philosophical reflections is the absence in his writings of any reference to past philosophical use of the term common sense.¹⁶ He was silent on the British common sense philosophers as much as he was on the champions of the French Enlightenment to whom the expression was very dear. Nor did he refer to any of the widely read books of nineteenth-century French Catholic apologists who often endorsed in various degrees Lamennais' emphasis on commonly held opinions.¹⁷ While that literature, heavily tending towards fideism, could not be unknown to Duhem, he would have looked in vain there for an appreciative appraisal of the point championed a hundred years earlier by the Jesuit Claude Buffier that common sense assured us of the truth of external reality,¹⁸ a point which Duhem would have found very much to his liking. Such a realist functioning of common sense he could hardly derive from the intuitionist trend of which he must have heard aplenty while at the Ecole Normale. There Ollé-Laprune, a teacher of Bergson, owed much to the writings of the Abbé Gratry, who was director of Stanislas prior to his taking in 1853 the post of chaplain at the Ecole. Yet Duhem was never an intuitionist to the extent of repeating Pascal's claim that 'all our reasoning consisted in yielding to sentiments.'¹⁹ Sentimental

14. *Ibid.*, #381 (p. 1188).

15. *Ibid.*, #21 (p. 1093). Pascal was, of course, only one of the leading French thinkers who celebrated *bon sens*. Just as for Descartes, already quoted, for Bossuet too it was 'the master of human life.' The *philosophes* prided themselves of having taught but *bon sens*. On July 30, 1895, Henri Bergson chose for his topic 'Le bon sens et les études classiques,' as he presided over the distribution of prizes at the concours général (see *Henri Bergson. Ecrits et paroles, textes rassemblés par R. M. Mosse-Bastide. Tome Premier* [Paris: Presses Universitaires de France, 1957], pp. 84-94). None of these and other great minds offered, however, much that was specific. The same was true of the otherwise excellent three-volume work, *Pascal et son temps* (Paris: Plon, 1907-10, and several subsequent editions), by F.J. Strowski, a friend of Duhem and also a colleague of his at the University of Bordeaux. Strowski benefited from his contacts with Duhem concerning Pascal the scientist (see *ibid.*, 2:59, 393, and 401).

16. The survey of schools in 'Common Sense' by S. A. Grave in *The Encyclopedia of Philosophy*, ed. P. Edwards (New York: Macmillan, 1967), 2:155-60, begins with Berkeley! The article is heavy on language philosophers who cared less for reality than for clarity. Not surprisingly, Grave's long bibliography does not contain the best monograph on the realist bearing of common sense: *Réalisme Thomiste et critique de la connaissance* by E. Gilson (Paris: J. Vrin, 1939); see especially ch. 1.

17. Lamennais did so above all in his *Essai sur l'indifférence en matière de religion* (1817), which by 1829 was in its 8th edition and translated into English, Spanish, and German as well.

18. In his *Traité des premières vérités et de la source de nos jugements* (1732), Buffier opposed Descartes' use of common sense because, in his view, it led to solipsism. For a brief account of Buffier's use of common sense, see Gilson, *Réalisme Thomiste*, pp. 16-17, where it is also pointed out that Reid was familiar with Buffier's work, and that because of his anti-Cartesianism Buffier was referred to by Voltaire as the only sensible Jesuit philosopher.

19. *Pensées*, #474, *ibid.*, p. 1221.

trust in the ability of reason to know reality above all was a mere overtone, very faint in some cases, of Duhem's recourse to the expression 'common sense.'

Attitude to metaphysics

If Duhem ever looked for a philosophical justification of his realist utterances, it would have been in the direction of Aristotle whom he learned to read in the original while at Stanislas. He was, however, more attracted to the author of the two *Analytics* and the *Organon* than of the *Metaphysics*. The Aristotle he knew and loved was the one set forth in 1846 by F. Ravaisson-Mollien²⁰ who hardly anticipated the thrust of the Neo-Thomist reliance on Aristotle. Of Aquinas and of the Thomistic revival launched by Leo XIII in 1879 Duhem did not learn while at Stanislas. A quarter of a century later Gilson could go through a Catholic lycée in Paris without ever hearing of Thomism.²¹ Duhem could acquire more than a hearsay knowledge about Thomism during his years in Lille. There he had friends at the Institut Catholique which was in close contact with the Catholic University of Louvain where Mercier, the future Cardinal, spearheaded the Thomistic revival.

Early familiarity with at least some positions of Aquinas could also come to Duhem through reading the *Revue des questions scientifiques* which had a strong base in Louvain and carried by 1890 several articles on the relevance of Thomism for the interpretation of science. An evidence of that familiarity was the ease with which Duhem met E. Vicaire's criticism²² of his introductory lecture on theoretical physics.²³ Vicaire, who claimed that the grounds of his criticism were of the essence of scholastic philosophy, aimed above all at Duhem's separation of physics from metaphysics. He failed to note the very narrow perspective within which Duhem advocated that separation. In Duhem's introductory lecture metaphysics figured only as exemplified by mechanistic theories which he held up as an aberration of true physical theory and the source of endless disillusion. Metaphysics, Duhem insisted, was an explanation and not, unlike physics, a mere co-ordination of data. Mechanistic physics was a source of repeated failures because it claimed to know that the nature or essence of things was mechanical and in a very specific visualizable sense. Such a specific sense was not compatible with the freedom with which the physicist could give, in practically unlimited ways, a symbolic translation of the data provided by sensory experience. The pivotal part of Vicaire's criticism was that physical science not only classified data but also looked after their causes, a pursuit plainly metaphysical in the Aristotelian-Scholastic sense which Vicaire tried to vindicate. References to Aristotle or Scholasticism were not at all the starting

20. Duhem's reliance on Ravaisson's *Essai sur la métaphysique d'Aristôte* (Paris, 1846) was particularly heavy in his discussion of Neoplatonism among the Arabs in the *Système du monde*, which he introduced with the remark, 'guided by the great metaphysician who was Felix Ravaisson . . .' (4:322).

21. See Gilson's autobiographical *The Philosopher and Theology*, tr. C. Gilson (New York: Random House, 1962), p. 17.

22. E. Vicaire, 'De la valeur objective des hypothèses physiques à propos d'un article de M. P. Duhem,' *RQSc* 33 (1893):451-510.

23. 'Quelques réflexions au sujet des théories physiques,' 1892 (6).

point of Duhem's reply.²⁴ He insisted, without even referring to common sense, that reliance on metaphysics was not necessary for the physicist who had at his disposal with immediate obviousness all the basic notions needed for his work.²⁵ At the same time Duhem recognized that the theoretical justification of that obviousness was a task of metaphysics, adding however that the assurance acquired thereby did not add to the obviousness and certainty of those notions as needed by the physicist.²⁶ The physicist, he noted in another context, needed only to hold that 'physics at its start was but attentive common sense.'²⁷ It is within such restrictions that Duhem voiced (then and later) the often misunderstood statement that physics was absolutely independent of metaphysics. In Duhem's usage too, as all too often in French parlance, the word *absolument* could simply mean plain emphasis and 'absolutely' nothing more. The independence was only that from specific inferences of an elaborate metaphysical system, but not from assertions which, however metaphysical, were to be accepted as obvious by the working physicist. The independence in question was all the less 'absolute' because Duhem argued spiritedly that his theory of physics was neither sceptical nor positivistic. The obviousness of the notions listed above barred scepticism. As to positivism, Duhem declared: 'To be a positivist is to state that there is no other logical [rational] method than the method of the positive sciences, that whatever cannot be approached by that method and whatever cannot be known by the positive sciences is in itself absolutely unknowable.' And he asked: 'Is this what we support?'²⁸

Duhem's positivism was a mere technique and not that creed which bans metaphysics. That he did not insist on the metaphysical character of the obviousness of notions indispensable for the physicist may have been the reason why logical positivists took him, rather illogically, for an ally whom they obviously read very selectively. At any rate, Duhem's lack of insistence is another evidence of the very limited perspective, the perspective of doing physics, in which he was interested in philosophy in general and metaphysics in particular. This is why his admiration for the Ecole, or Aristotelian-Thomistic tradition, was largely restricted to a view within that tradition on the role of astronomy, the only developed branch of physics until the 17th century. The role was not an explanation, that is, a search for causes, but merely the role of 'saving the phenomena,' a point which Duhem in his reply to Vicaire illustrated by a series of quotations from ancient sources including a quotation from Thomas Aquinas.²⁹ Confusion of these two roles was in Duhem's eyes the very source of the ills and woes plaguing classical physics from Descartes and

24. 'Physique et métaphysique,' 1893 (8).

25. *Ibid.*, p. 62.

26. *Ibid.*, p. 64.

27. 'Quelques réflexions au sujet de la physique expérimentale,' 1894 (5), p. 186.

28. 'Physique et métaphysique,' p. 70.

29. *Ibid.*, p. 72. In marshalling quotations from half a dozen authors ranging from Aristotle to Osiander, Duhem registered his debt to a short paper (18 pp) by P. Mansion, just published under the title, 'Sur les principes fondamentaux de la géométrie, de la mécanique et de l'astronomie' (Paris: Gauthier-Villars, 1893).

Galileo to the 19th century. He pointed his finger at the 17th-century 'revolution which played havoc with the world of reason,' through its abandonment of the 'traditional respect of the Ecole for the principle of *distinguo*.'³⁰ Here Bacon and Descartes were the special targets of Duhem's strictures, whereas Newton's dislike of hypotheses was held up by him as something that harked back to the tradition of the Ecole. Newton, Laplace, and Ampère have shown us, Duhem wrote toward the very end of his reply to Vicaire, 'that even in modern times, so proud of the developments of positive science, the sane and prudent tradition of the Ecole has not disappeared entirely, that the greatest among physicists have always recognized . . . that mathematical theories had for their object the co-ordination of natural laws and that the search for causes constituted another problem.'³¹

Duhem viewed and endorsed that 'sane and prudent' metaphysical tradition not so much for its intrinsic merits but rather as a safeguard of the autonomy of physics. To be sure, Duhem was fully aware of the fact that the metaphysical tradition in question could fulfill that role only inasmuch as it possessed a set of truths. Had Duhem been a philosopher for philosophy's sake, he would have been drawn to a thorough airing of those truths. Being above all a physicist, interested in philosophy only for physics' sake, he left that potentially rich target of positive truths unexplored. He merely stated in his reply to Vicaire that those truths were few and mostly negative. Once more he spoke with an eye on physics as he insisted that no matter how complete was one's knowledge of physical reality, the inference from it to the essence of things remained 'a knowledge which is very incomplete, very imperfect. That knowledge proceeds rather through negations than by affirmation, rather by the exclusion of certain hypotheses, which could be made on the nature of things, than by positive information on that nature. It is only in very rare cases, by the exclusion of all hypotheses except one, that we succeed in acquiring a positive datum on the essence of material things.'³²

Whatever Duhem's firm commitment to those metaphysical truths, he was distinctly wary of metaphysical systems. Unlike those truths, mostly negative, a metaphysical system was for him 'an ensemble of positive judgements which were hypothetical for the most part.' No matter how acceptable and satisfactory a metaphysical system may appear, Duhem warned in the same breath, it is 'always hypothetical for the most part.'³³ It seems indeed that Duhem's insistence on the absolute separation of physics and metaphysics was that between physics and a system of metaphysics, and not between physics and some metaphysical statements that were obvious. One may wonder what Duhem's answer would have been if asked what he meant, as he spoke three years later, 'of the great work of the Stagerite and of the masters of the Ecole, such as Thomas Aquinas.'³⁴ Could a metaphysical work, if truly great, amount to the articulation of a few, and almost invariably negative,

30. *Ibid.*, p. 75.

31. *Ibid.*, p. 82.

32. *Ibid.*, p. 60.

33. *Ibid.*

34. 'L'évolution des théories physiques . . .' 1896 (11), p. 468.

truths? Or could, as Duhem claimed, the great work of great Scholastics be merely a docility to Greek logic, and the absence of that docility be the sole cause of the decay of Scholasticism?³⁵ Duhem failed to perceive that such a work demanded more of the physicist than a rigorous observance of the distinction between physics and metaphysics. Engrossed with that distinction, he let his strictures bear heavily on any and all unobservant of it, whether a Galileo, a Descartes, or a Bacon. The latter was repeatedly singled out by him as one who precisely for that reason remained in the dark as to what science was about.³⁶

Duhem's overriding interest, the independence of physics, had its nerve center in his view that precisely because the particularly positive statements of metaphysical systems were highly hypothetical, they could never furnish an unambiguous law of physics, however elementary and fundamental. This did not contradict his insistence that those obvious notions, which the physicist took for granted on the basis of common sense, were in nature metaphysical and obviated positivism. Had he been told that his unconditional affirmation of man's ability to know reality was a genuinely metaphysical proposition, his sole caveat may have been a reference to decaying Scholasticism, wrapped up in futile distinctions.

His caveat could however issue in statements utterly void of any nuance, such as his references to metaphysics as being in his own time still in that decay into which it sank during late Scholasticism.³⁷ Yet, had he not been convinced of the intrinsic vitality of scholastic philosophy, he would not have cooperated in the launching, in 1900, of the *Revue de philosophie*. True, the *Revue* was Thomistic only in that broad sense which Duhem helped to impose on it from the start with his series of essays on the history of the notion of the 'mixed.'³⁸ In itself his essays were more germane to the history of chemistry than to philosophy. They had, however, a philosophical bearing in the sense that an analysis of what happened in science to an idea was a source of ever fresh material for the illustration and amplification of genuine philosophical truths which, however old, have an unageing timeliness. The idea of philosophia perennis, as pursued by Neo-Scholasticism, was not foreign to Duhem's thinking. It is worth noting that during the overreaction of some officials in the Vatican during the pontificate of Pius X to the modernist crisis, the *Revue de philosophie* escaped censure. The opposite was true of the *Annales de philosophie chrétienne* whose editor, the Abbé Lucien Laberthonnière, was on good terms with Duhem, which however did not make the latter a modernist.³⁹ The censure which befell on the *Annales* was certainly not prompted by the publication there of

35. 'Physique et métaphysique,' p. 75.

36. Especially in 'L'évolution des théories physiques . . .' pp. 468-70.

37. 'L'école anglaise et les théories physiques,' 1893 (9), p. 452.

38. See 1901 (1) and 1902 (2).

39. Guilt by association is the basis of the main contention of the article, 'The Catholicism of a Physicist: Pierre Duhem and the Modernist Connection,' (1976; published in mimeographed form) by R. H. D. Martin, who is inattentive to the substantial difference between modernism, such as the one professed by Loisy, who admitted no supernatural whatever, and 'modernism,' such as the one entertained by Laberthonnière and other ecclesiastics, which did not prevent them from promptly submitting to Rome.

Duhem's spirited defense, against Rey, of his philosophy of physics in which he stated that 'in order to find the title to establish its legitimacy, physical theory has to demand it of metaphysics.'⁴⁰ Such was on Duhem's part a commitment to *philosophia perennis* which long antedated the modernist crisis. Duhem would have voiced that commitment in his debate with Vicaire in terms far less damaging to positivism had he not been at heart the kind of metaphysician which every realist is.

By profession Duhem was not a metaphysician. His profession was physics and all his philosophizing was subordinate to his practising physics, yet never in a sense to make metaphysics meaningless, however indirectly. This is why a sustained reflection on physics as a field enjoying an 'absolute' independence of metaphysics did not become in Duhem's case tantamount to a mere logical analysis of physics, or to an exclusively psychological and sociological appraisal of it, let alone to a turning of logic, psychology, and sociology into ultimate frameworks of explanation. This is all the more significant because from the very start Duhem offered, as will be seen, extensive and penetrating views on physics that would have done credit to any professional investigator of the psychology and sociology of physics and to any logical analyst. But unlike most cultivators of these fields, very fashionable for the past forty or so years, Duhem never raised logic, psychology, and sociology to the status of pseudometaphysics. So much about Duhem the realist and the metaphysician, insofar as he was a physicist and wanted to achieve a thorough and cogent grasp of what physics stood for.

Rigor as strength and weakness

Duhem's reflections on physics, as presented in those early essays, have the commitment to rigor as their chief characteristic. The commitment was indeed to an absolute rigor. It is difficult to read his introductory lecture on theoretical physics without feeling that its high point is reached with the statement:

The series of deductions, which begin with the hypothesis and constitute the development of the theory, is in all its extent and in all its rigor subject to the law of physics. It is not allowed to conceal there any hole, small as it may be. If that hole is not filled, it must be filled; if it cannot be filled, it must at least be clearly delimited and presented in the form of a postulate. Much less can any contradiction be tolerated there.⁴¹

The lonely position, which Duhem began to stake out for himself and to which he remained faithful for the rest of his life, is a position demanded by rigorous logic. He knew that fashionable preferences of the times tended in the opposite direction. The exigencies of logic 'seemed to be exaggerated to many minds, even perhaps to great thinkers.'⁴² He singled out Maxwell whom he faulted for endless disregard for rigor to say nothing of his many admirers. Duhem faulted for lack of rigor those physicists who 'want mathematics only in some of its branches. They find other branches of mathematics too lofty and therefore useless. When a defi-

40. 'Physique de croyant,' 1905 (8); see English translation, 1954 (3), p. 298.

41. 'Quelques réflexions au sujet des théories physiques,' pp. 166-67.

42. *Ibid.*, p. 168.

niton appears to them too meticulous, or a proof too difficult, or a calculus too long, they declare that physics can do without.⁴³ Physics being essentially a translation of data through mathematical symbolism, it had to be subject to the dictates of that 'utmost rigor'⁴⁴ which mathematics alone could command. Logical rigor, it is well to recall, is the basis of the 'absolute separation' that Duhem saw between metaphysics and physics. It is through that rigor that he reassured himself and his students that the symbolic translation in physics, always mathematical, is not a one-to-one correspondence between facts and formalism. Devotedness to rigor prompted him to say that logic as such provided no absolute rules for the choice of hypotheses and that logic merely required that one remain consistent with the hypotheses once they were chosen. Fondness for rigor lay at the basis of his statement that physics was merely a convenient aid of memory, that hypotheses in physics had in themselves no relation whatsoever to experience,⁴⁵ that is, the real world, and that physical theories as such had an altogether relative character.

The most remembered aspect of Duhem's philosophy of physics, his insistence on the impossibility of an *experimentum crucis*, is a corollary to his bent on rigor, to his being attentive to any and all implications of his primary thesis concerning the symbolic translation of experimental data. Since such a translation could not claim a necessarily one-to-one correspondence to reality, no laws grouping those translations could be considered exhaustive, and the same held true of the hypotheses interpreting those laws. In addition, and it is here that Duhem pushed to the limit his attention to rigor, no one could ever be absolutely certain that all imaginable hypotheses had been listed concerning a group of phenomena. It was the absence of that absolute certainty that pre-empted the notion of *experimentum crucis* of its reliability. Such was the ground on which Duhem disposed of the case when in all appearance the possible choice was only between two hypotheses, the celebrated case being the conflict between the undulatory and corpuscular theories of light. The appearance, however well founded, remained but an appearance. Therefore, Duhem insisted, 'the truth of a physical theory is not decided by heads or tails.'⁴⁶ Inattention to this could only lead, he warned, to the establishment of a 'new article of the scientific *Credo*.'⁴⁷

The impossibility of *experimentum crucis* was one of the negative aspects of Duhem's taking rigorously the always partial reliability of the symbolic translation. The other, no less important and positive side of the coin was the reliability of that translation, however non-exclusive and incomplete. Duhem from the start opted for a course between dogmatism and scepticism. Precisely because of that reliability Duhem could be assured of something positive in any phase of physical theory. Herein lay the logical foundation of Duhem's insistence on the continuity

43. *Ibid.*, p. 172.

44. *Ibid.*, p. 173.

45. *Ibid.*, p. 148.

46. 'Quelques réflexions au sujet de la physique expérimentale,' p. 195.

47. *Ibid.*, p. 194.

of physical science and of his justification to render to mechanistic physics its due while relentlessly combating it as the wrong ideal.

Duhem's notion of the continuity of physics, as a derivative of his concern to be rigorous and consistent with his analysis of physics as a theory, naturally led to his notion of the progress of physics as advocated in those early essays. Since physics rests on a symbolic translation of sensory data into quantitative parameters, which are not necessarily exhaustive, the progress of physics could not be considered something equivalent to the progress of a deductive system, best exemplified in Euclidean geometry. Physics did not progress through the logical and rigorous addition of one truth to another. But since the same translation could not be conceived, even in its early and primitive stage, as something altogether wrong, the succession of physical theories implied a genuine growth, indeed a progress toward a classification which was less and less artificial and more and more natural.⁴⁸ Long before his *Théorie physique* Duhem included in his reflections on physical theory the ideal of natural classification and he did so in a truly Aristotelian vein. In his essay on the English school he spoke of natural classification as something which mirrored 'more and more perfectly that order in which the laws [of physics] would be arranged by an intelligence which sees the *essence* of things.' (Italics added).⁴⁹ Such was the parlance of a realist not at all hostile to essentialism, a parlance very different from that of a pure logician. After all, it was not in logic as such that Duhem saw the ultimate reason why incoherence among hypotheses making up the theory had to be avoided. Incoherence could not be tolerated because, and he used capitals, 'IT HARMED THE PERFECTION OF PHYSICS.'⁵⁰ Unlike in the *Théorie physique*, where he made recourse to the ability of the 'heart,' as articulated by Pascal,⁵¹ to provide a further basis for the validity of the ideal of perfect knowledge about reality, here the standard of perfection as implied by rigor in reasoning was a sufficient foundation.

Rigor in reasoning as a commitment to the idea of perfection was no less a determining factor in the broader aspects — psychological, sociological, and historical — of Duhem's portrayal of the philosophy of physics in those early essays. As was already noted, Duhem's chief grievance against mechanics was its incurable involvement in assumptions which resisted rigorous justification and invariably led to contradictory assertions about the constitution of matter. Yet the very flourishing of mechanistic physics for over two hundred years evinced at least two things: mechanistic physics was very fertile in discoveries and a large number of physicists gladly lived with its inconsistencies. Duhem credited that fertility not to mechanics as such, but to the fact that, as any other sufficiently rational science, physical science too tended to be mechanical in its youth.⁵² He also insisted that whatever there was of lasting value in the various discoveries and achievements of mechan-

48. 'L'école anglaise et les théories physiques,' pp. 369-70.

49. *Ibid.*, p. 370.

50. *Ibid.*, p. 367.

51. See English translation, *The Aim and Structure . . .*, 1954 (3), p. 27.

52. 'Quelques réflexions au sujet des théories physiques,' pp. 162-63.

istic physics, it did not derive from mechanical assumptions as such but from the mathematical formalism into which mechanistic physics was translated. Mechanistic physics as an ideal was in Duhem's eyes similar to the fabled land of Eldorado. The fact that in the vain search for that land many interesting discoveries were made, did not justify the putting of Eldorado on the map.⁵³ As to the satisfaction felt by physicists about mechanistic science, he gladly granted it to the Anglo-Saxons. He felt that the very opposite was true of French (and German) physicists whose thinking was by and large dominated by rigor and consistency.

This coupling by Duhem of French and German, that is, continental mentality with the ideal of physics as he conceived it, is noteworthy not so much because of its measure of reliability (which is very modest at most), but because of the glimpses it gives into the personal roots of Duhem's philosophy of physics and also into its high degree of originality. Undoubtedly, Duhem was familiar with Taine's *Notes sur l'Angleterre*, a book two decades old by 1893 and of nine editions, in which a chapter dealt with the comparison of the English and French ways of thinking.⁵⁴ Such a comparison, made popular by Edmund Burke and Mme Stael, bore mostly on artistic, political, and moral characteristics but hardly ever on science. It should seem curious that Taine's aside on the difference between a Stevenson, who imagined all parts of a locomotive before constructing it, and a Foucault, who was led to the idea of a gyroscope by unfolding the logical consequences of a theorem in mechanics, did not prompt any scientist in France to develop a potentially rich theme. Duhem, who did not utilize this detail, could hardly learn anything along such lines from Taine's nephew, Chevrillon, his colleague and good friend in Lille who taught English literature there. For his insights on the difference between English and French novelists, Chevrillon may have received no less valuable details concerning the frames of mind of French and English physicists which Duhem portrayed systematically in a long essay in 1893.⁵⁵ Poincaré's few words on the subject⁵⁶ may have sparked Duhem's re-

53. 'Physique et métaphysique,' p. 83.

54. See ch. 8, 'The English Mind,' in Taine's *Notes on England*, translated with an introduction by E. Hyams (Fair Lawn NJ: Essential Books, 1958), pp. 242-77, where learning, art (painting), and religion form the three main topics. In discussing English painters Taine had, of course, to go beyond Turgot, who in the 1750s still could speak of an absence of great painters in England and ascribed it to Protestant insistence on simplicity of worship. On scientific creativity, the context of Turgot's remarks, see my Fremantle Lectures (Oxford), *The Origin of Science and the Science of its Origin* (Edinburgh: Scottish Academic Press, 1978), pp. 32-34.

55. 'L'école anglaise et les théories physiques,' 1893 (9). Chevrillon left Lille three years before the publication of that essay. This may explain why there is no reference to its topic in Chevrillon's long letter to Hélène Duhem, quoted in Ch. 2, although Chevrillon keenly remembered his discussions with Duhem on the purely instrumental character of scientific theories. Chevrillon's *Etudes anglaises* (1901) and *Nouvelles études anglaises* (1910) were on purely literary topics.

56. In the opening pages of Poincaré's introduction to his *Electricité et optique. I. Les théories de Maxwell et la théorie électromagnétique de la lumière. Leçons professées pendant le second semestre 1888-89*, rédigées par J. Blondin (Paris: Georges Carré, 1890), pp. v-vi. For quotations from it, see the preceding Chapter.

flections but did not diminish his originality, which stands out in comparison with the lengthy discourse devoted by J. T. Merz to the topic in 1896.⁵⁷ At any rate, Duhem did not claim originality in his stressing, in general, the rigorousness of French thinking, or in particular, in his contrasting French law, a systematic code, and English law, a confusing superposition of customs, because such views had long been commonplace.⁵⁸

Duhem's essay amply reveals his personal conviction that physics should be cultivated by French physicists in a manner compatible with their national and cultural identity. To articulate that message was not without its hazards which may have outweighed its opportunities. Duhem obviously relished the opportunity to discuss aspects of physical theory that reflected more than the strictly reasoning and purely observational faculties of man. A chief of those aspects was the role of imagination, robust in the English mind to the point of luxuriance. That mind Duhem saw forcefully exemplified in Dickens' novels where enormously composite series of scenes best revealed their unity to one's imagination. Was the French mind as frustrated by a vigorous display of imagination as the contrast drawn by Duhem seemed to indicate? His drawing of that contrast was in fact faulted by more than one, almost deliberate, oversight. In saying that the imaginative British mind did not issue in one single metaphysician, Duhem had to overlook Bishop Berkeley whose criticism of the mechanistic ideology within Newtonian physics would have done credit to any French mind. Duhem could not deny that Newton's *Principia* was far superior to any presentation of Cartesian physics, precisely because of Newton's emphasis on mathematics, a characteristic largely reserved by Duhem to physics as cultivated by the French. He failed to recall that the *Principia* was first under suspicion in France because it appeared there too mathematical to qualify for physics. Duhem made much of the love of mechanical models as characteristic of the English mind, not remembering at the same time that Descartes was a passionate model maker. There was only a touch of truth in

57. The first three chapters on scientific spirit in France, Germany, and England, respectively, in J. T. Merz's *A History of European Thought in the Nineteenth Century* (1896; New York: Dover, 1965) offer much more on the organization of scientific research than on the spirit in which it is carried out. While Merz's book is quoted by A. Feuillerat in his *French Life and Ideals* (tr. Vera Barbour; New Haven: Yale University Press, 1925), the English text of his lectures at Yale in 1919-20, he did not seem to know of Duhem's long essay. A curious fact, indeed, because Feuillerat (1874-1952) was professor of English literature at the University of Rennes from 1910 until taking in 1929 the post of director of French studies at Yale.

58. 'L'école anglaise . . .,' p. 362. That commonplace character was well attested by Fichte's remark made in connection with the preface Schelling wrote to the German translation of Cousin's *Philosophie française et allemande* (1835): 'What distinguishes the French in their scientific productions and what has a deeper connection than people suppose with the real appreciation of truth, is the lucidity, the harmonious completeness of the idea, the rigorousness with which it is stated, and the clarity of the definitions . . . By the degree in which the French assimilate our theories we can recognize the degree of finality of those theories. They are the first and the most unanswerable judges of the lucidity, maturity, and the truth of an idea' (quoted by Feuillerat, *French Life and Ideals*, p. 66). Needless to say, by scientific (wissenschaftlich) Fichte meant above all philosophical notions and themes.

Duhem's generalization that the English mind loved complex mechanical models, whereas the French loved the simple ones. Duhem saw differences even in the respective uses of mathematics by English and French physicists. The former, according to him, were interested in calculational skill, the latter in theorems.

The contrast as drawn by Duhem between the freedom of the physics teacher in England, who could play on the imagination of his audience, and the constraint of the physics teacher in France, who had to obey the craving of his audience for systems, was clearly exaggerated.⁵⁹ Was it really a characteristic of imaginative English physics that some English physicists fell ready prey to spiritism and kindred pursuits?⁶⁰ Was it more than an occasional aberration that a false system was in France preferred to no system at all, with the consequent symptom of some charlatanism in teaching? Was it again a matter of difference between national mentalities that many more discoveries and inventions were made in the Anglo-Saxon world than in France? Was not this due rather to the fact, not broached by Duhem, that by the 1890s the combined scientific and technological resources of Great Britain and the United States were far vaster than those of France? Was it really convincing to represent Kelvin's theories as a vast bouquet of flowers thrown together at random, and Helmholtz's theories as a huge oak tree expressing a unity of structure?⁶¹ It was only two decades later, as will be seen, that Duhem acknowledged the ability of a true genius to transcend his 'national' limitations, with the result that he could no longer take his hero, Helmholtz, for a representative of the German mind or even for the continental mind for that matter.

That Duhem more than suspected the fragility of the contrasts he had painted with sweeping strokes was all too clear from the concluding chapter of his essay. There he stated that truth, and certainly scientific truth, was above race, culture, language, and nationality. The spirit of truth, as Duhem admitted, could blow where it wanted to. Still he felt that something of the contrasts he had drawn could be saved by attributing if not to truths, at least to errors some recognizably national character. The same was true of the choice among hypotheses, never purely a matter of logic.⁶² Therefore the contrasts were so many useful suggestions about intangible factors at play in the construction of physical theories. His fond-

59. 'L'école anglaise . . .', p. 372.

60. *Ibid.*, p. 371. Duhem listed Crookes, Lodge, and Tait, of whom the first two were notorious on that score.

61. *Ibid.*, p. 375.

62. *Ibid.*, p. 376. This was Duhem's reply to an animated criticism of Poincaré's introduction by Joseph Bertrand, perpetual secretary of the Académie des Sciences, who asked: 'Why should we assume that an Englishman or a German would be less upset by the lack of rigor? Have two centuries been enough to change the spirit of nations, and do the descendants of Newton take today imagination in physics while leaving to the compatriots of Descartes respect for rigor and love of precision?' (*Journal des savants*, Dec. 1891, pp. 742-49; for quotation see p. 743). Bertrand was in full agreement with the emphasis laid on rigor by the 'new school' of French physicists, who claimed in Bertrand's words, not quoted by Duhem: 'It matters little that a proof set forth in a few lines be more or less easy to complete; rather, it is dangerous to propose to young students proofs without full rigor. This is the trend of the new school' (*ibid.*, p. 748).

ness for those contrasts was a derivative of his desire to do full justice to the nature of physical theory, a desire revealing once more the realist he was at core. Completeness was also part of rigor which he never abandoned as a standard. Part of that completeness was the inevitable incompleteness of the individual embodying strength as well as weakness. Physics could in no way be completed by a single man, whatever his genius, or by a single epoch, culture, or nation. While he pleaded for teaching physics in France in the French way, that is, in a logically rigorous way, he did not want to impose that way outside France, nor was he blind to the weaknesses it revealed. Perhaps he even sensed that he was painting his own profile as a physicist whose strength was the firm hold on what had already been conquered and not the vigor of advancing boldly into the unknown:

The [methodical] need to connect logically his deductions, to render his thoughts orderly, leads the French or German physicist to be prudent and even timorous. He wants to tolerate in his theories neither contradictions nor any hiatus. Therefore every proposition whose tie with the principles assumed is not clear and evident, all that is strange, all that is surprising, appears to him by that very fact as something which must be called into doubt . . . The prudent mind of the physicists of the continent is marked above all by the hesitation with which they face certain questions situated at the outer limits of science: the inner constitutions of the material world, the world as it existed millions of centuries ago, the world as it will be in millions of centuries. These questions, so vast, complex and troublesome, we cannot see them resolved without being shaken by an impulse of scepticism . . . Our need for not admitting anything which does not follow clearly from accepted principles makes us diffident of all unexpected discovery. Of this need there follows the routine thinking, hostile to novelties, so often held against the scientists of the continent and against the Academies they compose. This fear of the unforeseen, born enemy of the inventive genius, the discoverer finds it not only around himself but even in himself. Even his own reason refuses to admit the exactness of the new idea which germinates in him as long as he has not analyzed that idea and has not entered it in a system of logically connected deductions.⁶³

Admirable as such a passage is for its candor and consistency, it reveals in Duhem's stance a weakness which in retrospect could seem to be a reason for the muted reaction to Duhem's early philosophical writings. They did not exude enthusiasm for novelty at a time when cathode rays, radioactivity, and X-rays began to give physical research unexpectedly new perspectives. It would, of course, be very wrong to picture all the physicists around 1900 as riveted on those novelties. Even among the relatively few who kept abreast with the latest, and indeed produced it, there were some, such as Poincaré, who retained fairly traditional views. Few leading physicists were indeed more consciously cautious about discarding the ether than was Poincaré. There is therefore more than what meets the eye in Poincaré's disinterest in Duhem's philosophy. Poincaré was not only a creative mathematical physicist but also professed a philosophy of physics which in several points showed superficial resemblances to that of Duhem, as can be seen from Poincaré's *La science et l'hypothèse*, first published in 1903. A year earlier Poincaré provided unwitting evidence of his familiarity with Duhem's articles,

63. 'L'école anglaise . . .', pp. 370-72.

especially with the longest of them on experimental physics. In a review of Edouard Le Roy's long essay on science and philosophy, published in 1899 in the *Revue de métaphysique et de morale*, Poincaré tried to shore up mechanistic physics against Le Roy, who based in part his defense of human freedom on Duhem's argument that physical theory in general and classical Newtonian mechanism in particular (which implied strict determinism) never could be final. In this connection Duhem set great store by the complexity of any theory and illustrated it by a conceptual analysis of the measurement of electric current. Without referring to Duhem, Poincaré set forth the same example⁶⁴ in order to refute the philosophical gist attributed to it by Duhem, who insisted on the impossibility of an experiment that could definitely prove or disprove a particular theory.

Such a failure to give proper credit does not seem to have been an accident. Poincaré in fact had already been reminded by Hadamard of Duhem's priority and in no less a prominent forum than the International Congress of Philosophy held in Paris in 1900, following Poincaré's argumentation that no experiment can verify the basic principles of mechanics.⁶⁵ It seems indeed that because of his incisive attacks on mechanism Duhem was slated for deliberate slighting within an establishment, of which Poincaré was a leading figure and where the truth of mechanistic physics was the basis of a scientific *Weltanschauung*. What that establishment expected to hear from physicists was rather the utterance of Cornu, made also in 1900 at the International Congress of Physics held in Paris: 'the more we penetrate into the knowledge of natural phenomena, the more developed and

64. H. Poincaré, 'Sur la valeur objective des théories physiques,' *RMM* 10 (1902): 263-93; see especially pp. 270-72. The best part in Poincaré's article was his remark, 'c'est librement qu'on est déterministe' (p. 288), whose vast metaphysical bearing he was reluctant to recognize, in line with the philosophical superficiality with which he added one sparkling phrase to another.

65. Poincaré's argumentation was part of his paper, 'Sur les principes de la mécanique,' read in the general session (Aug. 2, 1900) of the section 'Logique et histoire des sciences.' For the summary of that session, see *RMM* 8 (1900):555-61, where Hadamard's intervention is reported on p. 559. The report contains no indication that in his reply to Hadamard Poincaré had referred to Duhem. Poincaré's paper prompted several participants to rally to the defense of reality as the object of scientific work, which Poincaré parried with the remark that the question of the reality of the external world be better discussed in another section of the Congress! Possibly, at that point some participants recalled that already in 1888, as he eulogized Sully Prudhomme, whose chair he took in the Académie Française, Poincaré declared: 'Tout ce qui n'est pas pensée est le pur néant.' Such idealism bordering on solipsism was a lasting conviction with Poincaré, as witnessed by the concluding paragraph of his essay, 'Science and Reality,' in which he repeated the same phrase and added as an explanation: 'Since we can think only thought and all the words we use to speak of things can express only thoughts, to say there is something other than thought, is therefore an affirmation which can have no meaning.' *The Value of Science*, authorized translation with an introduction by G. B. Halsted, with a special prefatory essay (New York: Dover, 1958), p. 142. The French original appeared in 1913, a year after Poincaré's death.

precise is the audacious Cartesian conception of the mechanism of the universe.⁶⁶

Such a boast was symptomatic of a weakness, compared with which Duhem's view of physics could, for all its weaknesses, appear very robust indeed. Certainly, that view was much stronger than the implicit identification of realism and mechanism which underlay the position of some Neothomist critics of Duhem's early philosophical essays, such as Vicaire and Count de Vorges, an identification which, as Lacombe's defense of Duhem showed, revealed a lack of grasp of what Thomism was about.⁶⁷ The failure of leading Neothomists to discuss Duhem's essays may have been motivated by their weakness in physics. The very muted reaction to those essays by the intuitionists among antipositivists seems to suggest that the rigor in Duhem's reasoning was unpalatable to them. Bergson failed to react, although he could not be unaware of those essays. It is most likely that Bergson discussed the contents of a long paper which Edouard Le Roy, his favorite student and future successor at the Collège de France, published in two parts in 1899 and 1900 in the *Revue de métaphysique et de morale*. Le Roy, who at that time was still a teacher of special mathematics at the Collège Stanislas, seized on Duhem's rebuttal of the idea of *experimentum crucis* as he pleaded the cause of freedom, intuition, and metaphysics.⁶⁸ Le Roy's paper, which prompted Poincaré to defend mechanistic physics, was not the only reference to Duhem's philosophy in that journal. Also in 1899 E. Wilbois referred there to Duhem's essay on experimental physics in discussing the philosophy of science.⁶⁹ More significant was the reference to Duhem's essay, 'si intéressant et si complet' by G. Milhaud, who followed in the footsteps of Boutroux in combating scientific dogmatism, in the summary of his course on 'rational science,' published in the same *Revue* three years earlier.⁷⁰ Such was however the recognition by the disciples of the significance of Duhem the philosopher and not by their masters who to a man kept aloof.

Philosophy through history

While Duhem could take some gratification from these short references, he could

66. *Travaux du Congrès International de Physique, Paris 1900*, ed. C.-E. Guillaume and L. Poincaré, vol. IV (Paris: Gauthier-Villars, 1901), p. 7. As to Henri Poincaré, he endorsed as late as 1908 the mechanical explanation of electron theory; see his 'La dynamique de l'électron,' *RGS&PA* 19 (1908):386-402.

67. As discussed in Ch. 4.

68. E. Le Roy, 'Science et philosophie,' *RMM* 7 (1899):375-425, 503-62 and 8 (1900):37-72. Le Roy's statement, 'la contingence des lois scientifiques résulte encore de leur incroyable complexité; c'est un point que M. Duhem a remarquablement développé' (p. 328), seemed to imply uncertainty in the physical interactions themselves, an inference which Duhem would have considered an unjustified extension of his reasoning.

69. E. Wilbois, 'La méthode des sciences physiques,' *RMM* 7 (1899):579-615. Duhem must have been puzzled on seeing his rejection of an *experimentum crucis* used by Wilbois as a proof that 'le mot certitude en physique n'a donc pas le même sens qu'en histoire' (p. 602). He must have been even more puzzled by the absence of reference to him as Wilbois presented a historical material, a good part of which was identical with the historical documentation in Duhem's article on experimental physics!

70. G. Milhaud, 'La science rationnelle,' *RMM* 4 (1896):280-302.

on the whole but feel frustrated, though not vanquished. He was a born fighter whom no adversity or lack of adequate response would discourage. He was totally committed to his philosophy which, as was already noted, though it cannot be emphasized enough, had the proper idea of physics for its sole concern. The core of that idea was the point that the physicist must avoid attributing some specific hidden constitution to matter, an attribution particularly evident in mechanistic theories dominating various branches of physics, if the physicist did not want to become trapped in contradictions. Avoidance of imagining underlying structures entailed the limiting of the physicist's attention to observable data, obtained either directly by the senses or through the mediation of instruments. Duhem saw this point vividly illustrated in the historical development of any major branch of physics, and he considered this illustration particularly telling and effective. It was also an illustration which, in all evidence, he relished to set forth. Two of his philosophical articles published during his last years in Lille were heavily historical and were followed up by a no less philosophically oriented history of optics and of the physics of heat. Between 1901 and 1903 he published three major historical essays, one dealing with chemistry, another with electromagnetics, and the third with mechanics.

Telling as these studies were of his mastery of the historical material, the latter was distinctly in the service of the philosophical point. The point was in itself a precept of logical rigor, but closely attached to it was the role of common sense, the source of all data useful for physics, data either obtained directly through the senses or through the mediation of instruments. Duhem saw in thermodynamics, developed during the last quarter of the 19th century in opposition to mechanistic theories, the peremptory vote of physics on behalf of the fundamental and irreplaceable role of common sense, that is, sensory evidence as the sole object of physics, a discipline with built-in incompleteness. That the mathematical formalization of the laws, which grouped sensory data, could never claim strict one-to-one correspondence with physical reality was one major argument in Duhem's eyes of the essential incompleteness of physics, the other being the richness and complexity of physical reality which commonsense observation, however sustained and meticulous, could not exhaust.⁷¹ Yet, insistence on common sense, or rather on the ultimate reliability of sense data, made sense only if one assumed external reality to be thoroughly lawful and if one also assumed the efforts of the human mind to be progressively successful. While Duhem was increasingly wont to justify these assumptions in Pascalian terms, he was more a disciple of Aristotle than of Pascal.

Indeed, he considered the whole argument of his historical critical study of the notion of 'mixed substance' (compounds) as a commentary on the theme on which Aristotle clashed with the atomists and which, so Duhem believed, proved Aristotle's view victorious. The view was the primacy of commonsense evidence.

71. *L'évolution de la mécanique*; see English translation, *The Evolution of Mechanics*, 1980 (1), p. 187. The same idea is also stressed in *La théorie physique*; see English translation, 1954 (3), p. 22.

Duhem's long and meticulous survey of the various steps, through which chemistry tried to come to terms with the problem of compounds (steps of which well over the greater half related to the history of chemistry after Lavoisier), ended with the declaration that 'chemistry in its latest and most developed form, or chemical mechanics, tends to take on a peripatetic form.'⁷² The expression 'form' was more telling on Duhem's part than perhaps he suspected. It was clearly dictated by the very restricted perspective in which philosophy served his purpose. He claimed that peripatetic physics and modern physics had one starting point: the logical analysis of sense data. Duhem simply assumed the acquisition of such data through common sense which was in fact the crucial starting point for Aristotle. Form or formalism made no sense without something to be formalized, a point which Duhem would have been the first to admit, but which, on account of his very restricted perspective, he easily overlooked at crucial junctions. What he was interested in proving above all was that physics did not have to admit hypotheses, so many forms of metaphysics, about the structure of matter. This was, of course, an indirect way of asserting the primacy and adequacy of a commonsense perception of reality. He said very little about the fact that his very interest rested on a metaphysics which could not help being ushered in by reliance on common sense.

Logic and reality were in Duhem's view two mutually irreducible sides of the same coin, but he was much more intent on articulating the rule of logic in physics than the role of reality. A case in point was his great critical essay on Maxwell which in turn was supported by a long historical analysis of the basic notions of electrostatics and electromagnetics. From almost the very start Duhem kept referring to the indispensability of rigor and to its absence in Maxwell's theory. The genius of Maxwell he certainly acknowledged, but added in the same breath that 'there is no genius so great as to be above the laws of reason.'⁷³ Those laws implied that reality be retained as the basis of physical theory, if indeed Maxwell's greatest disregard of logic consisted in his introducing a mathematical factor, denoted as dielectric current, to which no physical magnitude corresponded. Duhem's cursory though emphatic attention to reality should seem all the more inconsistent with his precepts and strictures as he insisted that 'physical theory should give as simple a description of the physical world as possible.'⁷⁴ In stating this Duhem meant the real physical world and not merely the world of sensations in the Machist sense. Yet Duhem's overriding concern was the *description* of reality and above all the simplicity of that description. An articulation of the philosophical significance of reality was not prompted by that concern.

This is not to suggest that Duhem was not aware of the philosophical potentiality of a detailed analysis of the various phases undergone by physical theory. In speaking about the radical shift of perspective which witnessed the reversal of

72. *La notion de mixte*, 1900 (1), p. 740.

73. *Les théories électriques de J. Clerk Maxwell*, 1902 (3), p. 15.

74. *Ibid.*, p. 7.

fortunes in the seventeenth century between old scholasticism and new physics Duhem characterized that shift as being 'full of philosophical instructiveness,'⁷⁵ and hoped to set it forth eventually in all detail. Duhem made this remark in the very first of his eight essays (*L'évolution de la mécanique*) which appeared between January 15 and April 30 in eight consecutive issues of the bimonthly, *Revue générale des sciences*. The series of essays, invited by the editor of the *Revue*, gave a choice opportunity for Duhem to expound with respect to mechanics, the basic physical science, the very same essential lesson which he had already elaborated with respect to the narrower topics of chemical compounds and electromagnetism. The lesson, as was already noted, was above all a lesson for physics though with a very specific philosophical component. Duhem called for an abandonment of the metaphysical garbs which the science of mechanics assumed between Descartes and Kelvin, and also for a reinstatement of the objective value of some secondary qualities and especially of the Aristotelian concept of motion.

Not that Duhem wanted to subject physics to another metaphysics. The secondary qualities, especially the sensation of heat, were to be reintroduced only inasmuch as they could be subject to mathematical treatment. Yet recognition of any secondary qualities implied a vote on behalf of that realism which had already been eroded through the handling of primary qualities from Descartes to Kelvin and beyond. Material reality seemed indeed to dissipate as the logic of Cartesian assumptions slowly but relentlessly unfolded itself. The ether constituting Kelvin's vortex atom, Duhem argued, was not really different from that pure spatial extension to which Descartes reduced matter.⁷⁶ Physics was, in the virtue of the same logic, becoming the study of purely spatial alterations in which the total energy was conserved. Energy then simply could displace material reality, a point made by Ostwald, according to whom when one was hit by a stick, it was the energy difference touched off in one's senses that was to be resented and not the stick. While Duhem was willing to resent the energy difference, he was most unwilling to slight the existence of a stick.⁷⁷ Ostwald's claim that matter was merely

75. *The Evolution of Mechanics*, p. 5. Apart from the many typographical errors, this translation can only be faulted on account of its too great fidelity to the original.

76. *Ibid.*, p. 94.

77. *Ibid.*, p. 95. Duhem's reference was to Ostwald's article, 'La dérouté de l'atomisme contemporain,' which, when published in *RGS CPA* (15 nov. 1895, pp. 953-58), created quite a stir. No wonder. Ostwald's antiatomism was a radical antirealism. According to him 'la matière est une invention, assez imparfaite d'ailleurs, que nous nous sommes forgée, pour représenter ce qu'il y a de permanent dans toutes les vicissitudes' (p. 956). Ostwald's article prompted two rebuttals in the December 15 issue of the same Journal of which one, by A. Cornu, was a stereotyped defense of mechanism. In the other, by M. Brillouin (then maître de conférences at the Ecole Normale), reference was made to a group of physicists, who on some points fight on Ostwald's side, among whom, Brillouin wrote, 'I must cite Duhem because of his profound knowledge of topics which he does not disdain to popularize and because of his lofty conception of scientific knowledge' ('Pour la matière,' *ibid.*, p. 1033). Duhem would have been more pleased if Brillouin had referred to his defense of material reality, a topic on which Brillouin did not show much incisiveness.

a fiction to account for the permanence of our sensations was unacceptable to Duhem because that claim struck by the same stroke at the root of philosophy as well as physics. The idea of physics as the localisation of phenomena in an extension devoid of matter was for Duhem 'an attack of vertigo.' Against it the sole remedy was to

cling with all our strength to the bedrock of common sense; for our most sublime scientific knowledge, in the final analysis, has no other foundation than the facts admitted by common sense; if one puts in doubt the certainties of common sense, the entire edifice of scientific truth totters upon its foundations and tumbles down.⁷⁸

Clearly, when Duhem described himself privately as 'the apostle of common sense,' he did not emphasize an aspect of his philosophy that had not always been fundamental. He did not want to appear the kind of philosopher for which he was largely taken decades after his death, especially in the Anglo-Saxon world, a philosopher lost in logical analysis, however powerful, or a philosopher wrapped up in graphic portrayals of the psychological components of scientific thinking. Nor did he want to appear as one pursuing rigor for rigor's sake. Yet for all these misinterpretations he had a blame to share. His insistence, however emphatic, in the concluding chapter of the first half of *L'évolution de la mécanique* on the grasp of reality by common sense, dwarfs in length with respect to philosophically secondary points developed there. One is the explanation of his claim that 'for physicists the hypothesis that all phenomena can be mechanically explained is neither true nor false; there is no meaning in saying so.'⁷⁹ The other is his account of the respective chances of abstract and imaginative minds with respect to the impasse in which mechanistic explanation finds itself.⁸⁰ Again, while Duhem was not mistaken in attributing crucial importance and originality to his views on quality as a category which permits quantitative treatment, his discussion of this point in the same series of essays far exceeds in length⁸¹ his statement there about the philosophically much more fundamental topic of the commonsense grasp of reality. Yet the status of qualities was essentially dependent on the validity of common sense and the latter was the only philosophical justification of his own idea of physics and of its continuous progress and evolution.

Much of the second part of *L'évolution de la mécanique* was taken up with the

78. *The Evolution of Mechanics*, p. 95.

79. *Ibid.*, p. 97. The phrase is in Italics in the original as well as in the translation.

80. *Ibid.*, pp. 99-101. Duhem argued that the imaginative thinking, heavily relying as it does on constructing mechanical models, has a threefold disadvantage. First, the models cannot be specific enough and therefore run the risk of becoming occult qualities; second, no mechanical model can claim exclusive validity because an infinity of other models can also be constructed, third, the imaginative process, unable to secure clarity among the large number of alternatives, would foment a conceptual chaos. Brillouin's characterization of the imaginative approach as 'rapid, intuitive, and fertile' was strongly doubted by Duhem whose singling out Brillouin as a spokesman of that approach could be a reaction on Duhem's part to Brillouin's wholly negative attitude toward Marchis' doctoral thesis.

81. Indeed, he devoted to it an entire chapter; *ibid.*, pp. 105-10.

detailed account of what was accomplished by him in articulating a new type of physics, an account indispensable for the evaluation of Duhem the physicist. The contribution of that second part for an understanding of Duhem the philosopher is in the general conclusion where Duhem emphasized the organic continuous growth of physics and in the first chapter devoted to the question of quality as subject matter for physics. Those familiar with the fact that the second part of Duhem's best known philosophical work, *La théorie physique*, also begins with a chapter on qualities will not miss the significance of that similarity. *La théorie physique*, which is all too often read with no consideration of Duhem's previous publications on the philosophy of physics, is in fact an organic outgrowth from them which anticipate it not only in content but also in format and above all in purpose and emphasis. Had this continuity or repetitive pattern been paid more attention, Duhem the philosopher would be known today in a way more genuine than actually is the case.

Philosopher on trial

The *Théorie physique*, which first appeared as a series of monthly articles between April 1904 and June 1905 in the *Revue de philosophie*, is not absolutely indispensable for a careful reader of Duhem's previous publications to form a substantially correct idea of Duhem's philosophy. Abel Rey, whose over 40-page-long essay on Duhem's 'scientific philosophy' appeared in the July 1904 issue of the *Revue de métaphysique et de morale*, was correct in stating in a last-minute footnote that those articles 'change nothing in the general teaching of their author.'⁸² Certainly, the *Théorie physique* represented no *essential* change in respect to the *Evolution de la mécanique* and earlier publications by Duhem. Yet the really fundamental facet of Duhem's philosophy could be overlooked or at least misconstrued by a reader, however careful, of what Duhem published prior to the *Théorie physique* if he had no eyes for that facet. Rey's article retains a lasting instructiveness precisely as such a misconstruction and oversight. Not that Rey's approach, a portrayal of the two main interpretations of science, the causalist and the commodist, had not been auspicious for a proper grasp of Duhem's philosophy. Even Rey's description of the causalist or mechanistic notion of science in terms of long quotes from Berthelot's writings⁸³ could be seen justified, as Berthelot was in the eyes of many its authoritative spokesman. Yet in an article on Duhem a prominent recourse to Berthelot at the very start may have also signaled a subtle declaration of loyalty on the part of Rey, still a mere agrégé and a teacher of philosophy in a lycée in the provinces.⁸⁴ Indeed, Rey put Duhem the philosopher on trial in the

82. A. Rey, 'La philosophie scientifique de M. Duhem,' *RMM* 12 (1904):699-744.

83. They were taken from a letter of Berthelot to Renan, published in the latter's *Dialogues et fragments philosophiques* (3d ed.; Paris: Calman Lévy, 1886), p. 196, where Berthelot spoke of the rapidly growing pyramid of scientifically established interconnection of causal laws in nature.

84. The lycée in question was in Beauvais. Rey arrived in Paris in 1919, after serving on the Faculté des Lettres of the University of Dijon.

court of Berthelot's scientism where some important and very relevant considerations had no right to be heard.

At any rate, Rey was correct in his resolve to make Duhem's philosophy appear in terms of Duhem's ideal of physics, that is, a philosophy as different from the philosophy of mechanistic physics as from its commodist or pragmatist interpretation. About the originality of Duhem's effort 'to pitch his tent'⁸⁵ between these two camps Rey made no secret. But was the effort as purely scientific as Duhem claimed it to be? The very opposite was true, Rey claimed, because Duhem refused to accept the fact that the Cartesian or mechanistic universe was intelligibility itself. By refusing that intelligibility Duhem was forced to look for an explanation in metaphysics which for Rey was not knowledge but faith. Duhem's philosophy of science became therefore in Rey's eyes a 'profession of metaphysical faith,' and 'the scientific philosophy of a believer.'⁸⁶ Such a scientific philosophy, Rey stated not too implicitly, was mystery-mongering the essence of which was a 'counter-revolution' against the clarity of the scientific Renaissance.⁸⁷ Rey therefore was forced to speak of Duhem's philosophy of science as something which scientifically and not only metaphysically takes the universe for an ultimately mysterious entity and specified the 'sheer will of its author'⁸⁸ as the basis of that philosophy. Such was an inevitable verdict if metaphysics was not rational knowledge. Yet even within the particular context of Rey's evaluation of Duhem's philosophy that verdict could pass for scholarship only if a reasoned rebuttal had been offered by him on what Duhem said on the role of common sense and on natural classification as reflecting on ontological order. On both counts, Rey uttered not a word. He made himself thereby a most vulnerable target to Duhem's famed rebuttal, 'Physique de croyant,' in the October 1905 issue of the *Annales de philosophie chrétienne*.⁸⁹

Duhem's moving profession of his Catholic faith which started his reply to Rey was in a sense irrelevant to the issue. Duhem himself admitted that Rey did not mean that his physics was that of a *Catholic* or religious believer. Yet the unabashed sincerity with which Duhem spoke of his Catholic faith was an assurance that the same sincerity would be accorded to Duhem's account of the genesis of his notion of physics, a genesis in which religious considerations played no part. That genesis postdated the years when in Stanislas he was tutored by Moutier. Whatever Moutier's critical sense and his grasp of the importance of thermodynamics, he was, in Duhem's words, a convinced mechanist. And so was Duhem himself through all his years at the Ecole Normale. In his belief that mechanical theories gave an explanation, he was certainly not shaken by the 'jesting scepticism' of Bertin, who lectured on physics at the Ecole Normale. The insistence of his beloved

85. Rey, 'La philosophie scientifique de M. Duhem,' p. 704.

86. *Ibid.*, pp. 734 and 741.

87. *Ibid.*, p. 741.

88. *Ibid.*, p. 743.

89. 1905 (8). References will be to the English translation in *The Aim and Structure of Physical Theory*, 1954 (3), pp. 273-311.

mathematics teacher, Jules Tannery, on utmost rigor in scientific reasoning, may have helped Duhem in seeing the non sequiturs in this or that mechanistic theory, but he still felt assured about the correctness of Newton's mechanics which he took to be free of any explanation or hypotheses on the mere basis of Newton's disavowal of hypotheses in the Scholium to the *Principia*.⁹⁰ As a Normalien Duhem still thought that an ideal physics, 'the supreme goal of our efforts,' could be construed on a purely inductive basis. Relentless queries of his students at Lille, 'an elite audience,' together with their demands that he should write for them a booklet on the foundations of thermodynamics, provided the turning point:

We then had an intuition of the truths which since that time we have continually affirmed: we understood that physical theory is neither a metaphysical explanation nor a set of general laws whose truth is established by experiment and induction; that it is an artificial construction manufactured with the aid of mathematical magnitudes; that the relation of these magnitudes to the abstract notions emergent from experiment is simply that relation which signs have to the things signified; that this theory constitutes a kind of synoptic painting or schematic sketch suited to summarize and classify the laws of observation; that it may be developed with the same rigor as an algebraic doctrine, for in imitation of the latter it is constructed wholly with the aid of combinations of magnitudes that we have ourselves arranged in our own manner.⁹¹

Duhem then could claim that his physical theory was free of metaphysical beliefs and in that sense was purely positivist in character in its origin as well as in its technical conclusions. That such a physics could pose no threat to a spiritualist metaphysics or belief, and Catholic belief in particular, was, Duhem insisted, merely a welcome result but in no way a motivating consideration let alone a principal motivation, and there is no reason to doubt him on this score.⁹² It was in this context that Duhem gave a mere half a page to his philosophy insofar as it was more than philosophy of physics.⁹³ That surplus was a realist metaphysics. Its propositions were bearing on objective reality and on its attributes; its truthfulness was a function of common sense which first registers facts of experience and then notices their correlations (laws) without recourse to scientific theories. This realist metaphysics was related to physics only on two counts. First, it supplied physics with a set of judgments whose targets were objective realities – one of the two elements which blended in intimate union in physical theory. The other element was a system of signs serving to transform those judgments into mathematical propositions. Second, those propositions implied in an increasing extent a classification or facts which, if physics was to be about reality, must have been

90. Duhem's oversight of explicitly stated hypotheses in the third book of the *Principia* is a perfect illustration of the grip which hallowed clichés can have even on the keenest minds. While those hypotheses were not crudely mechanistic, the *Opticks* were full of them.

91. *Ibid.*, p. 277.

92. Doubts are especially entertained by those who equate unbelief with scholarly objectivity and keep disbelieving that a Catholic can have a passionate interest in physics for physics' sake.

93. *Ibid.*, p. 283.

supposed to reflect an ontological classification or order. The tie between metaphysics and physics was therefore fundamental: 'In order to find the title to establish its legitimacy, physical theory has to demand it of metaphysics.'⁹⁴ Thus cosmology, the epitome of explanation in the broadest sense, which at first was banished by Duhem from physical theory, was regrafted on it as its final justification, another proof of its realist and metaphysical thrust.

Whatever one might think of that regrafting of metaphysics on physics, metaphysics was certainly not absent from the basic presuppositions of the mechanistic physics which Rey defended. Rey himself admitted this, though in a somewhat roundabout way, in his brief comment to Duhem's rebuttal of his article: 'I would call by the same token,' wrote Rey in trying to look even-handed, 'a philosophy which claimed that science is capable of explaining by itself the physical universe, the unbeliever's philosophy because it would pretend that the scientific and rational method give, in the end, a sufficient explanation of things and replace all beliefs in the ordinary sense of the word.'⁹⁵ A very generous admission, although Rey was eager to rescind much of it by taking refuge in a qualified agnosticism. True positivism, he claimed, was neither *ignorabimus*, nor *scimus*, but merely provisional *ignoramus*.⁹⁶ Such was a convenient escape from the crux of the matter, namely a facing up to the question whether rationality was confined to sensory evidence and mathematical notions, or whether it was still strictly rational to trust commonsense judgments to the point of claiming on their basis an ontological order.

Although that question was ruled out of court by Rey's *ignoramus*, a garb of scientism, his lack of evenhandedness could not easily be exposed by the brevity and scarcity of Duhem's dicta that asserted or implied a realist metaphysics and epistemology. Those dicta, whatever their occasional clarity and incisiveness, were too short and wholly subordinate to his favorite themes, so many particularities of physical theory as he conceived it. All those dicta could easily be lost on a positivist like Rey, who in fact put Duhem in a class with such non-realists as Kant, Schopenhauer, Secrétan, and Le Roy — so many 'believers' according to Rey's classification, because they claimed that science pointed beyond itself.⁹⁷ For such a strange classification and for the subsequent classification of Duhem as a positivist, Duhem was in part responsible. Bafflingly, he seemed to feel that with his reply to Rey, which he thought he could delay until the summer vacation of 1905 (he finished writing it in the Gorges du Tarn on September 9), he said all that Rey's widely read objection to a metaphysical (and realist) justification of physics required in a way of clarification. He failed to see that such a justification required a detailed discourse on metaphysics, common sense, and rationality.

94. *Ibid.*, p. 298.

95. Rey, 'La physique de M. Duhem,' *APC* 1 (1906):536.

96. *Ibid.*, p. 537.

97. *Ibid.*, p. 536.

The Théorie physique

Duhem's failure in that respect was all the more regrettable because he had on hand at that time a golden opportunity to forestall future misinterpretations of his philosophy. He could have done this in the spring of 1905 as he was writing the last instalment to his series of articles on physical theory. In fact, as late as the fall of that year he could have added a systematically philosophical concluding chapter to the book edition of that series slated to be published together the next year. After all, Emile Peillaube, whom Duhem helped in 1900 with the launching of the *Revue de philosophie*, was not only the director of a series of monographs on experimental philosophy, among which the *Théorie physique* was to be the second,⁹⁸ but also influential in persuading Duhem about the need to give an up-to-date form to his early essays on the philosophy of physics. A chief reason for Duhem's failure to come up with such a chapter seems to be his overriding attention to physics and physicists which made him largely forgetful of philosophers. If he saw a golden opportunity, it did not relate to philosophers but to physicists. Yet his view, stated in the *Evolution de la mécanique*, that an increasing number of physicists were abandoning mechanistic precepts, must have appeared even to him too optimistic.⁹⁹ Most physicists, French and foreign, were still committed to the ideal of a mechanistic physics or were eagerly looking for the harvest of new discoveries regardless of precepts and rigor. Duhem could expect all the less to convert them to his strongly antimechanistic views as he had admitted that the choice of the type or method of physics was not merely a question of logic but also of mental attitudes and preferences. In no way did he want the 'imaginative' physicists, mostly Anglo-Saxon, to change their ways. Possibly he hoped to influence some French physicists of his age and especially the younger ones through his idea of physics which he held to be particularly expressive of the French way of thinking bent on abstraction and logic. He had realized as early as 1903 that his own approach, a logically rigorous expansion of thermodynamical concepts, was as yet impotent to deal with the new phenomena of radiation which, as he acknowledged, 'lavished upon experimentalists opportunities for discoveries.'¹⁰⁰ Moreover,

98. As the expertise of Emile Peillaube (1864-1943), a Marianist priest and professor at the Institut Catholique (Paris) from 1896, lay in experimental psychology, the series, which by 1929 comprised fourteen volumes, was heavy on topics relating to that field. The author of the fifth volume, *Cournot et la renaissance du probabilisme au XIX^e siècle* (Paris: Marcel Rivière, 1908), was F. Mentré, professor at the Ecole des Roches, a friend and correspondent of Duhem.

99. *The Evolution of Mechanics*, p. 101. Here Duhem created the impression that a considerable number of physicists were abandoning atomism, which was far from being true. In 1903 it was even more true than was the case a decade earlier that, although 'corpuscular theories are now altogether banished from certain domains of physics and the most weighty of the attacks yet made on the atomic hypothesis have been delivered by those who are mainly occupied with the problems and abstract conceptions of energy, . . . belief in the existence of atoms has been enormously strengthened.' So stated very aptly in his *Essays in Historical Chemistry* (London: Macmillan, 1894, p. 370) T. E. Thorpe, who in 1903 could have listed many more arguments in favor of atomism and an even greater number of leading physicists and chemists.

100. *Ibid.*, p. 185.

he foresaw the radical novelty of the new mechanics which he predicted in the same context to rise under the impact of those very new phenomena. At any rate, he was not that unfamiliar with the preferences of his own profession as to expect that the chances of having a share in the harvest of new discoveries would less attract most French physicists, especially the younger ones, than the meticulous attention to logical rigor, an attention that could easily distract from spotting novelties tantamount to notable discoveries.

He remained confident nonetheless that whatever the shortcomings of his generalized thermodynamics, his idea or philosophy of physics would in the long run command general assent mainly because it obeyed the dictates of logic. As he was to put later in a memorable context, logic, being eternal, could afford to be patient.¹⁰¹ Indeed the very first phrase in the introduction of his *Théorie* was a reference to logic: 'We shall in this book offer a simple logical analysis of the method by which physical science makes progress.'¹⁰² In the same breath he insisted that he did not want to go beyond that restricted domain, vaster and more interesting as might be the domain of the philosophy of science in general. His philosophy was above all a logical analysis of only one science, physics, and only insofar as the healthy progress of that science demanded such an analysis. He was not however to speak as a mere logician. The same introduction also contained two all-important points for the proper understanding of Duhem's philosophy. One related to the origin of his philosophical reflections. He specified that origin as the exigencies of having practiced physics for twenty years and the exigencies of teaching over the same period. The significance of this remark will be clear when a look will be taken at nineteenth-century French philosophers – several and very notable ones among them had science in focus – as possible sources of Duhem's philosophy. The other point was contained in a philosophically most important though somewhat fleeting phrase in which Duhem referred to his resolve to avoid 'any locutions which fail to bring us into immediate contact with reality.'¹⁰³

Duhem was indeed much more a realist than a mere logician, let alone a mere phenomenologist of science, but he was hardly a good spokesman for the very foundation of his philosophical message which was realism itself. The narrowness of Duhem's aim and strategy in the *Théorie physique* is an ample illustration of this. There metaphysics appears only in the context of the claim (which Duhem fights tooth and nail) that it is the business of physical theory to give explanation and that since explanation is a metaphysical procedure, physics is subject to metaphysics. Everything that Duhem says of metaphysics in that context can appear, on a superficial reading and in disregard of other statements of Duhem, as a rejection of metaphysics, a rejection worthy of a thoroughbred positivist. Curiously, it is not Duhem but the representative of that claim who seems to state in that

101. *Notice sur . . . Pierre Duhem*, 1913 (1), p. 107.

102. *The Aim and Structure of Physical Theory*, p. 3.

103. *Ibid.*

context that beneath the sensory appearances, as revealed to our perception, there is a reality distinct from those appearances, and that the existence of such a reality must be granted if the search for a physical explanation should have a meaning. The same is true of the rest of the articulation of that claim which predicates the explanation of things on knowing their nature, a procedure ascribed to metaphysics. When in the next breath metaphysics is described as the domain from which answer can be had to the questions, 'Does there exist a material reality distinct from sensible appearances?' and 'What is the nature of this reality?', this is done as part of the claim that physics is not autonomous but subject to metaphysics – a claim, which Duhem then rebuts by arguments that can only discredit metaphysics, however different his real intention may have been. Of course, Duhem's overriding interest is not metaphysics but physics, or more specifically 'its growth as calm and as regular as that of mathematics.'¹⁰⁴ Such a growth, steeped 'in the precision and rigor of the methods of demonstration,' Duhem adds by voicing again a notion most cherished by him, cannot be guaranteed by the well-known dissensions among metaphysical systems. Indeed Duhem's first argument against the supremacy of metaphysics over physics is a portrayal of the absence of any agreement among such systems. This apparent relativization of metaphysical truth is then illustrated by the well-known quarrel among physicists during the 17th and 18th centuries over occult causes, so many 'explanations' of the nature of matter. Finally, Duhem points out again with reference to concrete historical examples that no specific physical law can be derived from metaphysical notions, however general and solid in themselves, such as the notion of sufficient cause. Anyone bent on routing metaphysics could not have done it much better.

Duhem's driving a sharp distinction between sensible appearances and external reality as such could also make him appear an enemy of metaphysics in the eyes of most of those, mostly realists in the Thomistic sense, who had read his early articles in the *Revue des questions scientifiques* and some of whom concluded that Duhem was an advocate of Kantianism. They perhaps remembered that in those articles, unlike in the *Théorie physique*, Duhem unambiguously and unconditionally recognized metaphysics as the sole area where rational justification can be found of the existence of reality, of the ultimate reliability of common-sense perceptions, and of all basic notions used in physics. In the *Théorie physique* Duhem does not care about such a justification. He is satisfied that reality and basic notions needed for physics are assured by common sense and by an innate feeling which cannot be evaded. Yet even then his chief interest is not with common sense or reality but with physical theory, the embodiment of rigor and precision. No wonder that he feels necessary to offer a self-defense which suited more the physicist than the philosopher: 'We do not say that the teachings of common sense are not true and very certain; . . . These certainties and truths of common sense are in the last analysis the source of all truth and all scientific certainty. But

104. *Ibid.*, p. 10.

we have also said that the observations of common sense are certain to the extent and degree to which they are deficient in detail and precision.¹⁰⁵

Tellingly enough the context is the last section of the concluding part of the *Théorie physique* where Duhem reveals the basic dialectic of his philosophy, which is a philosophy of physics, and not much more. In that dialectic he moves back and forth between the dictates of objective reality and scientific precision. Physical theory is least precise in its parts which must embody statements about objective reality and is most precise in parts which have the least connection with that reality. The context is noteworthy also because Duhem illustrates the gist of his thinking with words borrowed from Edouard Le Roy, a most eloquent spokesman of a philosophy in which vital intuition, not knowledge, is the ultimate access to the real.¹⁰⁶ But in final analysis, Duhem followed his own course even in this respect. As he referred to faith in reality and in its orderliness with a reference to Pascal, he also argued that the logical order and rigor built into physical theory increasingly reflected an 'ontological order' and that the latter was a reflection of natural classification very much in the Aristotelian sense.¹⁰⁷ Those who were really Pascalians and philosophers — Le Roy, Blondel, and Bergson — would not have argued in that vein. Unlike Duhem, they would have more readily recognized the difficulty of inferring to a natural classification and an ontological order on the basis of Pascal's philosophical faith. Nor did Duhem care to probe into the epistemological relation between that Pascalian faith and common sense. The ultimate anchor of his philosophy seems to have been a rational common sense even in the *Théorie physique* where he went farthest in the Pascalian direction. Even there he felt that doubters of a realist reasoning were 'excommunicated by common sense.'¹⁰⁸ Again, fond as he was of the economy of thought achieved through a good classification, he saw it justified by that common sense alone. Whatever the inappropriateness and vagueness of the term common sense for the purposes of a realist, Duhem's reliance on it was that of a realist: 'the *truths* which common sense reveals are so clear and so certain that we cannot either mistake them or cast doubt on them; furthermore, all scientific clarity and certainty are a reflection of the clarity and extension of the certainty of these common sense *truths*' (italics added).¹⁰⁹

It was not this fundamental and realist position that most provoked either positively or negatively the readers of the *Théorie physique*. Philosophically less fundamental theses in it were its most attractive parts. And it was Duhem's explicit intention to emphasize them. Pivotal among them was the impossibility of crucial experiment. It represented the convergence of such other aspects of Duhem's theory of physics as the never strictly logical choice of hypotheses and the difference between sensory data grouped into physical laws and their mathe-

105. *Ibid.*, p. 264.

106. *Ibid.*, p. 267.

107. *Ibid.*, pp. 26-7.

108. *Ibid.*, p. 104.

109. *Ibid.*

matical symbolization as the last step in constructing physical theory. These aspects were the chief results of his antimechanistic outlook which also implied that the thinking of the physicist was not a logic machine working deductively but an organism where all the intricacies and subtleties of human psychology and motivation were displayed. For all his insistence on the role of rigor in physical theory, Duhem had a broad vision for the role of many other factors in the building of physical theories, factors which are nowadays dealt with by psychologists and sociologists of science or unfortunately enough, by philosophers of science who take psychology, sociology, and biology for philosophy and metaphysics. Only a reader unfamiliar with the French original would be lured into thinking that Duhem was a forerunner of paradigmists. He never used that now famous word and, had he done so, it would have simply meant for him a 'typical example.'¹¹⁰ That a specific conceptual framework had a firm hold on the thinking of physicists for over long periods of time was well known to him and he also knew that the shift from one such framework to another was not so much a matter of quick reasoning but a slow and at times unconscious maturation. He had, however, more common sense than to reify, however surreptitiously, those shifts, let alone to personify them as if they and not the scientists themselves did the actual thinking implied in them.

Duhem was equally modern when he required that physical theory predict, through its mathematical formalism, the existence of still unobserved phenomena. He expected a good theory to call for and obey 'the bold injunction: Be a prophet for us!'¹¹¹ Here the *Théorie physique* went well beyond the position of the early papers.¹¹² In the verification of such predictions Duhem saw a particularly strong proof of the theory being a natural classification, that is, a reflection of ontological order. Duhem did not go as far as to elaborate on the mathematical structure of ontological reality, perhaps because, being an algebraist, he subconsciously recoiled from touching on a train of thought that might have led him to atomism. An insufficiently nuanced fondness for common sense made him stick with the ordinary. The eyes of his mind were not vibrant enough to see usefulness for the physicist in new and unusual forms of mathematics. One wonders what his reaction would have been had he lived to see the almost magic role played in quantum mechanics by polynomials named after that Hermite whom he first met as an upperclassman in Stanislas and had not ceased to hold in awe ever since.

But he seemed to perceive, however faintly, something far more fundamental concerning the role of mathematics in physical theory. In perhaps the most in-

110. Duhem's reference in the *Théorie physique* (1st ed. p. 151; 2d ed. p. 139) to thermodynamics as a 'type des théories abstraits' was translated by Wiener (*The Aim and Structure of Physical Theory*, p. 95) as 'paradigm of abstract theories,' an innocuous procedure well antedating the rash of paradigmizing.

111. *The Aim and Structure of Physical Theory*, p. 27.

112. References to the predictive role of mathematics are missing in 'Quelques réflexions au sujet des théories physiques' (1892), where Duhem sees in mathematics merely a tool which makes physical theory rigorous; see especially pp. 171-74.

cisive and least discussed pages of the *Théorie physique*, Duhem, with an eye on Hadamard's study of surfaces of negative curvature with multiple connections and with infinite folds,¹¹³ called attention to two consequences.¹¹⁴ One, the absence of one-to-one correspondence between an exact mathematical manifold and a never exact set of physical parameters as obtained through measurement (a major proof for Duhem of the radical imperfection of physical theory) was, of course, valid even within flat Euclidean three-dimensionality. Not so the other consequence which implied that a very large number of mathematical theorems would forever remain irrelevant for physical investigation. To be sure, the surfaces investigated by Hadamard and their applicability to the motion of celestial bodies appeared to Duhem, wrongly enough, as cases of such irrelevancy. Twentieth-century physics, however, amply showed that the effectiveness of mathematics in physics seems 'unreasonable' precisely because only a very few mathematical constructs fit the overall physical structures.

Critics of the Théorie physique

Duhem's brief emphasis on the predictive value of mathematics in physics was hardly a point to strike the readers of the *Théorie physique*. Most of them failed even to see the realist foundation of his philosophy, a relatively conspicuous aspect there. In both respects a notable exception was Pierre Léon Boutroux whose interest in the history of mathematics and in its philosophical and psychological roots¹¹⁵ was not the only trait that made him an ideal choice for reviewing the *Théorie physique*. Boutroux, a former Normalien and a doctor of mathematics at the age of 22, had made a name for himself also as the director of a vast new critical edition of Pascal's works by the time he reviewed the *Théorie physique* in 1907. Yet, for all these similarities of his intellectual preferences with those of Duhem, Boutroux took an essentially negative view of Duhem's book in the two reviews he was asked to write of it. As the author of a long essay on the role of imagination in Descartes' mathematical work,¹¹⁶ Boutroux concentrated in his longer review on the heuristic role which Duhem assigned to mathematics. According to Boutroux the role was ambiguous because if the rules of logic were

113. J. Hadamard, 'Les surfaces à courbures opposées et leurs lignes géodésiques,' *JMPA* 4 (1898):17-73; see especially p. 71, where Hadamard spells out the first consequence drawn by Duhem.

114. *The Aim and Structure of Physical Theory*, p. 143.

115. As evidenced by his works, *Les principes de l'analyse mathématique: exposé historique et critique* (Paris: A Hermann, 1914; 2d ed. 1919), and *L'idéal scientifique des mathématiciens dans l'antiquité et dans les temps modernes* (Paris: F. Alcan, 1920) which saw several re-editions. Boutroux, the son of Emile Boutroux, a leading French philosopher of the time, died in 1922, at the age of forty-one, shortly after there appeared in the October 1921 issue of *Isis* his essay, 'L'enseignement de la mécanique en France au XVII^e siècle,' which would have delighted Duhem.

116. *L'imagination et les mathématiques selon Descartes* (Paris: F. Alcan, 1900), a forty-five-page brochure written when Boutroux was not yet twenty. Boutroux seemed to overlook that imagination for Descartes was mere visualization and not a recondite type of intuition. Hence his criticism of Duhem had less cogency than it could appear.

always to be obeyed in the strictest sense, as Duhem insisted, the imaginative powers of the mathematician could not be given their due.¹¹⁷ The relation of physical theory to reality was the central point of Boutroux's shorter review in which he took Duhem to task concerning natural classification as reflecting an ontological order. Boutroux's blunt question, 'qu'en savez-vous?',¹¹⁸ was certainly justified insofar as Duhem failed to articulate himself on this point no less than was the case with his dicta on common sense as the access to reality. Yet, this lack of articulation could easily be redeemed, say, by the retort that Boutroux's question, if its target was real, assumed the validity of commonsense judgements about reality.

Duhem must have been pleased with the copious and mostly approving references to him as E. Meyerson discussed in his *Identité et réalité*, first published in 1907, his last major topic: common sense. For Meyerson common sense was man's link with real things and he stated that his conception of common sense was nearer to that of Duhem than to that of Le Roy, to say nothing of Mach and Ostwald.¹¹⁹ Yet, sympathetic as was Meyerson to Duhem's dicta on common sense, he found them wanting and for a reason which is the principal flaw in Duhem's philosophy of science. By trying to separate completely physics, as actually practiced, from metaphysics, Duhem did not give detailed attention to metaphysics as such and in particular to common sense. Thus in Meyerson's view Duhem was forced to put commonsense knowledge and scientific knowledge at opposite poles whereas they were essentially the same. While Meyerson seemed to overlook the statements of Duhem that science at its start is but attentive common sense,¹²⁰ the thrust of his criticism was correct and also very respectful. Duhem's competence and erudition were for Meyerson a constant source of admiration even when he thoroughly disagreed with him, for instance, on the parallel drawn by Duhem between Aristotelian physics and thermodynamics. That Duhem deserved full credit for showing the impossibility of *experimentum crucis* was emphatically acknowledged by Meyerson.¹²¹

Duhem's disproof of *experimentum crucis* was above all a feat of logical analysis of experiment and theory, the best remembered aspect of his philosophy. The strength of Duhem's philosophy with respect to logic was also its weakness. In his case too logic was more effective in dissecting than in putting together. Duhem certainly succeeded in dissecting beyond repair the philosophy underlying mechanistic physics. He succeeded far less in impressing his readers with the positive aspects of his philosophy. It was not without some justification that in Abel Rey's

117. P. Boutroux, 'La théorie physique de M. Duhem et les mathématiques,' *RMM* 15 (1907):363-76. Boutroux was at that time maître de conférences at the University of Montpellier.

118. *Scientia: Rivista di scienza*, 1 (1907):149-52; see especially p. 150.

119. See the English translation by M. Loewenberg, *Identity and Reality* (London: George Allen and Unwin, 1930; New York: Dover, 1962) p. 379. The subject index there lists under 'Duhem' almost forty different topics, a sign of Meyerson's high regard for, and thorough familiarity with, Duhem's thought.

120. 'Quelques réflexions au sujet de la physique expérimentale,' 1894 (5), p. 186.

121. *Identity and Reality*, pp. 391-2.

doctoral thesis he was placed in the category of those whose philosophy of science was essentially a hostility to mechanism.¹²² In his review of Rey's thesis,¹²³ Duhem remarked that had Rey paid attention to the *Théorie physique*, it would have made the positive aspects of his philosophy emerge clearly in Rey's mind. Rey of course paid some attention to that aspect but not in the sense in which Duhem had set it forth. The result was very clear in the monograph which Rey published in 1908 on the respective epistemological merits of energeticism and mechanism.¹²⁴ There Rey simply ignored the crucial role which Duhem attributed to common sense as a tie of physical theory to reality and he was equally silent on Duhem's dicta on the increasingly more accurate mirroring by physical theory of an ontological order. The fact that in 1908 Rey still ignored the *Théorie physique*, both in its serial and book forms, should speak for itself.

At any rate, although emphatic, Duhem was invariably short in his affirmations that physical science was not only a convenient collection of rules but also a reflection of ontological truths about nature. Duhem of course could argue that anyone who with Rey took mechanics for physics and for the sole depository of objective truths, which were self-sufficient in a subtly scientific sense, was guilty of such a degree of confusion as not to be able to see the obvious elsewhere. But the question remained whether the obvious truth was also an ontological truth. Obvious as it may have been that all physicists, even the most sceptical of them, reasserted realism instinctively, it was another matter to argue that they reasserted it as an objective ontological truth. By referring to common sense and truth, Duhem merely stated the obvious; by vindicating both with a reference to Pascal, he hardly provided a strict argument, impressive as some quotations from Pascal can be. Duhem did not achieve much more in the way of reasoning when he more correctly referred to metaphysics as the justification of common sense and ontological truths. He did so also at the end of his review of Rey's thesis.¹²⁵ It did not

122. A. Rey, *La théorie de la physique chez les physiciens contemporains* (Paris: F. Alcan, 1907), pp. 128-67. The category was all the more misleading because much of Rey's discussion of Duhem's work related to its positive and objectivist character and metaphysical basis (see especially pp. 140-67). The scientific thrust of Rey's thesis was set by its motto, a quotation from Renan's *L'avenir de la science*: 'La science, et la science seule, peut rendre à l'humanité ce sens sans quoi elle ne peut vivre, un symbole et une loi.' This motto did not appear in the work's second revised edition (Paris: Alcan, 1923), in which the chapter on Duhem did not receive as much revision or updating as a mere reference to the publication of the *Théorie physique*, which by then had seen its second edition in 1914 and included Duhem's famed reply to Rey. A third edition of Rey's thesis appeared in 1930, again with no mention of the *Théorie physique*!

123. 'La valeur de la théorie physique . . .,' 1908 (13).

124. A. Rey, *L'énergétique et le mécanisme au point de vue des conditions de la connaissance* (Paris: F. Alcan, 1908); on Duhem, see especially pp. 30-36, where Rey based his discussion of Duhem's energetics on his articles of 1903 on the evolution of mechanics. The injustice which Rey did to Duhem's thinking is particularly evident on p. 114, where Duhem is described as a pure formalist for whom 'physical theory is in the same relation to physical reality as logic is to facts.'

125. 'La valeur de la théorie physique . . .,' pp. 18-19; or its English translation, 1954 (3), pp. 334-35.

occur to him that metaphysics had to be highly articulated if it was to become a persuasive channel to and vigorous justification of objective truths which even his cherished physics could not dispense with.

The long review of the *Théorie physique*, which G. Lechalas wrote in 1910 for the *Année philosophique*,¹²⁶ may have been meant to draw Duhem's reflections in that direction. If so, Lechalas' strategy was to reach Duhem the philosopher through Duhem the physicist. But the strategy, a relentless emphasis on inconsistencies in some aspects of Duhem's physics and in his interpretation of the history of astronomy in terms of the motto, 'to save the phenomena,' could easily become counterproductive. By arguing that in his writings on acoustics and optics (early writings to be sure), Duhem often used the language of mechanists, which attributes an explanatory value to theories, Lechalas also reopened a sensitive subject which sixteen years earlier had provoked Duhem to protest heatedly.¹²⁷ Lechalas failed to recognize the importance of Duhem's continual endorsement of a common-sense epistemology as the basis of physical theory. Yet Duhem should have reflected why his discourse could be taken for a celebration of dichotomy. Or, as Lechalas asked at the end of his long review: 'Does not Duhem's indignant protestation reveal a profound attachment to the very reasons which reason does not know and which make him attribute the value of a metaphysical mirror-image to theories in which reason recognizes only a purely pragmatic value?'¹²⁸

Duhem was not stirred to replying and, of course, he would not dignify with a reply either the covert attacks on his *Théorie physique* or its rank slighting by silence which repeatedly occurred during the decade between its publication and his death. The first of these attacks was an article in which E. Bouty pleaded in 1907 for 'tolerance' in science.¹²⁹ That the *Théorie physique* must have been Bouty's target is suggested not only by his denouncing the 'dogmatism of facts and formulas,' but also by the organ, *Revue du mois*, then in its third year, whose editorial committee included Langevin and Perrin. Indeed, two years later Perrin took the opportunity there to discuss the respective merits of induction and deduction in scientific work.¹³⁰ Not that Perrin did not try to appear evenhanded. His charge against energeticists, that they furtively fell back on non-observables, was preceded by his stricture of atomists who hoped to explain everything by atoms. In fact, he insisted on the need for both the energeticist and the atomist approach! Still, only Duhem could be the target of Perrin's complaint about a 'unique intolerance' which, once virulent in the 19th century, seemed to him to make its presence felt again.

The next major instance of silence on Duhem's theory did not suggest anything critical of it. Yet, being a brilliant though tacit testimony to it, it could not fail to

126. A summary of that over thirty-page review (vol. 20, pp. 125-57) appeared in the 'récension des Revues' section of the *Revue de philosophie* 11 (Nov. 1910):546-47.

127. As discussed in Ch. 3.

128. *Année philosophique*, 20 (1910):157.

129. E. Bouty, 'Tolérance et science,' *RdM* 3 (1907):642-57.

130. J. Perrin 'Induction et intuition,' *RdM* 8 (1909):686-94; see especially p. 692.

perplex a judicious reader. The twelve essays contributed in 1913 by so many prominent scholars to a book on scientific method¹³¹ as evinced by research in all fields (including medicine, psychology, sociology, ethics, and history) complied in all appearances with an editorial policy which strictly forbade references to contemporary authors. But one wonders whether an exception should not have been called for in view of the fact that the three essays on method in mathematics, mechanics, and physics¹³² were an obvious restatement of the major ideas set forth in the *Théorie physique*. Quite possibly the policy in question was adopted to prevent the flare-up of resentment in some circles against the power of Duhem's arguments which shattered the splendid facades not only of explicitly 'scientific' ideologies, such as positivism and scientism, but also of an allegedly non-ideological scientific empiricism. Resentment was too deep to prevent occasional flare-ups. Such was Parodi's reaction to a book whose author claimed: 'It has recently been established, and in a manner which excludes doubt, that science is but a symbolism.' Asked Parodi in rebuttal: Does Duhem's *Théorie physique* possess the value of an uncontested dogma?'¹³³

Contested it was but in a roundabout way which rested on giving Duhem the silent treatment wholly or almost entirely. The absence of Duhem's name in any of Poincaré's three books on science published between 1902 and 1913 should have appeared notorious enough.¹³⁴ And so was the book which Pierre Delbet, professor of medicine at the Sorbonne, published on scientific method in 1913. A somewhat shorter book than the *Théorie physique*, Delbet's *Science et réalité* would have called in four of its five main parts for a discussion of Duhem's ideas.¹³⁵ Duhem did not figure even in the chapter 'Energie,' although he was the real target while Ostwald was attacked. No wonder. Delbet, who began his career as assistant in the laboratories of Lacaze-Duthiers, belonged to a coterie where, for all

131. P. F. Thomas (ed.), *De la méthode dans les sciences* (Paris: Félix Alcan, 1909).

132. Written respectively by E. Picard, P. Painlevé and H. Bouasse. The latter's article, 'Physique générale' (pp. 73-110), was an especially close and systematic rendering of Duhem's philosophy of physics.

133. In a review in *RdM* (11 [1911]:240) of Charles Dunan's *Les deux idéalismes* (Paris: F. Alcan, 1911).

134. Poincaré continually referred to Mach in the first two chapters, 'The Selection of Facts' and 'The Future of Mathematics', of his *Science et méthode* (1908); see English translation by F. Maitland, *Science and method* (New York: Dover, n. d.). pp. 15-45. In the concluding chapter, 'Science and Reality,' of his *La valeur de la science* (1913) Poincaré discussed at length the ideas of Le Roy; see English translation, *The Value of Science*, by G. B. Halsted (New York: Dover, 1958), pp. 129-42. Although Poincaré's *La science et l'hypothèse* (1902) antedated by three years Duhem's *Théorie physique*, Duhem's earlier publications would have more than called for a reference to him in Poincaré's chapters on 'Energy and Thermodynamics' and 'Hypotheses in Physics'. See their English translation in *Science and Hypothesis* (New York: Dover, 1952) pp. 123-59.

135. P. Delbet's *La science et la réalité* (Paris: Flammarion, 1913) consisted of five 'livres' dealing in turn with (I) transformism; (II) abstractions, space, time, energy; (III) generalization and extrapolation; (IV) demonstration and discovery; (V) foundations of science and the constitution of matter; for the chapter on energy see pp. 166-89.

the lip-service paid to unconditional respect for scholarly merit, Duhem could not be mentioned. The most complete silence on Duhem, the philosopher, had a classic instance in the article which Bergson wrote on philosophy in France for a volume to represent contemporary French culture at the San Francisco World Fair in 1915. Bergson, who extolled the merits of Poincaré and Milhaud as the two who showed the limitations of scientific method,¹³⁶ had to admit two decades later that 'Duhem preceded both in that critical look at science.'¹³⁷

Christian positivism

Duhem, who reacted only to broadly articulated misrepresentations of his philosophical views, had no wish to waste his energies by calling attention to the silent treatment accorded to them. More importantly, he was, in his own eyes, a physicist, not a philosopher and much less a metaphysician. Also, his interest in metaphysics was minimal, whatever his occasional espousal or criticism of it. That his interest in philosophy was a function of his overriding interest in theoretical physics was all too clear when in 1913 he prepared his *Notice* in support of his candidacy for membership in the Académie. His ten-page account of his work in philosophy was only one tenth of his account of his work in physics and even shorter than his account of his work as a historian. The title of that account, 'logical examination of physical theory,'¹³⁸ spoke for itself. It perfectly expressed the gist of his philosophy and much of his philosophical reflections on physics or, rather, on his ideal of physics. That ideal was such as to assure to physics a conceptually undisturbed growth and a broad acceptance. Mechanism and atomism were at variance with that ideal on account of their heavy borrowing from metaphysics and cosmologies about the nature of matter, notions subject to the vicissitudes of metaphysical systems. Newtonianism as an inductive science ceased to be practicable from the logical point of view, Duhem argued, as soon as the data at the basis of induction were more than data of common sense. Such were all data based on instrumental observation as they were all loaded with theories none of which could be necessarily true.

The ideal physics could not be based on pragmatism or commodism either. A physicist, however pragmatist, had to recognize, Duhem argued, that his work was meaningless if it did not touch on reality, if his systematization of data did not reflect an ontological or metaphysical order. Duhem admitted though that in a sense his theory was a vote on behalf of pragmatism. Otherwise his analysis of physical theory would not have found 'great favor with several pragmatists: they applied to it the most varied fields, to history, to exegesis, to theology.'¹³⁹ Duhem

136. H. Bergson, 'La philosophie,' in L. Poincaré (ed.), *La Science Française. Tome Premier* (Paris: Larousse, 1915), pp. 15-37. Duhem came in only in a note (p. 27) as one of a dozen authors writing on the scientific method.

137. See *Henri Bergson: Ecrits et paroles*. Textes rassemblés par R. M. Mosse-Bastide (Paris: Presses Universitaires de France, 1958-59), 2:428.

138. References are to the reprinting of that section of the *Notice* in *RSc*, 1913 (15).

139. *Ibid.*, p. 739.

did not name these authors. He merely cautioned about such trends on the basis that dissimilarity between physics and those other fields was far greater than any similarity. Once more he spoke as befitted a logical analyst: more negatively than positively. He indicated more what his theory was not than what it was. What he said of what it was bespoke in him, however, the kind of logician who did not want to stifle the elemental longing for reality and ontological truth just because that longing could not be justified by the methods of logic. The starting point of Duhem's ideal of physics was a set of logical postulates. To be sure, they were not constructed 'in the air' but with a view to laws which co-ordinated the sense experiences. With a view to those laws, though not with a claim to a one-to-one correspondence between those laws and postulates. Upon those postulates rested a mathematical symbolization of physical magnitudes to be interpreted through hypotheses. The question of agreement with reality was raised only when the theoretical edifice was completed.

In 1913 Duhem could not ignore the great and spectacular strides made by atomists. He was unmoved. He did not share the general sentiment that atomic theory provided a 'divining vision.' Atoms he still regarded as mere models whose usefulness in physics he did not deny. His view was fixed not on tomorrow but on a more distant future where the inevitably growing complexity of models would once more be viewed as an impediment rather than a help. Then, having put aside those hypothetical mechanisms, the physicist 'would carefully separate from them the experimental laws which helped in the process of discovery without pretending to explain these laws; he would seek to clarify them according to the method which we have just analyzed and to include them in a modified and amplified energetics.'¹⁴⁰

Energetics, taken in that sense, stood for the ideal form of physics and rested on philosophical considerations which were not, however, sufficiently articulated by Duhem to constitute a systematic philosophy. To be sure, the basic dialectic of his philosophical reflections stood out clearly. The more a proposition had scientific (quantitative) exactness, the less ontological certainty could be assigned to it. The destructiveness of such a dialectic for a scientific way of philosophizing was obvious. Science, Duhem emphatically argued, was not, even in its progressive approximation of its ideal form, the source of ontological certainty.¹⁴¹ Yet, to secure the constructiveness of that dialectic demanded much more than generic assertion, however spirited, about common sense as the source of ontological certainty. Those assertions of Duhem had now a Pascalian, now an Aristotelian-

140. *Ibid.*, p. 740. The future when the atomic realm, so simple and uncomplicated in all appearance in 1913, would reveal a bewildering complexity and a 'material unreality,' was not distant at all. In a decade or so not only the nucleus revealed itself as being composed of protons and electrons, but protons, neutrons, as well as electrons began to be sublimated into mere wave packets. Research of the past twenty years centering on quarks with 'colors,' 'flavors,' 'charms,' and even 'bottoms' and 'tops,' has further revealed that the 'divining vision' of the atomists Duhem opposed was anything but a spectacle of the bedrock of material reality. Today, Duhem would have fun in commenting on the 120-page Particle Properties Data Booklet bursting with the names and characteristics of 'fundamental' particles.

141. On Duhem's emphasis on the radical incompleteness of physics, see especially his *Aim and Structure of Physical Theory*, pp. 172-74.

Thomistic ring. Of Pascal's philosophy Duhem never wrote systematically.¹⁴² As to Aristotle, the over a hundred pages on Aristotle's physics in the second volume of the *Système du monde* could have been so many occasions for Duhem to say something of Aristotelian epistemology and realism.¹⁴³ He did not seize on any of these occasions, not even when he discussed the Aristotelian distinction between act and potency. The doctrine of act and potency was for him of interest only as the basis of Aristotelian physics, although that physics was, as he fully knew, more philosophy than science in the modern sense. As to Aquinas, the fifth volume of the *Système du monde* contains on him a chapter of some hundred pages, a source of astonishment from start to end.¹⁴⁴ The start could not have been more genuinely philosophical as it dealt with Thomas' most incisive philosophical treatise, *De ente et essentia*. Duhem's conclusion, that Thomas took there a strictly conceptualist position,¹⁴⁵ appears less astonishing if one keeps in mind a very revealing fact. Throughout that long chapter Duhem did not refer to any modern monograph, of which Neoscholasticism had already produced many, on this or any other fundamental aspect of Thomas' philosophy.¹⁴⁶ All those monographs supported the contention that a synthesis between Aristotelian philosophy and Christian faith was intrinsically possible, the very opposite to the claim which Duhem kept driving home throughout those hundred pages. They were full of variations of Duhem's basic charge against Thomas, the charge of inconsistency and illogicality, the worst offenses in the eyes of Duhem so profoundly a logician. Of course, there were points where Aristotelian philosophy and Christian faith were irreconcilable. But

142. A curious fact because according to Duhem 'Pascal is always to be quoted when one presumes to speak of the scientific method' (see 1915 (3), p. 659). The Preface which Duhem wrote to Maire's book, 1912 (10), was too brief to qualify for a systematic study. Nor did the method embodied in Pascal's scientific work on the void retain Duhem's attention. His lengthy discussion of that work, 1916 (22, 23), aimed essentially at vindicating Pascal's originality with respect to Descartes and others.

143. Those pages (130-241) are followed by an equally long chapter (pp. 242-350) on the notions of time, place, and void in Aristotle's doctrine where one would look again in vain for probings on Duhem's part into basic questions of epistemology.

144. Even Duhem's good friend, Dufourcq, who had much sympathy for the anti-Thomist thrust of the decree of 1277, was struck by the sharpness of Duhem's strictures of Aquinas; see *Un savant français*, p. 203.

145. *Le Système du monde*, 5:480.

146. The most brilliant of these and witnessing powerfully to Thomas' realism was the doctoral dissertation which the Jesuit Pierre Rousselot defended at the Sorbonne in 1908 and published in the same year under the title *L'intellectualisme de Saint Thomas*. It appeared in a second edition in 1924, enlarged with a biographical notice on the author and with a bibliography of his works (Paris: Beauchêne, 1924). Tellingly, Duhem's correspondence with such prominent Dominican philosophers as Gardeil and Garrigou-Lagrange did not relate to basic questions of Thomism. The best comment on the merits of Duhem's charging Aquinas with inconsistencies was offered by E. Gilson: 'Pierre Duhem would have been right if the doctrine of Saint Thomas had been in his mind the outcome of this incongruous mixture of various philosophies. But to credit Aquinas with such an intention is a mistake in history. The meaning of these philosophies in his mind follows from the theological criticism to which he submits them.' (*The Philosopher and Theology* [New York: Random House, 1962], p. 103).

was this also true of the basic Aristotelian position which charted a realist middle course between Platonist idealism and Parmenidan illusionism? More importantly, was that position so distinct from and irrelevant to that commonsense perception of reality which Duhem espoused with all his heart and mind? Yet for all their obvious identity Duhem never dwelt on it. It beckoned a broad philosophical view, if not the broadest and deepest, which far transcended Duhem's view of physical theory. He was fully aware of the limitedness of what one could understand through physics, even through that ideal one in whose service he put all the intellectual energies of all his adult life. All his philosophical dicta and discourses were in full consistency with that awareness.

What Duhem did not perceive was the dynamics of proportion in philosophical discourse. Emphatic as were his endorsements of metaphysical realism, they could not pose, because of their brevity, enough counterweight to his lengthy elaborations that were methodically positivist. Thus he appeared a spokesman of Kantian idealism to Lenin,¹⁴⁷ who in turn failed to see that his own professed realism was pre-empted by Marxist dialectic which could never liberate itself of its erstwhile source, the rank idealism of Hegel. The stereotype classification of Duhem as representative of positivism received a powerful boost through the preface which Mach wrote to the German translation of the *Théorie physique*.¹⁴⁸ The tactic of that preface, in which Mach extolled mere economic classification as Duhem's ideal of science, but ignored its Duhemian role as a pointer to a natural or ontological classification, served as a model for members of the Vienna Circle. They often took Duhem for an ally apparently in the belief that Duhem's emphatic assertion of realism, so contrary to their trend of thought, could readily be overlooked both on account of their brevity and of their apparent inconsistency with his logical analysis, positivist in character. Had the publication of the sixth volume of Duhem's *Système du monde* not been delayed by almost four decades, positivists in Vienna and elsewhere might even have found apparent evidence of that inconsistency in the conclusion of that volume where Duhem characterized Buridan's and his disciples' position, out of which modern science arose, as Christian positivism!¹⁴⁹ Was Christianity still needed once positivism was espoused?

Yet, if confronted with the evidence that Buridan's positivism, or rather nominalism, was merely nominal¹⁵⁰ and that underneath it there was a metaphysics which, though skeletal and imposed by Christian faith, was still a metaphysics thoroughly respectful of human reason, Duhem would have gone along. A strong indication of this in his series of lectures on German science, his last opportunity to discourse on

147. V. I. Lenin, *Materialism and Empirio-criticism* (New York: International Publishers, 1927), pp. 322-24.

148. *Ziel und Struktur der physikalischen Theorien*, 1908 (10), p. iii.

149. *Le système du monde*, 6:729.

150. Precisely because of his admission that contingent ontological order was a proof of the existence of God, an admission that would have been an anathema to Ockham and to any of his genuine followers. For further details, see my *The Road of Science and the Ways to God* (Chicago: University of Chicago Press, 1978), p. 43.

philosophical matters. In the first of these lectures he drew a contrast between the intuitive French mind, steeped in common sense, and the German mind, given to laborious deductions, which in the end, as evidenced by Kant's system of philosophy, despairs of reason. Duhem found the cause for that debacle of the intellect in the contention that a chain of deductions was the sole source of intellectual certainty.¹⁵¹ Hence Kant conceded moral certitude only after the laborious deductions of the *Critique of Practical Reason* and even then he could not accord to that certitude a genuine intellectual value. The only way of escaping from that scepticism, Duhem argued, was a recognition that 'all assurance of *truth* comes from common sense' (*italics added*). To be sure, he saw that 'sense' residing in the heart as specified by Pascal whom, Duhem said in the same context, one could not study enough. But if that heart was also the source, as Duhem emphasized, of our certitude about mathematical axioms as well,¹⁵² then the heart in question was very intellectual indeed. Duhem was not to celebrate a sentimentalist or nebulously intuitive heart at the expense of intellectual clarity. His fondness for Pascal was not a diffidence in a metaphysics which can go beyond mere logic, be it taken for science, to reality itself. Or to quote the grand conclusion of his article on German science where from the start he kept referring to Pascal: 'The logical rigor of science is not the truth [about reality]. The discerning mind (*esprit de finesse*) alone decides whether the principles of deduction are acceptable, whether the consequences of demonstration are in conformity with reality. In order that science be true it is not enough that it be rigorous; it must also start with common sense in order to end in common sense.'¹⁵³ Clearly, Duhem's philosophy rested on the tenet that judgments about existence are more fundamentally true than mere logical relations. Herein lies the key to the resolution of that apparent dichotomy in his dicta between logical systematization and ontological order which baffles so many modern readers of Duhem who are not prepared to sense the significance of the glimpses which Duhem gave of his metaphysics.

French philosophers

Had Duhem elaborated on that metaphysics, which he certainly held, he would still have been deemed guilty of injecting his religious beliefs into his interpretation of science. Charges of infraction of objective scholarship are often a convenient cover-up for honoring that objectivity in the breach, a case all too evident in the two pages devoted to Duhem in the survey by D. Parodi, inspector of public education, of contemporary philosophy in France, a work which went through three editions between 1919 and 1925.¹⁵⁴ Parodi clearly stood for the laic dogmas of the French academic establishment which could never really feel at ease in the

151. *La science allemande*, 1915 (2), pp. 17-18.

152. *Ibid.*, p. 6.

153. 'Quelques réflexions sur la science allemande,' 1915 (3), pp. 659 and 686.

154. D. Parodi, *La philosophie contemporaine en France: Essai de classification des doctrines* (Paris: F. Alcan, 1919), pp. 240-42.

presence of Duhem's scholarship. Scholarship fared badly when Parodi took Abel Rey as sole authority on Duhem's thought and quoted Duhem himself only once, and only from a secondary source. 'One notices,' Parodi wrote, 'with stupor that this Catholic physicist leads us back to the scholastic teaching of substantial forms, to the physics of Aristotle and Saint Thomas.' Even a modest familiarity with Duhem's statements about Aristotle's physics, let alone about the physics of Thomas Aquinas, should be enough to make one shudder about Parodi's measure of information on a subject about which he wrote with no trace of hesitation. But for many of his readers Parodi must have appeared a safe guide once he declared at the outset that Duhem exemplified scientists 'who in their interest in an updated religious apologetics pushed even further the cause of scepticism in respect to positive sciences.'¹⁵⁵ What could be in their eyes a more reprehensible procedure than undermining, however slightly, the supreme authority of science?

About the same time Duhem was labeled a promoter of a 'mystical vogue.' Jules Sageret's reason for putting such a label on Duhem originated in that intellectual milieu of which Parodi was a representative and in which metaphysics was thoroughly resented for being a pointer to non-material realities. The gist of Sageret's book¹⁵⁶ was that rational philosophy was equivalent to positive sciences and that mysticism was the proper name for reflections and aspirations that were not scientific. While Sageret was resigned to the inextricable presence of that mystical proclivity in man, he did not take kindly to its recurring invasions into philosophy. The first decades of the twentieth century were for him a prime example of a major invasion of this type. His main examples were pragmatism (William James), vitalism (Bergson), contingency (Boutroux), and energeticism. Concerning the latter's representatives, Ostwald, Neothomism, and Duhem were made good bedfellows, a telling indication of the generalization which Sageret's prejudices could generate. Duhem's admiration for Aristotle was, in Sageret's eyes, a good reason for doubting the reliability of his Neothomism!

While the evaluation of Duhem's philosophy had to be a miscarriage of justice and objectivity in the hands of advocates of scientism,¹⁵⁷ very constructive remarks about it were possible even in the absence of a basic sympathy for Duhem's objectives. A striking illustration of this was provided in 1920 by Pierre Boutroux, by then professor at the Collège de France, in his book dealing with the scientific ideal of mathematicians in ancient and modern times.¹⁵⁸ The book did a pioneering

155. *Ibid.*, p. 242.

156. J. Sageret, *La vague mystique. Henri Poincaré—Énergétisme (W. Ostwald)—Néothomisme (P. Duhem)—Bergsonisme, Pragmatisme—Émile Boutroux* (Paris: E. Flammarion, 1920); see especially pp. 100-03.

157. Illustrations of this are A. Cresson's *Les courants de la pensée philosophique française* (Paris: A. Colin, 1927), where Duhem is twice mentioned in the chapter, 'Les mouvements anti-scientistes,' (pp. 181-207), and A. Lalande's *Les théories de l'induction et de l'expérimentation* (Paris: Boivin et Cie, 1929), based on a course given at the Sorbonne in 1921-22. For Lalande, who does not mention Duhem's refutation of an *experimentum crucis*, Duhem is merely one of the pragmatist critics of science.

158. P. Boutroux, *L'idéal scientifique des mathématiciens dans l'antiquité et dans les temps modernes* (Paris: F. Alcan, 1920).

service in drawing attention to the fact that intuition played an ever stronger role in new advances made in mathematics during the previous half century. If, however, such was the case, the role which mathematics was expected to play in giving exactness to other fields of inquiry, especially to physics, had to be reconsidered. Boutroux felt that nothing could illustrate this point better than a critical recall of what was said on the topic by Duhem, 'one of the great theoreticians of physics of our time.'¹⁵⁹ Using Duhem's dicta as a background was in Boutroux's eyes all the more instructive because Duhem clearly perceived that ordinary algebra, which could readily be translated into symbolic logic, was not the kind of mathematics needed and used by physicists relying on the spirit of discernment (*esprit de finesse*). As is well known, Duhem saw in the preference for complex algebraic operations a trait of the weak or imaginative mind (*esprit géométrique*). Yet, if mathematics was in its deeper forms a heavily intuitive activity, then Duhem's identification of logic and mathematics raised serious questions about the rigorosity which Duhem wanted to obtain in physical theory. While as late as the early 19th century it could still be believed that mathematics was strictly a chain of syllogisms, it was impossible, Boutroux argued, to see modern mathematics in that light. Hence, since Duhem was preoccupied, to quote Boutroux, with science 'as it was being done,'¹⁶⁰ his views on the role of mathematics in physical theory had to be re-examined. The question which in particular had to be reopened, Boutroux argued, was the manner in which new discoveries could be generated by the mathematical formalization of data and laws.

Herein lay an exciting prospect for a debate had Duhem been still alive. He would have undoubtedly relished a vibrant exchange of ideas with Boutroux, especially if the latter had provided examples of the daring use of mathematics in the latest developments of physics, such as Bohr's theory of the atom and Einstein's general theory of relativity which had just received a stunning confirmation through Eddington's observation, during a solar eclipse, of the bending of starlight around the sun. But even as they stood, Boutroux's reflections would have given an all the more welcome challenge to Duhem as Boutroux was eager to show that modern mathematics revealed those startling traits which Duhem showed physics to possess, namely, the implicit reassertion of primary qualities and the impossibility of a decisive (crucial) experiment or demonstration. Boutroux, who died at forty-one in 1922, was not to see the day when Gödel read his famous papers on the essential incompleteness of mathematics which he might have readily recognized as a major support of his views on the not strictly rigorous nature of mathematics.¹⁶¹

Duhem would have also been delighted by the chapter on him in Boutroux's book because it did not bring metaphysics in unnecessarily. The opposite was the case with some Neothomist evaluations of Duhem's philosophy of physics published

159. *Ibid.*, p. 233.

160. *Ibid.*, p. 239.

161. On the major efforts aimed at the complete formalization of mathematics to which a fatal blow was dealt through Gödel's papers, see my *The Relevance of Physics* (Chicago: University of Chicago Press, 1966), pp. 125-30, and *Cosmos and Creator* (Edinburgh: Scottish Academic Press, 1981), pp. 45-53.

in the early 1920s. Duhem's insistence that physics does not in itself provide a direct knowledge of the nature of reality was in apparent variance with Thomist realism, but, in addition, it seems to have been rebuffed by the latest advances concerning electrons and atoms. A. Witz, corresponding member of the Académie des Sciences and dean emeritus of the Science Faculty at the Catholic University of Lille, was keen on buttressing his realist interpretation of the knowledge provided by physics with quotations of statements made by Langevin, Perrin, and Mme Curie on the reality of ions, atoms, and radioactive products. That Witz concluded his long essay¹⁶² with a declaration of belief in the steady advance of physics toward a full conquest of electricity and the ether, 'these two chief items among the material constituents of the Universe,' may, in retrospect, appear a telling indication of the pitfalls of a realism based on physics. By 1920 little was left of the ether in better informed circles. A decade later atoms began to dissolve into mere wave packets, an outcome that would have made Duhem chuckle. He would have been rankled by Witz's claim that in the *Théorie physique* he was taking 'the road to Damascus' in the form of a rejection of his early positivism in favor of a subtly realist position.¹⁶³ Witz, who nowhere mentioned Duhem's insistence on common sense, wholly overlooked the realist statements in Duhem's early papers. Also, contrary to Witz's claim, Duhem insisted on natural classification long before the *Théorie physique*.

Duhem's statement on natural classification had, of course, one notable shortcoming, namely, its being simply stated with no significant elaboration. 'A rather strange thing,' observed V. Schaeffers, editor of the *Revue des questions scientifiques*, 'on the part of a thinker so fond of logical rigor; to my knowledge he does not care to define anywhere that natural classification to which he attaches so much importance. He even seems to renounce its comprehensibility and is resigned to accept it almost with closed eyes. We strongly believe that there lies the cause of his disagreement with the generally accepted view.'¹⁶⁴ The view in question was realism as evinced by the reality of atoms. Schaeffers like Witz felt philosophical realism to have been vindicated by the latest advances in physics. In fact Schaeffers was so impressed by them as to take the view that an evaluation of Duhem's theory or philosophy of physics was best done in their perspective. Duhem might have replied with a recall of what he said in his famed reply to Rey about the 'gossip of the moment.'¹⁶⁵ Duhem could also have said on his behalf that contrary to Schaeffers' claim he admitted the objective reality of natural classification though only analogically. He could have added that Thomists themselves professed such a knowledge of reality which was steeped in the analogy of being. To be sure, Duhem did not elaborate on this crucial notion and role of analogy, nor did his otherwise

162. A. Witz, 'Le conflit sur la valeur des théories physiques,' *RQSc* 77 (1920):84-108 and 271-301.

163. *Ibid.*, p. 102.

164. V. Schaeffers, 'Pierre Duhem et la théorie physique,' *RQSc* 81 (1922):42-72; see especially pp. 63-4.

165. *The Aim and Structure of Physical Theory*, p. 304.

admiring critics. Like Witz, Schaeffers too overlooked Duhem's emphasis on common sense and its epistemological significance in his theory of physics.

Those realist statements were, of course, potentially undermined by Duhem's frequent invocation of Pascal, a point emphasized by F. Mentré as he portrayed in two articles Duhem the theorist for the readers of the *Revue de philosophie*.¹⁶⁶ Whether Duhem would have, through a continued reading of the Scholastics, realized the weaknesses of Pascal's fideism — a hope voiced by Mentré, is rather debatable, in view of Duhem's evaluation of the respective merits of Thomas and Ockham. At any rate, Mentré recognized that 'in spite of his encyclopedic culture Duhem did not have a sufficiently broad vision of the real.' Mentré felt that Duhem might have done better justice to the real had he cultivated the biological and psychological sciences and that his 'scientific philosophy, although superior to that of H. Poincaré,' remains incomplete even on the ground he had chosen.¹⁶⁷ Curiously, Mentré kept to a brief note his own remarks on that ground, common sense, although he quoted, obviously from Picard's eulogy on Duhem, the latter's self-portrayal as an 'apostle of common sense.' For it is there, at its very foundation, that Duhem's philosophy is incomplete. The specification which Duhem provided in that respect did not, Mentré noted, go beyond the distinction between 'bon sens' and 'sens commun.' By the latter, according to Mentré, Duhem denoted that invariable faculty in the individual by which he grasps reality. By the former he meant in one context at least the fund of data relating to reality, a fund growing as physics progressed.¹⁶⁸

The role of common sense figured only in an incidental quotation from Duhem in O. Manville's essay on Duhem's notion of physical theory. The essay, a clearly structured popularization, avoided problems and depth.¹⁶⁹ The dozen pages devoted to Duhem in J. Benrubi's vast survey of contemporary French philosophy, Duhem's realist conviction, that physical theory must reflect an ontological order, was ascribed to his 'Catholic faith,' as if Duhem had not explained himself on this point in his famed reply to A. Rey which Benrubi failed to mention.¹⁷⁰ Nor did he mention common sense as the access in Duhem's philosophy to reality. This role of common sense was equally ignored in the chapter which P. Humbert devoted in

166. F. Mentré, 'Pierre Duhem, le théoreticien (1861-1916), 'RP 29 (1922):449-73 and 608-27.

167. *Ibid.*, p. 460.

168. *Ibid.*, p. 458. Mentré referred to pp. 357 and 429-30 of the first edition of the *Théorie physique*, corresponding to pp. 217 and 260-61 of the English translation.

169. O. Manville, 'La réponse de Pierre Duhem,' in *Qu'est-ce que la science?*, Nr. 5 in the series *Cahiers de la Nouvelle Journée* (Paris: Bloud & Gay, 1926), pp. 7-44. Two other essays offered an answer with respect to Poincaré and Meyerson. The concluding essay was E. Le Roy's own answer.

170. J. Benrubi, *Les sources et les courants de la philosophie contemporaine en France* (Paris: F. Alcan, 1933), 1:380-91. With respect to Duhem this vast work represented no advance over Benrubi's earlier and shorter work, where the claim is made that 'even as a physicist Duhem avows himself a follower of Thomas Aquinas' (see *Contemporary Thought of France*, tr. E. B. Dicker [London: Williams and Norgate, 1926], p. 103).

1933 to Duhem's philosophy in a short monograph on him.¹⁷¹ Three years later Rey himself chose to sidestep the issue as one of the six speakers at a special meeting which the French branch of the Académie Internationale d'Histoire des Sciences devoted to Duhem's thought. Rey, since 1932-professor at the Sorbonne and director of the Institut de l'Histoire des Sciences et Techniques, spoke of Duhem, the historian of science.¹⁷² Not entirely, though. Rey introduced his remarks on Duhem the historian of science with a reference to the culmination of Duhem's philosophy in the idea of natural classification: 'It is there that Duhem encounters history.'¹⁷³ Fortunately, Rey's allusion was developed by Hélène Metzger-Bruhl, who disclosed that when in 1918, only two years after Duhem's death, she defended her doctoral thesis on the genesis of crystallography,¹⁷⁴ she was astonished to hear one of the examiners' remark about some of her notions as already well developed in Duhem's *Théorie physique*, a book unknown to her until then. She quickly became an admirer of that book and of its author, as shown by her next book, *Les concepts scientifiques*. There, not only was Duhem by far the most often quoted author, but also full agreement was expressed with his 'apparent nominalism, under which there lies disguised a very deep realist conviction.'¹⁷⁵ Such was the background of Metzger's moving statement at that meeting:

Pierre Duhem is not only a scientist, a philosopher, and a historian of science, but also a great writer who knows all the secrets of persuasion. In reading him we become his ally and instead of criticising his assertions we wish to defend him against all critics.¹⁷⁶

Few shared these sentiments in France in the late 1930s. By then Meyerson, who in his last major writing still expressed his esteem for Duhem's insights, was dead.¹⁷⁷ France was in the hold of the Front Populaire which adopted the creed of scientism in its science policy.¹⁷⁸ Curiously, the chief French critics of that scientism, coming as they did from the Catholic camp, were almost entirely forgetful of the help which Duhem's philosophy of science could render to their cause.¹⁷⁹ Of

171. P. Humbert, *Pierre Duhem* (Paris: Bloud & Gay, 1933), pp. 59-84.

172. The procès-verbaux of the meeting and the text of the speeches delivered there were published in *Archeion* 19 (1937):121-51.

173. *Ibid.*, p. 130.

174. H. Metzger, *La g n se de la science des cristaux* (Paris: A. Blanchard, 1969).

175. H. Metzger, *Les concepts scientifiques* (Paris: F. Alcan, 1926) p. 160. This incisive statement has never been recalled by authors fond of quoting Metzger.

176. *Archeion*, 19 (1937):139.

177. E. Meyerson, *Du cheminement de la pens e* (Paris: F. Alcan, 1931), 1:125.

178. See H. E. Guerlac, 'Science and French National Strength,' in E. M. Earle (ed.), *Modern France: Problems of the Third and Fourth Republics* (Princeton: Princeton University Press, 1951), p. 93.

179. Particularly glaring should seem the absence of any reference to Duhem in the chapter 'La valeur d'usage, les limites et les incertitudes de la science' (pp. 152-83) in *L'Eglise et la science* (Paris: Bernard Grasset, 1936) by L. de Launay, member of the Acad mie des Sciences, who was certainly familiar with and appreciative of Duhem's work. 'Berthelot's simplistic ideas in the philosophy of science were contradicted by Poincar , whom nobody can reject in this respect, and also by Pierre Duhem, Edouard Le Roy and many others' is the only reference to Duhem in *L'avenir de la science* (Paris: Plon, 1941, p. 55), a collection of essays against scientism by six prominent French Catholic intellectuals, among them Louis de Broglie.

course, that help could be effective only if Duhem's philosophy had been developed upon the fundamental points of a realist epistemology and metaphysics on which Duhem said much too little. That in the absence of that development Duhem's philosophy could be counterproductive even in physics was pointed out by no less a Thomist than Maritain, who argued that Duhem's 'over-rarified conception would have destroyed the main incentives arising from the discovery of facts, without which physics would not exist at all.'¹⁸⁰ G. Bachelard, who by the late 1930s established himself as the leading French philosopher of science, was steeped too much in psychologism, and in an almost willful manner, to have any appreciation for the ideal of rigor, consistency, and clarity which Duhem held high.¹⁸¹ Meanwhile, not a few members of the Vienna Circle with some interest in Duhem, the positivist, were migrating to the United States which was to become the center of interest in Duhem's thought and work in the years following World War II.

American dissertations

This is not to suggest that Duhem fared well in a land where the lure of the latest fashion and the urge to innovate for the sake of innovation do not find warning signs in monuments of a long historical past, awareness of which was central to Duhem's thinking. Duhem's keenness on logic as valid beyond the most distant future could not strike a sympathetic chord with pragmatism, a trend which can largely claim America as its birthplace, where pluralism, a forerunner of pragmatism, had William James for a spokesman. That logical positivism, represented by emigrated members of the Vienna Circle, was able to plant itself everywhere in the American academia after World War II showed all too clearly the common character of the two trends. The essentially negative reaction within both trends to the realist and metaphysical foundation of Duhem's philosophy was an unintended witness to its true nature. Duhem's philosophy will, of course, remain the potential victim of misinterpretation on account of his failure to explain himself on his espousal of a realist epistemology and metaphysics. Yet, his brevity in this respect should seem loquacity itself when compared with the total lack of justification of the respective philosophical tenets, pragmatist and positivist, from which his philosophy was evaluated in two dissertations defended in 1941 and 1957 respectively at Columbia University. In the earlier one by A. Lowinger¹⁸² the tenet is the claim that scientific

180. J. Maritain, *Distinguish to Unite: or, The Degrees of Knowledge* (New York: Scribner, 1959), p. 44. The validity of that stricture is reduced somewhat by Maritain's oversight of Duhem's insistence on natural classification.

181. It was highly ironic that Bachelard denounced Duhem's philosophy as a source of learned scepticism in his *L'activité rationaliste de la physique contemporaine* (Paris: Presses Universitaires de France, 1951, pp. 46-7) as if Bachelard's viewing the 'progress' of rational perception in terms of 'genetic mutations' had not been an invitation to scepticism! But at least he mentioned Duhem, which was not the case in G. Canguilhem's essay, 'L'évolution du concept de méthode de C. Hernard à G. Bachelard,' in *Etudes d'histoire et de philosophie des sciences* (Paris: J. Vrin, 1969), pp. 162-71.

182. A. Lowinger, *The Methodology of Pierre Duhem* (New York: Columbia University Press, 1941).

methodology is purely descriptive in character. According to that claim one takes science at its pragmatist best and tries to identify its principal features of operation. Such is a purely relativist and pluralist outlook which excludes any proposition, logical and ontological, with unconditional validity. Within such an outlook, especially if not even a modest effort is made to validate it, Duhem's methodology will not even get a proper label. To call, as Lowinger did, Duhem's methodology 'monistic'¹⁸³ is a very poor usage in view of that materialistic metaphysics which is the classic meaning of monism. Lowinger's recourse to that label is above all a reflection of that deep-seated hostility toward *truth* that can be sensed in any paragraph written by philosophers of pragmatist persuasion, undoubtedly the inspirations and mentors of his thesis. Of course, if a philosophical construct, such as Duhem's methodology of science, is laden with contradiction or flies in the face of historical evidence, it can be held up to ridicule without the necessity on the part of the critic to declare his philosophical stance. Lowinger, who largely kept his criticism to the concluding chapter, failed to make good with respect to logical analysis. As to historical ineptitude, he could hardly make Duhem guilty of it since he described Duhem's historical researches as 'magnificent.'¹⁸⁴ Lowinger's descriptions of Duhem's concept of physics as 'fantastic' and Duhem's doctrine as 'metaphysical phantasy'¹⁸⁵ still must have had a reason which seems to have been Lowinger's rejection of metaphysics, a rejection implied in his definition of methodology. No wonder that Lowinger saw no significance in Duhem's assertions of common sense and that Duhem's espousal of metaphysics and ontology were for Lowinger simply a matter of 'faith,' a term which Lowinger did not care to probe but which once more was a handy label to discredit a potential threat.

In the other dissertation, the ultimate norm of judgment was a sociological version of pragmatism. A perspective in which science is but a communal enterprise (which it certainly is though only in addition to being many other things as well) provides for Duhem's philosophy a Procrustean bed in which every question can be accommodated except the question about objective truth, so central to Duhem's philosophy. As one would expect, references to common sense and natural classification as reflecting objective reality are few and fleeting in L. C. Feldstein's thesis.¹⁸⁶ There, instead of truths, there are only 'imperatives.' Duhem would have felt only revulsion on finding Feldstein declare: 'All directives of science are, in effect, inductive generalizations based upon the collective experience of the scientific community. Their import is fixed by innumerable decisions whereby the community determines their scope and interprets their significance for specific investigations. And they become scientific imperatives when the community

183. *Ibid.*, p. 163.

184. *Ibid.*, 168.

185. *Ibid.*, p. 171.

186. L. C. Feldstein, *The Norms of Science: An Explanation of the View of Meyerson, Duhem, and Peirce* (Ann Arbor, MI: University of Microfilms, 1957); on Duhem, see pp. 104-93.

declares them necessary conditions for the conduct of inquiry.¹⁸⁷ To Feldstein's defense, that some prominent recent authors said so, Duhem would have simply recalled that 'ipse dixit', his reply to the unmindful yielding by men of science to current fashions.¹⁸⁸ Had he known the description by S. P. Langley, an American astronomer, of that yielding as the reckless rush of a pack of hounds, now in one now in another direction,¹⁸⁹ he would have nodded. With his sharp logic Duhem would have also pointed out that such sociologist views of science were harbingers of dictatorship, not only scientific, but also political, and especially in an age in which almost anything can be sold in the name of science.

The insensitivity, which an instruction steeped in logical positivism inspires for what is real as the ultimate and fundamental datum of philosophy, ran its full course in the third dissertation, defended in 1972. In that dissertation measurement was taken for the ultimate link in Duhem's philosophy between physical theory and an observational data, that is, reality. Once this starting point was granted, the scalpel of the logical analyst could work unhindered, until 'in final analysis any theory may be, not a realistic painting of the world, but a caricature of it.'¹⁹⁰ Such is indeed the jeering outcome of mere logicism when it takes for its starting point something which cannot have in itself absolute certainty. Measurements, Duhem insisted, were loaded with theories about which, because of their fusion and interdependence, no simple judgment could be made. Duhem would have, of course, agreed that if the starting point was uncertain the end result, being the product of further steps, each more or less uncertain, could only be uncertainty compounded, a caricature of the aim and motivation of physicists. But was his starting point the uncertainty of measurements or of anything else? Did he not state all too clearly and all too emphatically already at a very early stage of his philosophical reflections on physics that the starting point was the registering by common sense of facts of reality, as so many certainties? That so obvious and emphatic a point in Duhem's philosophy could pass unnoticed through the strainer of logical positivists is a proof that the holes of that strainer are much larger than generally suspected.

It should seem very revealing that when Duhem's philosophy of science was evaluated in a dissertation written in a department dedicated to Thomistic realism, ample material was found in his writings to let him emerge as a metaphysical realist.¹⁹¹ Unlike in the former theses, where Duhem's dicta on natural classification received only cursory attention, in that fourth thesis the same dicta provided material for a whole chapter. No less surprisingly the last word in that thesis was a statement of Duhem on common sense. Since, when logic and consistency are obeyed, last words are implied in the first words, the first word in that dissertation

187. *Ibid.*, p. 293.

188. *The Evolution of Mechanics*, p. 183.

189. S. P. Langley, 'The History of a Doctrine,' *Science* 12 (1888):74.

190. C. E. Cardwell, *Representation and Uncertainty: An Essay on Pierre Duhem's Philosophy of Science* (University of Rochester; Ann Arbor, MI: University Microfilms, 1972), p. 219.

191. J. J. O'Malley, *Material Being and Scientific Knowledge according to Pierre Duhem* (Marquette University; Ann Arbor, MI: University Microfilms, 1965), p. 219.

had to be a chapter on material being, that is, on flesh and blood reality, so germane to Duhem's thinking and so foreign to logicians and to any philosopher who shies away from realist metaphysics. For it is only in that realist perspective that the work of Duhem's philosophical genius can be treated in its own right and not that of a 'whipping boy' or 'straw man' serving triumphalist interests or presuppositions totally different from his own. Within those latter presuppositions, Duhem's thought can only emerge as a fantasy and a caricature.

The crux of the matter

The patent failure of some doctoral candidates to do elementary justice to Duhem's thought is, of course, a reflection of the failure of their at times prominent teachers to come to grips with Duhem. Not that they did not try. But being committed mostly to logical analysis and distrustful of, if not simply hostile to, a realist metaphysics, they could but fall very short of the target. Their performance at times appears outright suspect. In any big monograph on the structure of science, which begins with an analysis of laws obtained by common sense and continues with chapters on deductive patterns of explanation, on the logical structure of scientific laws, and on experimental laws and theories, one could all the more expect a reference or two to Duhem's *Théorie physique*, as it has been available for years in English translation as well. No such expectation is to be fulfilled on reading E. Nagel's *The Structure of Science*.¹⁹² Nagel's silence on Duhem will appear a very polite policy to anyone mindful of his labeling, in another context, realist metaphysics as 'malicious.'¹⁹³

For such frankness one should be grateful. Once it is absent, distortions (however unintended) of what Duhem stated at crucial junctures are the inevitable result. A case in point is J. Agassi's review of that English translation in which Duhem is represented as admitting defeat by stating that our longing for ontological coherence is 'an intuition we are powerless to justify.'¹⁹⁴ What Agassi should have added was that in Duhem's eyes this powerlessness was that of *logic* but not of *common sense* which he held to be no less a *rational* faculty of man. Thus Duhem long preceded Popper, whom Agassi takes for a guide, in advocating a middle road between essentialism and pragmatism. Most importantly, Duhem did not base that third road on what, according to Agassi, 'matters most, namely intellectual independence.'¹⁹⁵ In Duhem's view all science had its start in utter dependence on common-

192. New York: Harcourt, Brace and World, 1961.

193. See ch. 1, 'Malicious Philosophies of Science,' in Nagel's *Sovereign Reason* (Glencoe, IL.: The Free Press, 1954), where Maritain and Gilson are the chief targets.

194. J. Agassi, 'Duhem versus Galileo,' *British Journal for the Philosophy of Science* 8 (1957-58):237-48; see p. 244.

195. *Ibid.*, p. 247. Independence of what? — one may ask. Of truth or of reality or of both? As one may expect, Agassi, who presents Duhem's philosophy as a function of his Roman Catholic faith, ignores Duhem's famed rebuttal of such view. Agassi equally ignores the fact that if Duhem's religious orthodoxy, which Duhem never concealed, is an important point to note, then fairness requires that his critic too should disclose his 'orthodoxy,' be it the religion of rationalism or of agnosticism.

sense acknowledgement of reality, the crux of all matter, and the ultimate source of trustworthiness for any road, including that of philosophical clarity.

The cause of that clarity would have certainly been served if a well-known book on the so-called Duhem-Quine thesis¹⁹⁶ had included a specification of the basic epistemological stance of its contributors. After all, if it passes for scholarship to put such facile label on Duhem's philosophy of science as a system rooted in his mystical intuitionism, let alone in his Roman Catholicism, then the same rules of philosophical psychoanalysis obligate his critics as well to make a profession of their 'faiths'. Their silence is understandable. The days, when one could earn accolades for explicitly characterizing one's own research, philosophy, and criticism as *purely* objective and free of all presuppositions, are long past. Implicit claims of that type, based either on clever avoidance of basic issues or on sheer equivocations about them, still pass for scholarly procedure. More than scholarship, the cause of science, nay the cause of plain truth, becomes thereby threatened. That the book in question is brought to a conclusion with a contribution by P. K. Feyerabend is very illustrative of that threat. Feyerabend attacks the rationality of science in the obvious expectation that once that rationality is discredited, one is free of the tyranny of *truth*. Thus in a book, in which the first and longest selection is from Duhem's *Théorie physique*,¹⁹⁷ though, tellingly enough, a selection not including his passionate plea on behalf of a physical theory which progressively mirrors ontological order and truth, the last word is given to Feyerabend's claim that 'the choice of a basic cosmology may become a matter of taste' and that it is right to turn science 'from a stern and demanding mistress into an attractive and yielding courtesan who tries to anticipate every wish of her lover, . . . [for] it is up to us to choose either a dragon or a pussycat as our companion.'¹⁹⁸ Such an outcome could be seen as a foregone conclusion to anyone taking a close look at the final suggestion in that book's preface, written by its editor, Sandra G. Harding. According to her the 'Duhem-Quine thesis may well take its place in the history of ideas as signaling a radical change in our understanding of the nature of both human knowledge and human knowers.'¹⁹⁹

196. S. G. Harding (ed.), *Can Theories be Refuted? Essays on the Duhem-Quine Thesis* (Dordrecht: D. Reidel, 1976).

197. The addition of the mere twelve pages of ch. ii of Bk. I of the *Aim and Structure of Physical Theory* (pp. 19-30), where Duhem states the ontological bearing of physical theory through natural classification, would have hardly broken the spine of an already more than 300-page book. Those pages would have clearly exposed the shallowness of the philosophies of most of the contributors, mainly interested in logical analysis and fearful of a physical reality independent of both psychological and sociological analysis, though wholly dependent on the reality of a metaphysical order. The section included from the *Aim and Structure* is ch. vi of Bk. II on physical theory and experiment.

198. *Can Theories be Refuted?*, pp. 310-11.

199. *Ibid.*, p. xxi. A similar and wholly un-Duhemian view might have been tacked on Duhem under the label "Duhem-Popper thesis" had Popper dignified Duhem to more than cursory references.

One can easily imagine the fury with which Duhem would have descended on such a claim and on the whole book, for that matter, in which only two out of a dozen prominent contributors served evidence of having spoken on the basis of a careful study of, and with an apparently serious interest in, Duhem's thesis on the impossibility of a crucial experiment.²⁰⁰ Duhem would have indeed been all too justified in expressing his wonderment about the existence of a so-called Duhem-Quine thesis. Has not Quine himself stated that his contention, 'that our statements about the external world face the tribunal of sense experience not individually but only as a corporate body,' issued 'essentially from Carnap's doctrine of the physical world in the *Aufbau*'?²⁰¹ In view of the disappearance of the real world in Carnap's *Aufbau* and in view of Quine's ontological relativity, which is but a specious label for subjectivism, one would be more justified in speaking of a Carnap-Quine thesis. Such a thesis can in no way be tacked on Duhem's passionate endorsement of ontological reality and truth, acceptance of which he defined as the indispensable condition so that the work of the physicist may make any sense whatsoever. Staying within the logical perspective, Duhem would have rightly protested against the turning of his logical analysis into an epistemology. He would have seen the contributions by I. Lakatos and T. S. Kuhn,²⁰² and by many lesser figures, as transparent efforts to sell sociologism, psychologism, and historicism as substitutes for epistemology and realist metaphysics.

There are, of course, many sparkling paragraphs in Duhem's classic which by their contents and conciseness provide much food for thought for students of the psychology, sociology, and history of physics. But not one line in those paragraphs contains a justification, however slight, for turning Duhem into an advocate of any of those 'isms' (including its most seductive kind, 'logicism'), so many vast shallows on which the philosophy of science finds itself moored nowadays. All of Duhem's thinking rested on metaphysical realism, a fact that can be recognized even if one views that realism as something which trapped Duhem in 'an intuitionism of intrin-

200. The two are L. Laudan and C. Giannoni.

201. *Ibid.*, p. 58.

202. The inclusion of a section from T. S. Kuhn's *The Structure of Scientific Revolutions* (first published in 1962), a book rightly criticized for its startling paucity of references and documentation (see review by D. J. de Solla Price in *American Scientist*, 51 [1963]:294A), should seem especially startling in view of there not being a single reference to Duhem. A judicious reader, familiar with Duhem's classic, must be even more startled on finding passages in Kuhn's book, say on the long maturing and sudden emergence of a new physical theory, that cannot help evoke entire paragraphs in Duhem's book. The fact was noted with all politeness, if not some concealed trembling, in Cardwell's doctoral dissertation (*Representation and Uncertainty*, pp. 198-99). After citing parallel passages from Duhem's and Kuhn's books on the manner in which a new theory replaces an old, O. Costa de Beauregard assumed with tactfulness that Kuhn was unfamiliar with Duhem's book ('La théorie physique, son objet, sa structure de Pierre Duhem,' *Revue d'histoire des sciences* 30 [1977]:361-66).

sic irrationality for the entire structure of historical epistemology.²⁰³ Whether a study of the science of physics (including its historical growth) is possible on the basis of a systematic avoidance of realistic metaphysics is a question which is not the scope of this study to answer. That the question calls for a negative answer is modestly suggested by the self-defeating character of studies, partial and total, of Duhem's philosophy of science when that avoidance is taken for a directive. Needless to say a proper grasp of what Duhem the philosopher wanted to convey can also be hampered by viewing it as part of a trend in apologetics which is not really trustworthy.²⁰⁴

At any rate, it was not from philosophers of physics but from physicists that Duhem expected a vote of confidence. That vote is much more in favor of Duhem's ideal of physics than the case may appear at a cursory look. There was a relatively brief period when relativity seemed to discredit common sense and first advances in atomic physics seemed to revalidate 'mechanistic realism.' Half a century later relativity is seen to break down with respect to the absolute reference system provided by the expansion of the universe and by the 3°K cosmic background radiation.²⁰⁵ Advances from the atom through the nucleus to a disturbing proliferation of 'elementary particles' make the more thoughtful physicists wonder whether their search is really about particles in the ordinary sense. Indeed, no sooner had the advent of the atomic age been hailed than leading theoretical physicists denounced efforts aimed at visualizing electron orbits and anything structural about atoms, nuclei and their constituents. Quantum mechanics, the most successful physical theory, insofar as it is distinct from its Copenhagen philosophy, is indeed operating along steps which, as was pointed out already in 1937 by a leading historian of

203. P. Redondi, *Epistemologia e storia della scienza. Le svolte teoriche da Duhem a Bachelard* (Milan: Feltrinelli, 1978), p. 33. In the decade preceding the publication of Redondi's book, there were two noteworthy statements (not noticed by him) on Duhem's realism. According to R. Poirier, who fails to quote Duhem's emphatic assertions of the immediate grasp of reality by common sense, 'Duhem never resorted to a moral or religious fideism, or for that matter to an intuition of the kind which is irreducible to science and which would directly give us the existent' (*L'épistémologie de Pierre Duhem et sa valeur actuelle*, *Les études philosophiques* 22 [1967]:406). In his great monograph, *The Compatibility of Science and Philosophy in France, 1840-1940* (Cape Town: A. A. Balkema, 1972), S. I. M. Du Plessis asserted that 'in spite of his closeness to Poincaré in matters of methodology, Duhem was committed to the moderate realism of the ontology and axiology of St. Thomas' (pp. 131-32), a statement which makes Duhem appear unduly dependent on Poincaré and all too sympathetic to, and familiar with, Thomas.

204. An illustration is the otherwise very informative long chapter, 'Pierre Duhem: The Scientific Philosophy of a Modern Believer,' in H. W. Paul's *The Edge of Contingency: French Catholic Reaction to Scientific Change from Darwin to Duhem* (Gainesville: University Presses of Florida, 1979), pp. 136-78. There the view is taken that the dispute between Duhem and Rey was intrinsically a draw.

205. As pointedly noted by P. G. Bergmann in his essay, 'Cosmology as a Science,' in R. J. Seeger and R. S. Cohen (eds.), *Philosophical Foundations of Science* (Dordrecht: D. Reidel, 1974), p. 185.

mechanics, are a reflection of methodological precepts outlined by Duhem concerning the systemization of data of observation.²⁰⁶

The last half century of physics provides an even more fundamental vote on behalf of Duhem's position. More fundamental because it relates to the very realist foundation of Duhem's ideal of physics. On the surface there is a misinformed trend toward idealism if not plain solipsism. The trend started with the discrediting of causality on the basis of the equivocation that entities, processes, and interactions that cannot be *measured* exactly cannot *exist* definitely. Reinforcing that trend was an anti-ontological philosophy which Bohr helped graft on quantum mechanics as mere science. The ultimate implications of that anti-ontologism are varied and all revealing. They range from the reification of reference systems and quantum states to claims that there are as many worlds as there are observers, and that subatomic particles communicate with one another.²⁰⁷ Duhem would have now plenty of new ammunition on behalf of his claim that without belief in an ontological order the work of the physicist makes no sense. Duhem could also notice that whatever their solipsist utterances, physicists are busy building ever more intricate (and expensive) instruments, so many proofs that their efforts are ultimately aimed at reality. He would quote with delight Einstein's famous dictum that it is the deeds and not the words of the physicists that ought to be consulted in assessing the real nature of their enterprise. After all, long before Einstein, the point was vastly articulated by Duhem that the lasting feats of atomists and mechanists were not the fruits of their 'metaphysical' dicta about the unseen constitution of matter. That physicists are driven by a vision of ontological order would appear to Duhem all too evident in the enormous work which is being spent on unified theories. As to common sense, he could quote not only an Einstein, a Heisenberg, but above all that Eddington who, for all his solipsistic idealism, acknowledged the primacy of commonsense realism even in physics as he declared: 'Molar physics always has the last word in observation, for the observer himself is molar.'²⁰⁸

Where Duhem would find least support in what had taken place in physics in this century relates to his insistence on full logic at all times. He was too bent on rigor to see a limited role for logic or to see how readily a system of logic could become a rigid logic-machine. He failed to see that his vote for logic could easily turn into a vote for a no less rigidly limited system than the framework of mechanistic models of which he wanted to free physics once and for all. A curious failure indeed because a limitation of the role of logic was implied in his view of physics: not a machine but an organism, a system much more complicated than any machine and infinitely richer in novelties. It is to these novelties, or rather to the scientific hunger in pursuit of discovering ever new facts, that he did not do justice. He erred not by putting logic on a very high pedestal, but by not making a reality

206. R. Dugas, whose remarks were discussed in the preceding Chapter.

207. See my article, 'Chance or Reality: Interaction in Nature versus Measurements in Physics,' *Philosophia* (Athens) 10-11 (1980-81):85-102.

208. A. S. Eddington, *The Philosophy of Physical Science* (New York: The Macmillan Company, 1939), p. 77.

inexhaustible in new facts just as prominent there. Thus on the short run his love of logic ran the risk of turning into the art of going wrong with confidence. As to the long run, he could be supremely confident, for logic, however simple, and the real, however complex, must ultimately coincide. It was very characteristic of him that as an ultimate justification of the truth of this long view he would point to the witness of the history of physical theories.

10. DUHEM THE HISTORIAN

A special historian

Duhem the physicist, dedicated to the cause of common sense, became a philosopher only in that special sense in which this was required by the ideal of physics he was pursuing. A telltale sign of the special nature of his philosophical quest was his independence of other philosophical schools. He certainly showed no concern for the school of commonsense philosophers. In his turning into not only a historian, but into a special one, he had hardly to be concerned about others. For better or for worse there has never been a school of commonsense historians and certainly not among historians of science, who a hundred years ago were too few to form any school. Anyone aiming at that time at becoming a really good historian of science obeyed common sense by cultivating utmost respect for facts. A brief recall of the notorious fact, much too in evidence in our times, that the utmost respect of a physicist for the facts of the laboratory is hardly ever matched with a similar respect on his part for the facts of the history of physics, should be enough to make that common sense appear in a rather special light. Moreover, a hundred years ago the pivotal facts of scientific history were, as will be seen, known to a much lesser degree than might have been suspected by a scholar bent on as complete a command of facts as possible. There was, of course, nothing special in looking at that time on facts as forming an organic succession. The Comtean view of history, which young Duhem imbued from Cons, his history teacher at Stanislas, and which constituted a climate of opinion, rested on such an outlook. It could seem a dictate of plain common sense.

Both with respect to utmost reverence for the historical record and to the organic continuity of the historical process Duhem could find impressive encouragement in the Ecole Normale which had in the 1870s and 1880s the historian Numa Denis Fustel de Coulanges as its chief luminary. Duhem was very much aware of Fustel's bent on utmost respect for the record. Thirty or so years after he had left the Ecole he pointedly recalled Fustel's insistent question, 'Do you have a text?' and he did so in a context replete with his references to common sense as the

ultimate criterion of any proposition, however learned.¹ As to the continuity, what he could absorb through intellectual osmosis at the Ecole should seem even more telling. He could hardly be unfamiliar with the often-quoted passage in Fustel's famed analysis of Greco-Roman social history:

Fortunately, the past never completely dies for man. He may forget it, but he always preserves it within him. For, take him at any epoch, and he is the product, the epitome, of all the earlier epochs. Let him look into his own soul, and he can find and distinguish these different epochs by what each of them has left within him.²

Even more important should seem for the formation of Duhem the historian the chief message of Fustel's classic. Its author argued that the three great social revolutions of classical times – the dethroning of theocratic kings, the breaking up of the *gens* as a family, and the entering of the *plebs* into the political life – were but vehicles of a continuity: the gradual extension of the idea of mutual responsibility which found its fulfillment in the advent of Christianity. Much the same was argued with respect to modern history by Gabriel Monod, also a professor of history at the Ecole. In launching in 1876 the *Revue historique*, an organ more secular than the older *Revue des questions historiques*, Monod exhorted its future contributors to see the logical connection which secures continuity even across such chasms as the French Revolution, the Protestant Reformation, and the Renaissance. As to contemporary interest in history, Monod merely had to register it: 'Our century is the century of history.'³

The thrust of the phrase was evolution through time. Duhem's fondness for the evolutionary perspective was certainly evidenced in his high esteem for the famed study of modern French history by H. Taine,⁴ a protagonist of Darwinism in political as well as intellectual history. Not that the common sense of Duhem would have subscribed to evolution in terms of blind chance. He emphatically rejected the portrayal of human history as seen through the inexorable struggle of the survival of the fittest which leaves no room for purpose. As a professor, who had to preside over examinations for licence, which included even for students of physics the topic of evolution, he was wont to deliver a scathing exposé

1. *La science allemande*, 1915 (2), p. 90. Fustel attached even greater importance to the impartiality with which the historian was to read the documents. See his inaugural lecture of his course on medieval history at the Sorbonne, the text of which was immediately printed in *Revue politique et littéraire* 8 (Feb. 8, 1879):745-51; especially p. 746.

2. Quoted from the English translation, *The Ancient City: A Study on the Religion, Laws, and Institutions of Ancient Greece and Rome*, by W. Small (4th ed.; Boston: Lee & Shepard, 1882, p. 13) of Fustel's classic, *La cité antique*, first published in 1864; it had already gone through a dozen editions by the time Duhem completed his studies at the Ecole.

3. G. Monod, 'Du progrès des études historiques en France depuis le XVI^e siècle,' *Revue historique* 1 (1876):5-38; see p. 27.

4. See *Un savant français*, pp. 129-30.

of the logical fallacies of Darwinism and dismiss the candidate with a good mark.⁵ He put himself on record in that connection in a context in which he evaluated the first volume of a vast Church history by his good friend, Albert Dufourcq. The two main points which Duhem warmly endorsed about the procedure of Dufourcq were obviously also valid for Duhem the historian. The time, January 1904, was also most significant. As will be seen, it was about that time that Duhem caught a glimpse of the remote – medieval – origins of classical physics and, through the relentless pursuit of the documentary evidence, he became a historian. One of the two points was the meaninglessness of an evolutionary rationalism contemptuous of a development evincing purpose which transcends mere material existence:

The work of chance or rather the inextricable weaving of fatal consequences produced by the interplay of laws with no purpose, this is what rationalism sees in the history of mankind; it merely sees the evolution of an animal species; the evolution of a species . . . where some individuals, in order to achieve a greater mastery over the forces of nature, invented the sciences whose sole legitimate objective is to increase the dose of physical enjoyments allotted to each representative of the species; an evolution with no purpose for the individual whom chemical forces will dissolve after the few years in which he experienced more bitterness than joy; an evolution with no purpose for the species whose last representatives will die of cold and hunger on a frozen planet where no geologist ever will exhume their fossils.

In such a ‘rationalist’ view it was impossible to argue, and this was Duhem’s first main point, that human history stood in the service of the unfolding of any idea, let alone of the great idea that ‘the goal of history is the realization of a common consciousness for mankind and that Christianity is the form of that universal consciousness.’

The other point related to the manner in which the historical unfolding of a great idea should be told by the historian. Those familiar with the writings of Duhem the historian will not fail to perceive the applicability to the history of science of his comments on Dufourcq’s procedure:

This great idea does not unfold itself under our eyes in the manner of philosophical dissertations. In line with the method dear to our modern historical school, that great idea does not want to be expressed in general propositions. It rather reveals itself as it has developed in the world, concretely and alive; it will speak through the mouths of those who had for their mission to teach humankind; it will vibrate in the tremblings of populist pressures, of upheavals, and of revolutions; one will see it run beneath the

5. See note 43 to Ch. 5. The good mark was, at least on one occasion, not the only price paid by Duhem, as recalled by Flotte, professeur honoraire at the University of Bordeaux, who had Duhem as one of his examiners around 1910. From criticizing Darwinism Duhem passed to criticizing its teachers and then turned to the young candidate: ‘If only I could get hold of your teacher!’ The teacher happened to be in the audience, stood up, confronted Duhem. The incident was officially reported to the rector, Thamin, who saved Duhem from embarrassment by securing a quick promotion for the teacher. The first-hand information on the story is P. Brouzeng, in his doctoral dissertation, ‘L’oeuvre scientifique de Pierre Duhem . . .’ (see note 222 to Ch. 8), 1:33.

crowded medley of events. Be it the speech of man or the recital of facts, all has passed through the crucible of severe critique . . .'⁶

In Duhem's case the crucible was the superhuman effort he expended over a dozen years to track down and set forth that record in its overwhelming and wholly unsuspected richness. In that sense too he was a very special historian. However, he would not have become a historian of physics in any special sense had his interest in physics not been very special. The special perspective of Duhem the historian was set by his theory of physical science according to which physics, having commonsense data and truths as its basis, was to remain, for its own good, free of hypotheses about the internal nature of matter. Duhem believed, and this is what made him a historian, that the historical survey of any major topic of physics would support the correctness of that perspective anchored in common sense. Tellingly, his *Traité d'Energétique*, the great synthesis of his work in physics, began with a reference to his historical researches. In speaking of the final justification of the criteria which in his view had to guide the choice of physicist among various methods, he declared:

The guidance is provided for us by our knowledge of the past of science. Principles have been formulated which were found to be in contradiction with experience. Other principles were put in their places which enjoyed a partial confirmation. These in turn were modified, corrected, securing with each step more exact agreement of their corollaries with facts. We are reassured that the garment of which we here cut out the shape will exactly fit the body which it has to cover because the customer had to have repeated fittings.⁷

The essays which Duhem published between 1893 and 1897 on the history of atomic flotation, of gravitational theories, of mechanical models, and on the evolution of science since the 17th century, have therefore an interest of their own. Written as they were in the same years when Duhem advanced a philosophically articulated view of what he was supposed to do as a physicist, who satisfied the dictates of logic and common sense, those essays also mark the making of Duhem the historian of physics in that specific sense. Apart from showing the specifically interpretative interest of their author in the history of his subject matter, physics, those essays also show his bent on rigor, another aspect of his interest in physics. Rigor in matters historical means above all a reliance on original sources. Such a reliance is an immediate antidote against being trapped in the perennial disease of repeating clichés, let alone of making up history. Those essays earned for Duhem the reputation of being an expert on the history of physics so effectively that soundings were made from high levels about his availability for the chair of the history of science at the Collège de France.⁸ In reading those essays one meets

6. Translated from Duhem's review of the first volume of Dufourcq's *L'avenir du christianisme. Introduction. La vie et la pensée chrétienne dans le passé* (Paris: Bloud et Cie, 1904, x + 799pp) in *RQSc* 55 (1904):252-54.

7. 1911 (1), 1:5.

8. See Jordan, 'Duhem,' p. 162, and Ch. 4.

with that type of physicist who unhesitatingly goes to the sources, even though written in Latin, and who knows what is the best among those sources. While quoting decisive passages from the works of a Descartes, a Huygens, and a Leibniz was already more than physicists dabbling in history would have done, only a born historian, determined to get the best evidence, would have taken the trouble of perusing an elusive book by such an elusive author as De Gamaches, a rear-guard Cartesian from the mid-eighteenth century.⁹ The last of those early essays, the one on the evolution of physics from the 17th century, comes to a close with two statements, each giving an early and important glimpse of Duhem the historian. In the first Duhem asserts the Aristotelian character of what is lasting in physics as evidenced in its latest development, thermodynamics. The second statement is no less noteworthy, partly because it gave rise to snide remarks rather than to serious criticism ready to face up to the ultimate implications of its own logic. In registering the return, though a very qualified one, of modern physics to some Aristotelian positions, Duhem may have easily confined himself to a remark celebrating the force with which logic asserts itself in the long run. Duhem was never a mere logician. The process is, in his eyes, rather an evidence that in the tortuous development of physical theory there is at work a superior directive force, Divine Providence:

Impatient to leave the terrain where the physics of the Scholastics enclosed it, the human spirit took three centuries and thousands of scientists to chart a road for itself toward the true science of the material universe. The direction of this road has very often changed, and today we register with astonishment that it returns upon itself by leading us to the point of departure. And yet, in that immense effort, there is no laborer whose work is lost. Not that the work has always served the goal intended by its author; the role which that work plays in the science of today often differs from the role which he assigned to it; it rather took the place designated in advance by the One who governs all that activity.¹⁰

Debunkers of such an elevated and far reaching perspective were, until rather recently, unwilling to see even that far where the idea of progress, once severed from metaphysics, becomes a disbelief in progress.¹¹ Duhem's belief in progress, expressed in the foregoing passage, never wavered. The same passage also gives a glimpse of related ideas dear to Duhem: the slowness of progress, the contribution to it by thousands of workers, and its frequent departures from the

9. The context was Duhem's essay-review of Leray's mechanical explanation of gravitational attraction ('Une nouvelle théorie . . .', 1893 [7], see especially pp. 114-23). Etienne-Simon de Gamaches (1672-1756), canon of Sainte-Croix de la Bretonnerie and member of the Académie des Sciences, had previously published *Système du mouvement* (1721), another effort of his to reconcile Cartesianism with Newtonianism.

10. 'L'évolution des théories physiques . . .', 1896 (11), p. 499.

11. Or as J. B. Bury, author of *The Idea of Progress: An Inquiry into its Origin and Growth* (1932; New York: Dover, 1960), mused with an eye on some tacit assumptions of Darwinian and Spencerian evolutionism: 'But if we accept the reasonings on which the dogma of Progress is based, must we not carry them to their full conclusion? In escaping from the illusion of finality, is it legitimate to exempt that dogma itself?' (pp. 351-53).

right direction. The kind of histories of physics which Duhem was to write on such a basis was well exemplified in the first half of his *Evolution de la mécanique*. There in fourteen chapters he gave a carefully documented account of a progress stretching from Aristotle to Hertz's mechanics and Kelvin's vortex atom. Well over three-fourths of that first half were devoted to the last hundred years, starting with the place of the idea of virtual velocities in Lagrange's statics. Duhem was a physicist's historian not an antiquarian. For him remote stages in the history of exact science could not rival phases of its recent development. The importance which he assigned to the role of virtual velocities was a dictate of interpretation, a dictate imposed from the standpoint of theoretical physics. Not history but theoretical insight made Duhem perceive the striking similarity between the thermodynamic potential and the principle of virtual velocities. That the latter was the germ out of which Lagrangian mechanics arose was also a point which took more a theoretician than a historian to perceive.

In respect to clarity of insight, richness of historical data, and grasp of the essential those fourteen chapters surpassed anything available at that time as an overview of the history of mechanics, restricted as was the perspective.¹² Those familiar with Duhem's essay from 1896 on the evolution of physics from the 17th century on were not surprised by his portrayal of the principal features of that development, which Duhem described above all as a genuine growth, an evolution. Being such a growth, it was to be open-ended. Then, as well as years later, Duhem was far from thinking that his thermodynamics or energetics was the last word in physics. He spoke of himself as he cautioned: 'It would be quite presumptuous to imagine that the system for whose achievement the physicist works will escape the fate common to the systems that have preceded it and will merit lasting longer than they.'¹³ But precisely because that evolution was a genuine growth, the theoretician, mindful of the necessary imperfection of his product, did not have to despair: 'each of the stages of this evolution is the natural corollary of the stages that have preceded it; it is the chief part of the stages which will follow it. Meditation upon this law has to be the theoretician's solace.'¹⁴

Thus, although the faint echoing by the latest in mechanics, or energetics, of some peripatetic notions could appear as a counterrevolution, especially to latter-day Cartesians, it did not have to be viewed as something disruptive. While often

12. That historical part of Duhem's *Evolution de la mécanique* presented, with its emphasis on 19th-century developments, a startling contrast even to Mach's *Die Mechanik in ihrer Entwicklung* (1883), a work in its 4th edition by 1901. Duhem may have first learned about the main points and general trend of Mach's book through a review of it in *BScM* 10 (1886): 97-99. In that review, written by H. (Hermite?), pointed reference was made to virtual velocity as the basis of all questions concerning equilibria according to Lagrange's *Mécanique analytique* (see note 26 below), a work on which Mach heavily relied. Duhem confined his criticism of Mach's work to a few factual details in the long review he wrote in 1903 of its French translation, 1903 (30). The half dozen letters, all brief and courteous, exchanged between Mach and Duhem, contain only generalities.

13. *The Evolution of Mechanics*, 1980 (1), p. 189.

14. *Ibid.*, p. 188.

making a recourse to the terms revolution and counterrevolution, Duhem seemed to be always aware of that marvellous insight provided by common sense into the true nature of both, an insight epitomized in the old saying: plus ça change, plus c'est la même chose. The next-to-last paragraph of the book was an amplification on the conclusion of the essay from 1896, with one difference though. Possibly because now he was writing to a wide scientific public Duhem did not ascribe the organic growth of science to a Providence governing it but to an *Idée directrice*.¹⁵ For those able to see in that *idée* more than teasing rhetoric, Providence was waiting in the wing. Duhem had no intention to quarrel with those for whom such an *idée*, through the inept reification of a concept, was a convenient evasion of deeper questions.

Duhem was clearly fascinated by the topic, the history of which he had to keep within strict limits for the readers of the *Revue générale des sciences*. His fascination demanded an outlet with generous concessions of space which he found in the *Revue des questions scientifiques* owing to the interest of its director, a Jesuit priest, Père Julien Thirion, a historian of mathematics and professor of physics at Louvain.¹⁶ Tellingly, Duhem did not find worth pursuing a theme which, as he put it in the first installment of his series of articles on the evolution of mechanics: 'would be an interesting task.' It would have consisted in portraying a 'sudden turn of fortune' for the sciences, once a break was made with the Aristotelian physics of qualities during 'the renaissance of the science at the beginning of the seventeenth century.'¹⁷ Not that Duhem would have subscribed to Molière's lampooning of scholastic thought as a mere evasion of issues by phrases such as 'virtus dormitiva' as the alleged cause of sleep induced by certain substances. Had the task appeared to have the kind of philosophical instructiveness which bears on physics, Duhem certainly would have already paid attention to it. But was there any real science to look for in the Middle Ages? A mere look at the best histories of science available in 1903 was enough to cure him of any illusion. They contained at most a generic reference to a few, such as Grosseteste, Roger Bacon, and Sacrobosco, who by some curious aberration from prevailing preferences took an interest in the little Greek science that had come down to them. For Whewell the Middle Ages remained a 'mid-day slumber.'¹⁸ In the first edition (1837) of his *History of the Inductive Sciences* the post-Greek story really began with Stevin, and in the second edition (1847), published after Whewell's exposure to Leonardo's manuscripts in Paris, with Leonardo himself.¹⁹ Mach's history of mechanics had but sarcastic

15. Ibid. Duhem had in mind Claude Bernard, as is clear from a similar reference by Duhem to the *idée directrice* in the conclusion of his *Origines de la statique*; see 1906 (3), p. 289.

16. For an account of his life and work, see V. Schaeffers, 'Le R. P. Julien Thirion,' *RQSc* 77 (1920):27-50.

17. *The Evolution of Mechanics*, p. 5.

18. W. Whewell, *History of the Inductive Sciences* (3rd ed., 1857; reprinted, London: Frank Cass, 1967), 1:9.

19. Tellingly, Whewell discovered even a Roger Bacon only in the third edition (1857) of his *History*.

words for an age steeped in theology.²⁰ The histories of physics published in 1880s by J. C. Poggendorff,²¹ F. Rosenberger,²² and A. Heller²³ were hardly an improvement on the little which Duhem could find in the much earlier work of J. E. Montucla²⁴ with respect to the 14th and 15th centuries. Different was the case as he pursued G. Libri's work, already in print for over sixty years, when he first quoted it in 1903. There he found a reference to Leonardo's notion of virtual velocity, a matter, as he immediately noted, of 'utmost importance.'²⁵ This meant the extension of the history of mechanics a hundred years farther back than Galileo, who was the start of that science in the historical introduction which Lagrange prefixed to his *Mécanique analytique*,²⁶ a work familiar to Duhem for some time. Beyond Leonardo there was in all appearance nothing to look for. The heavy lines which separated the section on the Greeks and the one on Leonardo

20. A subtle evidence of Mach's contempt for the medievals was his refusal to refer to them as such after he had to acknowledge Duhem's findings on the medieval origins of statics and on the medieval forerunners of Leonardo.

21. Poggendorff's *Geschichte der Physik*, the text of his lectures at the University of Berlin (Leipzig: J. A. Barth, 1879), was available in French since 1883.

22. The three volumes of Rosenberger's *Die Geschichte der Physik* (Braunschweig: F. Vieweg) were published between 1882 and 1890.

23. Heller's *Geschichte der Physik von Aristoteles bis auf die neueste Zeit* (1882) was reprinted in 1965 (Wiesbaden: M. Sändig). Compared with these works, only superficial popularization of the subject could be found in the two-volume *Histoire de la physique et de la chimie depuis les temps les plus reculés jusqu'à nos jours* (Paris: Firmin Didot Frères, 1866-69) by Jean-Christien-Ferdinand Hofer, a German-born French polygraph. His histories of astronomy, botany, and mathematics were on the same level. The twelve volumes, comprising almost 3000 pages, of the *Histoire des sciences mathématiques et physiques*, which Maximilien Marie, répétiteur at the Ecole Polytechnique, published between 1883 and 1887 (Paris: Gauthier-Villars), had their sumptuous printing as their only commendable feature. Scientific history for Marie existed in listing scientists in chronological order.

24. Jean-Etienne Montucla's *Histoire des mathématiques*, first published in two volumes in 1758, saw a second edition in four volumes in 1799 (the increase relating mostly to 18th-century developments), and a reprinting in 1968 (Paris: Blanchard).

25. See 1903 (16), p. 475 and 1905 (11), p. 13. The reference was to Libri's four-volume *Histoire des sciences mathématiques en Italie depuis la Renaissance des lettres jusqu'à la fin du xvii^e siècle* (Paris: J. Renouard, 1838-41). Duhem then quickly found out that Libri's statement (3:27) was a summary of the less than one page on the topic in the *Essai sur les ouvrages physico-mathématiques de Léonard de Vinci, avec des fragments tirés de ses manuscrits, apportés de l'Italie* (Paris: chez Duprat, An V [1797]) of J. B. Venturi, professor of physics in the lyceum of Modena, who read sections of it before the Académie des Sciences (Institut National des Sciences et Arts) as part of a general reporting on the artistic, scientific, and literary riches seized by French troops in Italy. The entire second half of the 56-page essay was on Leonardo's life and painting (pp. 33-57). Concerning Leonardo's physical science Venturi spoke 'of a few nuggets in a heap of useless sand' (p. 5). Among these were Leonardo's dicta on statics and on descent on an inclined plane, which Venturi summed up in two short chapters (pp. 17-21) with some references to the entries in the manuscripts. There was no hint whatever in Venturi's essay about the possible indebtedness of Leonardo to some earlier writers.

26. J. L. Lagrange, *Mécanique analytique* (new enlarged edition; Paris: Mme V^e Courcier, 1811), 1:221. Concerning the science of statics, Lagrange moved directly from Archimedes to Stevin (*ibid.*, p. 2).

in E. Wohlwill's long essay on the origin of the law of inertia, published in 1883-84,²⁷ was symbolic of a dark cleavage that apparently separated classical times from the rebirth of learning during the Renaissance.

Such an appearance had by then been a long-standing dogma of intellectual respectability. When in his preliminary discourse to the *Encyclopédie* d'Alembert spoke of the Dark Ages, he merely repeated a cliché dear to humanists as well as to reformers.²⁸ Irony was not of course lacking. Contempt for the Middle Ages was in part responsible for the speculations of Bailly, author of the first modern history of astronomy, about the birth of science in a mythical antediluvian culture somewhere in Outer Mongolia, speculations which earned him well-deserved ridicule.²⁹ To be sure, the Middle Ages regained sentimental respectability after the French Revolution showed something of the terrifying darkness which 'enlightened' reason could produce. It was gradually perceived that the small concession which Condorcet granted to the medievals³⁰ had to be enlarged if the law of three phases (adumbrated by Turgot, enunciated by Saint-Simon, and exploited by Comte) was to retain historical reliability.³¹ Yet, what was granted in one breath was taken back in the next. A typical example of this was provided by Victor Cousin who, in speaking at the start of his survey of modern philosophy about the Middle Ages as one of the great and splendid phases of history, hastened to add that all its achievements necessarily turned into so many hindrances of progress.³² Such a seemingly sophisticated discrediting of the Middle Ages could much more effectively sway the unwary than patently violent remarks of which leading pundits of the Third Republic often delivered themselves. Thus H. Taine described the

27. 'Die Entdeckung des Beharrungsgesetzes,' *Zeitschrift für Völkerpsychologie und Sprachwissenschaft* 14 (1883):365-410 and 15 (1884):337-87. For that horizontal line, see the first article, p. 380. Wohlwill, whose chief sources were Whewell, Poggendorff, and Mach, had, needless to say, no inkling of Buridan. He briefly mentioned Roger Bacon, but only in an appendix to the second article (p. 384). Wohlwill is better remembered for a two-volume work (1909-26) on Galileo and his struggle on behalf of Copernicanism.

28. For a documentation of early Protestant dicta on the Middle Ages, see W. K. Ferguson, *The Renaissance in Historical Thought: Four Centuries of Interpretation* (Cambridge, MA: Houghton Mifflin Co., 1948), pp. 46-58.

29. For details and documentation, see my Fremantle Lectures (Oxford), *The Origin of Science and the Science of its Origin* (Edinburgh: Scottish Academic Press, 1978), pp. 39-42.

30. In his *Esquisse d'un tableau des progrès de l'esprit humain* Condorcet credited the Schoolmen with more precise notions about the Supreme Being, with the distinction between the First Cause and the universe, and between mind and matter, with the different meanings of the word liberty, with the meaning of creation, with analysis of the various operations of the human mind, and with the classification of ideas (see modern English translation by J. Barraclough with an introduction by S. Hampshire, *Sketch for a Historical Picture of the Progress of the Human Mind* [New York: Noonday Press 1955], p. 95). Condorcet failed to perceive how momentous were those small concessions.

31. See Bury, *The Idea of Progress*, pp. 262-65.

32. V. Cousin, *Cours de l'histoire de la philosophie*, the text of Cousin's lectures during 1819-20 at the Sorbonne, was again published as *Cours de philosophie . . . Histoire de la philosophie* (Bruxelles: Société Belge de Libraire, 1840); see 1:9-10.

assault of schoolmen on the fortress of truth as a breakthrough which made them fall 'to the bottom of a dark ditch where three centuries of work could not enrich the human mind with a single notion.'³³ While Duhem could easily see through such claims as far as philosophy, the arts, and social development were concerned, he could hardly guess that the claim was utterly hollow with respect to the sciences.

Nothing was therefore more natural for Duhem than to move directly from Archimedean statics to Leonardo and state: 'The commentaries of the scholastics on the 'mechanical problems' of Aristotle do not add anything essential to the ideas of the Stagerite. In order to see these ideas issue in new offshoots and bear new fruit we must wait for the beginning of the 16th century,' that is, Leonardo da Vinci. So began the second chapter in that 60-page-long first instalment on the origins of statics which Duhem wrote in the late spring and early summer of 1903 and which saw print in the October issue of the *Revue des questions scientifiques*.³⁴ Concerning the scholastics he did not refer to any commentary. Possibly he saw one or two in the printed works of the great scholastics, and satisfied himself that no scholastic, great or minor, offered on the question pages worth studying. As far as the sciences were concerned he saw no reason to challenge the shibboleth about the darkness of the Middle Ages. Certainly no such challenge was intimated in Libri's history of the mathematical sciences in Italy³⁵ which Duhem took for a first guide. Again, there was no hint to scholastic predecessors of Leonardo in the introduction which Charles L. Ravaisson-Mollien wrote to his edition of Leonardo's manuscripts in the Bibliothèque Nationale,³⁶ an edition on which Duhem heavily relied.

To unsuspected headwaters

Duhem did not have to discover Cardan as a main link between Leonardo and Galileo, nor did he have to study manuscripts in order to form himself a fair idea of Cardan's contributions. Long as that first instalment was and expressive of the two thousand years stretching from Aristotle to Cardan, it could be written

33. H. Taine, *Histoire de la littérature anglaise* (2d rev. enlarged ed.; Paris: Hachette, 1866-78), 1:223. How far and wide Taine's dictum was carried can easily be gathered from the fact that this five-volume work went through ten printings before the end of the 19th century. Effectively as such statements could be rebutted at that time by Catholic scholars with respect to philosophy and the arts, they hardly sounded convincing as they took up the sciences, mathematical and empirical. Good illustrations, of this ineffectiveness are the chapters 'Les sciences mathématiques' (pp. 313-28) and 'Les sciences physiques et naturelles' (pp. 329-44) in *Le treizième siècle littéraire et scientifique* (Bruges: Société de Saint Augustin, 1894) by Albert Lecoy de la Marche, one of the better works of that type.

34. *Les origines de la statique*, 1905 (11), 1:13.

35. According to Libri, even mathematics, the only scientific field worth mentioning about the Middle Ages, was in 'a deplorable state' with the exception of some efforts made in Italy (2:156-64).

36. Ravaisson-Mollien was concerned mainly with the origin and history of the material he edited in the long preface to the first of the six folio volumes of *Les manuscrits de Léonard de Vinci* (Paris: A. Quantin, 1881-91).

with relative ease. Duhem expected only diligent study of already published material, especially the writings of Benedetti and Stevin, to carry on his project to the point where such intensely researched figures as Descartes and Galileo would take their turn in his narration. Contrary to the expectations of the readers and the editor of the *Revue des questions scientifiques*, familiar with Duhem's efficiency, the next instalment failed to come as scheduled.

The reason for this was correctly guessed by H. Bosmans, a Jesuit professor of mathematics at the Collège St. Michel in Bruxelles and an expert on the mathematics of the 16th century.³⁷ Sometime after the publication in October 1903 of the first installment, Fr. Bosmans visited Fr. Thirion in Louvain. Their conversation quickly turned to Duhem's project and Bosmans wondered whether he could take a look at the rest of the manuscript. 'I do not have it,' Fr. Thirion replied. 'Duhem has not finished it yet. He still has lots of reading to do. He promised me further chapters at the rate at which he writes them.' 'In that case,' Bosmans replied,

I would not be surprised if his new readings would not convince Duhem to add complementary chapters to the period whose history he has just written. I myself read Stevin a great deal. The man from Bruges further developed Archimedes and Cardan, but seems to ignore wholly Leonardo to whom Duhem attributes so great importance. If Stevin underwent Leonardo's influence, he did so in any case only very indirectly. On the other hand I know two small treatises 'de ponderibus', both attributed to Jordanus de Nemore. Duhem will end by finding them and I would be surprised if he were not to attribute some importance to them.³⁸

Duhem, as Bosmans added in recounting his words to Thirion, had by then made that find, owing to his bent on rigor and accuracy. He perused works of Tartaglia although his name, as he put it, 'is hardly pronounced in any history of statics.' This remark of Duhem is part of his famous preface to the first volume of the *Origines de la statique*,³⁹ where he disclosed the reason for the delay by three months of the second installment of his story. Readers of the first installment could confidently expect further interesting novelties from Duhem, who had just exposed the plagiarism of Cardan as a transmitter of important ideas of Leonardo to Descartes and Galileo. But neither those readers nor Duhem expected a novel find which would turn upside down well established views on the genesis of modern science.

Yet this is what was to come. In the second installment which appeared in April 1904, Duhem merely suggested a revolutionary finding. He presented there the reflections of medieval Arabs and Christians on a treatise on weights attributed

37. The Père Bosmans was the author of 241 articles and 278 reviews which are listed in *Archives internationales d'histoire des sciences* 3 (1950):619-56. A year earlier Sarton made an appeal in *Isis* for the republication of at least the major articles written by Bosmans, whose life and work was treated by A. Rome in *Isis* 12 (1929):88-112.

38. H. Bosmans, 'Pierre Duhem (1861-1916): Notice sur ses travaux relatifs à l'histoire des sciences,' *RQSc* 80 (1921):40-1 and 427-47.

39. *Les origines de la statique*, 1 :ii.

to Euclid, and added that those reflections refuted the view of Montucla (whose more than a hundred-year-old history of mathematical sciences in four volumes was still authoritative) according to whom the contents of that treatise were but the 'stutterings of a nascent physics.'⁴⁰ On the contrary, Duhem remarked, the treatise was seminal in producing in medieval times reflections very crucial for the future of physics. Although Jordanus de Nemore was repeatedly mentioned in the April installment, readers of the *Revue* could hardly have expected to be told by Duhem in the July installment that they would now be treated to some 'ingenious efforts whose fruitfulness has not yet been exhausted . . . We shall now see the Western mind get hold of debris [transmitted by the Arabs] . . . We shall assist at a work of transformation and organization, prodigiously intense and powerful, which will produce modern statics.'⁴¹ After discussing Jordanus de Nemore over twenty pages Duhem declared:

The equilibrium of the balance as a function of the equality between motor virtual work and resistance virtual work is the first seed of a principle whose full development will be reached only at the end of the 18th century in the *Mécanique analytique* of Lagrange. The study of the evolution by which this seed, minute in appearance, has arrived at its full form, under which we view it today, will be one of the principal objects of this study.⁴²

In the October issue, which carried the story beyond Jordanus de Nemore to Leonardo da Vinci, Duhem began with the declaration: 'Science does not know of spontaneous generation. Not even the most unforeseen discoveries have ever been made in all detail in the mind which generated them.'⁴³ Ominous words, especially if part of a story inching closer to that Galileo whose inclined plane had by then become the secular equivalent of Jacob's ladder. Its mystique made itself felt in most varied contexts, such as, to speak only of those years, in Bergson's *Evolution créatrice*, where it was spoken of as the very vehicle on which science descended upon the earth.⁴⁴ In the January 1905 issue Duhem threw down the gauntlet: 'In the very entourage of Galileo, there was familiarity with that old writing [of Jordanus] whose statics on certain points surpasses all that was given on that subject by the Florentine geometer.'⁴⁵ Everything was now ready for calling a spade a spade, which Duhem did in the April issue. In pointing his finger at Descartes's 'prodigious arrogance, which saw only errors in the past,' Duhem also evoked the guilt of modern times born in the spirit of Descartes who 'in his bril-

40. *Ibid.*, p. 79.

41. *Ibid.*, p. 98.

42. *Ibid.*, p. 123.

43. *Ibid.*, p. 156.

44. See *Creative Evolution*, authorized translation by A. Mitchell (New York: Modern Library, 1944), p. 364. The remark was all the more startling because Bergson was aware of Duhem as attested by his reference in the same work (p. 264) to Duhem's *Evolution de la mécanique*, which Bergson quoted with approval on the question of qualities.

45. *Les origines de la statique*, 1:262.

liant essay on statics said nothing that would not have been known long before him, in the school launched by Jordanus.⁴⁶

Meanwhile Duhem penned his preface to the first volume of his *Origines de la statique*, made up of the six installments, to be published immediately in book form by A. Hermann in Paris. The date, March 21, 1905, of that preface is a momentous event in the historiography of science. Although myths have a long survival value, a beacon of light was on that day turned on for those who wanted to see it. In that light the established tenet about a sudden enlightenment in the early 17th century became a spurious glitter:

The science of mechanics and physics, of which modern times are so rightfully proud, derives in an uninterrupted sequence of hardly visible improvements from doctrines professed in medieval schools. The pretended intellectual revolutions were all too often but slow and long-prepared evolutions. The so-called renaissances were often but unjust and sterile reactions. Respect for tradition is an essential condition of scientific progress.⁴⁷

As Duhem penned that preface, he was already writing the second volume, consisting of five installments, published between July 1905 and July 1906. They began with the medieval contributions to the problem of the center of gravity. In Duhem's portrayal of Albert of Saxony another medieval scientist, and no less important than Jordanus de Nemore, emerged on the scene. The installment, almost a hundred pages long, contained a footnote which referred to an article by Duhem on Albert of Saxony and Leonardo, just published in the *Bulletin Italien*.⁴⁸ Further installments contained references to further articles by Duhem on related topics in the same *Bulletin*. Duhem seemed to be overwhelmed by new vistas and he was not to be delayed in his bold advance toward the headwaters of science on an unsuspected continent. That in the process he had eyes for uncounted details is in itself an object of wonder. That he refused to be bogged down in minutiae, so that he might say the last word on any and all details, should be admired even more. Had Columbus been willing to embark on his historic voyage only after having on hand an exact chart of all currents of the Atlantic, America would not have been discovered until much later. Nor would Bohr's name be known today had he wanted right at the outset a theory of the hydrogen atom that could cope with all the complexities of its spectrum. Without viewing Duhem's bold march in this light, references to his findings will be so many occasions for mediocre talents to appear bigger by finding fault with the often startling opinions and conclusions of a genius.

Such a conclusion was offered in the second installment with respect to the so-called Copernican revolution and the true intellectual merits of the 16th century, the century of the Renaissance. On the former, Duhem pointed out the many traditional facets which Copernicus carefully retained. On the latter, Duhem

46. *Ibid.*, p. 352.

47. *Ibid.*, p. 2:iv.

48. *Ibid.*, p. 91. The article in question was 1905 (18).

singled out rigid Averroism, so averse to science, as a distinctive feature of the 16th century. Long hallowed clichés were unmasked as Duhem concluded the second installment which brought the history of statics up to Torricelli's principle:

By the very moment when the writing, which assured for Galileo the priority of that principle (provided one does not have to trace it to Leonardo), was printed, the geometers had for ten years been in the habit of attributing it to Torricelli. The history of the principle of Galileo and Torricelli offers us a remarkable example of the continuity along which scientific ideas most often develop. We could follow that development as the naturalist follows the development of an organism.⁴⁹

Looking in such a way at past developments was central to Duhem's philosophy of science in which the last word belonged to the witness of history. Duhem obviously was elated that a hitherto unexplored terrain, the science of four centuries before Galileo, was providing massive evidence on behalf of his theory of physics. Herein lies a principal explanation of the all-consuming zeal with which, from the late Fall of 1903 on, he delved deeper and deeper into historical research. A case in point is the paragraph which brought to a close his analysis of Torricelli's principle on the pressure of the air. In its unobjectionable form given to it by Torricelli, Duhem saw a classic illustration of the typical development of physics leading to pure formalism:

Torricelli made disappear all traces of the erroneous doctrine to which that principle gave birth. As many other propositions of physics, it is by denying its own origin that Torricelli's law became an irreproachable truth. But by breaking all links with the error which gave birth to it, it lost the apparent evidence which seemed to impose its acceptance. It showed henceforth what it really had been: a pure postulate justified only through the agreement of its consequence with reality.⁵⁰

Continuity through Leonardo

The last two installments published in April and July 1906 need not detain us. They dealt, with undeniable freshness though, with a phase of the story, stretching from Mersenne to Varignon in the early 18th century, a phase already explored in its essential features. But the grand conclusion of all five installments is worth recalling. It was introduced with Duhem's graphic description of Vis, a river in the Cévennes, one of his favorite hiking grounds, which suddenly disappears in underground cavities, breaks to the surface again miles downstream, forms a stretch of a narrow gorge strewn with dry stones, before, at long last, it turns into a steady onrush of water.⁵¹ Such was in Duhem's eyes the perfect image of the view according to which if there was any connection between Greek and Renaissance science, it was merely a long arid stretch: 'Senseless history,' Duhem cried out:

The historian, who is fond of simple and superficial views, celebrates the lightning discoveries which make the full daylight of truth to succeed the profound night of ignorance and darkness. But the one who subjects to a penetrating and detailed analysis the most novel and apparently most unexpected discovery, finds there almost invariably

49. *Ibid.*, p. 150.

50. *Ibid.*, p. 185.

51. For that passage in English translation see p. 148 above.

the result of a vast amount of imperceptible efforts and the confluence of an infinity of obscure trends. Each phase of the evolution which slowly leads science to its completion appears to that historian to be marked by two characteristics: continuity and complexity.⁵²

This continuity did not foreclose the role of geniuses. Duhem described Leonardo da Vinci as one who turned the flow of science into a 'tempestuous torrent.'⁵³ But because the flow was already there he was not 'the seer who suddenly discovers truths unsuspected until then.' The historical record was hardly more favorable to 'the legend which made Galileo the creator of modern dynamics.' The legend, if not the legendary figure, was the product of a 'too summary and too schematic historiography which made us behold a renaissance of the scientific method, forgotten since the Greeks, where we see the natural development of mechanics during the Middle Ages.' Descartes was cut to size as Duhem put his finger on the 'pride of the author of Cartesianism which duped the world into taking Cartesianism for a product curiously unforeseen and unsuspected.' The truth was an organic development, which Duhem illustrated with a simile in which both continuity and novelty were done full justice in an exemplary balance. The simile was also a warning which, in view of subsequent developments, may very well be the most needed and most ignored warning that could be addressed to latter-day historians of science: 'The graceful flight of the butterfly with glistening wings makes one forget the slow and painful crawling of the humble and somber caterpillar.'⁵⁴ On watching at close range the groping of so many workers over centuries toward an unobjectionable proposition, it seemed natural for Duhem to gain the impression of being in the presence of a superior plan of which the individual workers, perfecting this or that stone of a huge edifice, did not have cognizance. Believing as he did in evolution, organic and intellectual, but imbued sufficiently with logic not to be trapped by the magic of blind chance, Duhem conjured up, with no trace of embarrassment, not only the *idée directrice*, which for Claude Bernard was a reality, though not physical and chemical,⁵⁵ but also the sole factor which alone could make that reality meaningful:

52. *Les origines de la statique*, 2:278-79.

53. *Ibid.*, p. 282. Such a powerful metaphor, to say nothing of other encomiums heaped by Duhem on Leonardo, was hardly put in balance by A. Koyré, according to whom Duhem wanted to turn Leonardo 'into a trendy medieval' (see his *Etudes d'histoire de la pensée scientifique* [Paris: Presses Universitaires de France, 1966], p. 90).

54. *Les origines de la statique*, 2:286.

55. *Ibid.*, p. 289. Duhem had in mind section 1 of ch. 2 in Part II of Bernard's *Introduction à l'étude de la médecine expérimentale* (1865), where the 'guiding idea of vital evolution' is described as a factor which 'is essentially of the domain of life and belongs neither to chemistry nor to physics nor to anything else' (see English translation by H. C. Green, *An Introduction to the Study of Experimental Medicine* [1927: New York: Dover, 1957], p. 93). Bernard's dicta on 'guiding force' must have been all the more to Duhem's liking, because Bernard denied to that force, just as Duhem did to metaphysics in physics, any direct role in biological investigations: 'Certainly a special force in living beings, not met with elsewhere, presides over their organization; but the existence of this force cannot in any way change our idea of the properties of organic matter, — matter which when once created, is endowed with fixed and determinate, physico-chemical properties' (*ibid.*, p. 202).

Across the complex facts which compose this development we perceive the continued action of a Wisdom which foresees the ideal form toward which Science must tend and of a Power which makes converge toward that goal the efforts of all thinkers. In a word, we recognize there the work of Providence.⁵⁶

On October 26, 1905, when Duhem wrote the concluding words of his *Origines de la statique*, two and a half years after he started work on its first installment, he had already been more than half way through the eight installments in the *Bulletin Italien* forming much of the first volume of his Leonardo studies. At the very start of the first installment he showed full awareness of the fact that his concept of scientific history was diametrically opposed to fashionable ideas which, as described by him, are also a graphic portrait of presently prevailing fashions:

The history of science is distorted by two prejudices, so similar to one another that they could be fused into one: the current thinking is that scientific progress is made by a sequence of sudden and unforeseen discoveries. It is, according to general belief, the work of geniuses who have no precursors at all.⁵⁷

The objection that there was no point in wasting attention on Leonardo's forerunners, since they all lived 'in the obscure Middle Ages,' could easily be dealt with if one was truly an evolutionist as Duhem was: 'If the branches of the oak are so vast and if its foliage has so much freshness, it is only because the roots, vigorous and numerous, though hidden to the eye, obtain from the deepest soil the juices stored by the old vegetation. Those roots are visible to those who do not shun the labor of tilling the soil.'⁵⁸ Continuity was the principal lesson drawn from the comparison in the third installment, a comparison of the manuscripts of Leonardo with the writings of Villalpand: The study, Duhem wrote, 'narrow as it is in scope, is capable of discrediting some of the prejudices which distort the history of the scientific renaissance.'⁵⁹ One prejudice, which ascribed absolute originality to Leonardo, was countered with the words: 'Brilliant and solid link as Leonardo was, he takes his place in the chain of scientific tradition.'⁶⁰ As Duhem analyzed the influence of Baldi, another author of the same epoch, on Descartes and Roberval, another and more generic prejudice was contradicted with the phrase: 'Science, no more than nature, makes no brisk jumps.'⁶¹

With the sixth and seventh installments published in April and July 1906 Duhem discussed for the first time the influence on Leonardo by Themon, Son of the Jew, an incisive teacher at the Sorbonne in the mid-fourteenth century, whom Duhem practically rescued from complete oblivion. In Themon's commentaries on Aristotle's *Meteorologica* Duhem noticed remarks on hydrostatics which mark-

56. *Les origines de la statique*, 2:290.

57. *Etudes sur Léonard de Vinci*, 1:1.

58. *Ibid.*, p. 2.

59. *Ibid.*, p. 85.

60. *Ibid.*, p. 123.

61. *Ibid.*, p. 156.

edly anticipated some of Leonardo's dicta. Duhem was able to notice much more than that. The flow of information to Leonardo resembled a brook with several branches in the same way as did the flow from Leonardo to Pascal.⁶² Once united in a great mind those branches formed a powerful stream whose impact then became obvious everywhere. The eighth installment, devoted in part to Cardan's plagiarism of Jordanus de Nemore, was far less important than the first of two concluding chapters not published in the *Bulletin*. There, on the basis of careful studies of several medieval manuscripts of the science of weights, Duhem postulated the existence of a disciple of Jordanus, no less a genius than his master, whom Duhem called the precursor of Leonardo.⁶³ Duhem was very likely wrong, but if he erred it was not because he did not go to great lengths in studying elusive records. He never boasted of the immense efforts and expertise needed for pioneering the study of medieval science. He worked with no help from an army of graduate students and secretaries, with no photocopying machines, dictaphones, not even ballpoint pens, at his disposal. Only when he found out a year later that a decade or so earlier the importance of Jordanus had been set forth by that 'learned Tuscan priest,' Raffaello Caverni, in a vast work on the history of experimental method in Italy, did he complain of his condition 'of a solitary worker in the very poor library of a provincial university.'⁶⁴ He gave but a hint of his immense labors as he remarked on the garbled reading by an associate of Tartaglia of the manuscript containing the 'Precursor's' thought. In rendering the text faithfully Duhem's intension was not to display a mastery of minutiae. The text had an importance of its own: 'This short passage in itself greatly deserves to command the attention of the historian of science. For the first time since men considered questions of

62. *Ibid.*, p. 220.

63. *Ibid.*, p. 263.

64. *Ibid.*, 2:361. Whatever advantages the library of the University of Bordeaux had with respect to Lille, let alone to Rennes, the 343,129 volumes it contained as of January 1, 1922 (see p. 6 of the brochure, 'La bibliothèque universitaire de Bordeaux' [Bordeaux: G. Delmas, 1922; an extract from the April 28, 1922 issue of the *Sud-Ouest économique*] by the director of the library, H. Teulié) were distributed over the many areas of interest represented by the faculties of letters, science, law, and medicine, and provided only a limited help to Duhem's very specialized research. In the Fall of 1903, when Duhem first asked for a medieval manuscript to be sent to the University Library of Bordeaux from the Bibliothèque Mazarine, his request was denied. He obtained the manuscript five months later, in March 1904, after his rector, Bayet, called the attention of the Ministry of Public Instruction to the impropriety of depriving of source material a corresponding member of the Institut. Only after this *démarche* were Duhem's further requests promptly honored. As to the six volumes of Caverni's *Storia del metodo sperimentale in Italia* (Florence: G. Civelli, 1891-1900), the lack of proper organization and thorough interpretation of its storehouse of data was a reason for its not being widely read in scholarly circles. It was not reviewed in the leading French journals of historical studies. The first three volumes of Caverni's work were so exclusively limited to the description of instruments (vol. I), to branches of physics different from mechanics (vol. II), to medicine and botany (vol. III), that its readers could hardly be expected to look forward to anything relating to the pre-Galilean, let alone to the pre-Leonardo history of mechanics, treated in vol. IV. There (pp. 21-26) Caverni based his discussion of Nemorarius' ideas on a manuscript printed, as one could expect, with no great care by Petrus Apianus in 1523.

mechanics a magnitude of a connecting force is determined by an exact method.' His vast perspective as a historian made Duhem look beyond the fact, however important in itself: 'How much more this passage will command our attention when we shall have greeted the discoveries which it will suggest to Leonardo!'⁶⁵

The second additional chapter, and the last in the first volume of the Leonardo studies, was devoted to a survey of the writings of Albert of Saxony. 'The list,' Duhem concluded, 'is very likely incomplete. It suffices however to give an idea of the intellectual activity of this great philosopher to register the popularity which he enjoyed at the start of the Renaissance, and finally to combat the unexplainable oblivion where he is left by those who are interested in the progress of human thought in the course of the Middle Ages.'⁶⁶ Duhem's work challenged admirers of the Middle Ages no less than the devotees of the Renaissance. The challenge was above all a challenge to posterity. In the preface which Duhem wrote on July 27, 1906, to the first volume of his Leonardo studies, there is a paragraph which should strike today with its modernity (and with its moderation!) all those who take the notion of biological struggle for survival for an (let alone for *the*) explanatory device of the history of scientific ideas and pride themselves on originality. 'The mind of Leonardo,' Duhem wrote,

into which there fell this seed of [new] ideas was not at all similar to a razed and bare terrain. Other thoughts, vigorous and insistent, had already occupied it. They were implanted there by the lessons of the masters, whom Leonardo listened to, and especially by the teaching of the writings he meditated upon. To germinate and to grow, it was necessary that the newly-arrived seed should make use of an already developed vegetation or even to struggle against it.⁶⁷

The placing of Leonardo at mid-point of a sequence of authors 'whom he has read and who have read him,' to recall Duhem's priceless phrase, was the move of a convinced evolutionist, though of the kind of evolutionist mindful of the supreme challenge posed by evolution. That challenge is the securing of what endures in the process of change. Thus for Duhem evolution did not stand for a series of haphazard saltations but for the cement which turns mere succession into solid coherence: 'Between those whom he has read and who have read him, Leonardo stands in his true place. Connected with the past, the learning of which he gathered and on which he meditated, he remains no less attached to the future as one whose ideas fertilized science.'⁶⁸

In the first additional chapter there appeared, in a brief note, the name of

65. *Etudes sur Léonard de Vinci*, 1:300. Here too Duhem, the historian, seemed to be a disciple of Fustel de Coulanges, according to whom the science of history did not reside in the documents but in the intellect reading them, and who also held that the historian must consider long epochs, lest his narration should degenerate into mere stories (see J. Herrick, *The Historical Thought of Fustel de Coulanges* [Washington: The Catholic University of America Press, 1954], pp. 79-82).

66. *Etudes sur Léonard de Vinci*, 1:338.

67. *Ibid.*, p. vi.

68. *Ibid.*, p. vii.

Oresme in connection with the idea of the notion of a 'motus uniformiter difformis,' the scholastic term for constant acceleration. Duhem was already in the grip of the potentialities of an exploration of medieval writings on dynamics.⁶⁹ His plan of writing the origins of dynamics along lines similar to his *Origines de la statique* began to take concrete form. His daughter, then only fourteen, heard her father speak of such plans.⁷⁰ With Duhem, plans were as a rule quick steps to actual execution, but Leonardo represented a material too rich to part with quickly. His writings offered ample material for a second volume which dealt with his reflections on the infinitely small and the infinitely large, on the plurality of worlds, together with his indebtedness to Nicholas of Cusa, and with his pioneering the modern science of geology. The broad scope of the Leonardo studies permitted Duhem to move at ease back and forth between the 13th and the 17th centuries, but in all these moves Leonardo remained the center. Leonardo, wrote Duhem in the preface he penned on January 12, 1909, to the second volume, 'sums up and condenses so to speak in his person all the intellectual conflict through which the Italian Renaissance becomes the inheritor of the Parisian scholasticism.'⁷¹

The source of continuous growth

Continuity was the gist of Duhem's view of history, but because he viewed that continuity as something living he had eyes for the struggle and delayed outbursts of new growth, characteristic of all life. Above all he had an eye for the all-important question about living continuity, namely, its vital beginning. The preface of the second Leonardo volume contained two phrases which by their conspicuous place must have struck the eyes of all readers. In the first Duhem spoke of 'Christian thought, which at the end of the thirteenth century broke the tyranny of peripatetic philosophy.' In the second he referred to the contact made during the sixteenth century by Italian thinkers with ancient Greek geometry, which made them more receptive to the teaching of the Parisian masters of the 14th century: 'The contact infused into them a new life of which the renaissance of science is a witness.'⁷² Few readers went as far as Note F in the end of the book, where Duhem discussed the medieval break with the Aristotelian opposition to the plurality of worlds, or more specifically, to the infinity of 'worlds'. The break, which ultimately made possible the formulation of the concept of linear inertia, was of utmost importance for the future of science. Even more important had therefore to appear the force, Christian awareness of the Creator's unlimited powers, which made that break possible. This is why Duhem accorded decisive symbolic significance

69. Attested by his long essay, prepared for the Second International Congress of Philosophy (Geneva, Sept., 1904) and published two years later, 1906 (25). In that essay Duhem still moved almost directly from the Greeks to Leonardo de Vinci. He, however, assumed that at least some scholars in the 13th century held the notion of 'impressed motion' because of Aquinas' criticism of it; see especially pp. 867-68.

70. *Un savant français*, p. 191.

71. *Etudes sur Léonard de Vinci*, 2:iv.

72. *Ibid.*, pp. iii-iv.

to the condemnation on March 8, 1277, by Etienne Tempier, Bishop of Paris, of 216 propositions, among them the one denying the possibility of the plurality of worlds. Duhem felt that 'if we were to specify the birthdate of modern science, we would undoubtedly choose that year, 1277.'⁷³ Such was the debut of a phrase, which he was to repeat emphatically in evidence of the importance he attributed not so much to a mere date but to the question of live birth, the fundamental precondition of all continuity, including the continuity of growth, be it biological or intellectual.

These three phrases anticipated the gist of the third volume of the Leonardo studies, possibly the most dramatic volume ever published on the history of science. Its more than 600 pages were reserved for the birth and transmission of two pivotal notions of physics, the law of the conservation of momentum and the law of free fall. The former saw birth under the name of impetus in the commentaries of Buridan to various works of Aristotle, a chief advocate of the eternity of the world and its motions. Aristotle was also the originator of that concept of motion in which the mover had to be in continuous contact with the thing moved. Hence, in the Aristotelian discourse the Prime Mover (not unambiguously distinct from the world) had to remain in contact, however intellectualized, with the outermost of the heavenly orbs in order to secure the motion of all celestial bodies and through them all motion below the moon's orb. To part with such an explanation of motion demanded the recognition of the absurdity of the claim that, say, the flight of a projectile was due to the push of the air which closed in behind it almost as if somebody was to lift himself by his own bootstraps. No less needed was a shift in broader cosmological outlook concerning the very source of motion. The Christian view of creation provided that shift and also provided Buridan with his favorite account of the start of all physical motion. Buridan was fully aware that the view very much moulded his reflections. It was also a view which withstood any rational objection that reason could think of:

There is a view which I never could refute in a convincing manner. According to that view, from the very moment of the world's creation God made the heavens move with motions identical to the ones with which they still move. He impressed on them various *impeti* in virtue of which they continue to move with uniform velocity. As these *impeti* do not in fact encounter any resistance which would oppose them, they are never destroyed or diminished.⁷⁴

The crucial importance of this new cosmic outlook was not lost on Duhem. He wanted the reader of the third volume of his *Etudes* to be ready for a drama as soon as he started reading the Introduction to it: 'If one wanted to separate with a

73. *Ibid.*, p. 412. The statement forms part of Note F. In the previously unpublished essay, 'Léonard de Vinci et la pluralité des mondes,' which forms ch. 2 of the volume, Duhem discusses (pp. 75-82) in detail the various propositions condemned by Tempier without, however, attributing to his decree an epoch-making significance.

74. *Etudes sur Léonard de Vinci*, 3:52. The importance attached by Duhem to that passage can be seen from his quoting it also in the Préface of that volume (p. ix).

distinct line the reign of ancient science from modern science, one should trace that line to the moment when John Buridan conceived that theory; to the moment when one ceased looking at the planets as beings moved by divine intelligences; to the moment when one admitted that celestial and sublunary motions rested on the same mechanics.⁷⁵ A mere dozen years after a horizontal line, standing for a contemptuous recall of the presumed ignorance of medieval centuries, appeared in Wohlwill's account on the history of the law of inertia, there emerged another line cutting across the former. The new line witnessed to a genuine science in those centuries and symbolized a new vision. That line was also to separate true scholarship from well-worn clichés.

Duhem's account of the pre-Galilean history of the law of free fall was no less dramatic. Here too he was meticulous for details such as the lack of connection for over two centuries between two propositions: one about the velocity in uniformly accelerated motion, the other about the velocity as a function of time in free fall. But he also served evidence that by the time the Spanish Dominican, Domingo de Soto, educated in Paris, put in print around 1560 for the first time the correct law of free fall as a case of uniformly accelerated motion, the law seemed to have been common knowledge in Paris and elsewhere. Moreover, Duhem served evidence that Galileo was fully cognizant with the works of the 14th-century 'Parisian doctors.'⁷⁶ Such was the background of that declaration of his which is still to make its appropriate impact: 'While in support of these two propositions Galileo will be able to submit new arguments drawn either from reasoning or from experiment, he will not in the least need to discover them.'⁷⁷

No declaration ever made by a historian of science was more dramatic, bolder, more justified and yet so much resented or ignored. Yet, Duhem was only true to that balanced view of history in which continuity is the primary truth and the supreme standard of the recognition to be accorded. Thus he still could speak of the genius of Galileo as the one who, although not a discoverer of the law itself, provided the first geometrical (mathematical) proof of it and also, unlike his medieval forerunners, an experimental verification of the law: 'The Pisan arrived at the proper moment; . . . ripe ideas waited for a geometer of genius who would put in full light the truths living in them and who would launch the science of mechanics of modern times. Galileo was that geometer.'⁷⁸ Never in his admiration of the Middle Ages was Duhem a begrudger of Galileo's glory. He merely wanted, as befitted a historian respectful of fact, that glory to be free of the spurious resplendence of a sheer myth concocted for patently non-scientific purposes.

In the summer of 1910, when Duhem wrote those lines to be ready for the

75. *Ibid.*, p. ix.

76. *Ibid.*, p. 582. The correctness and significance of Duhem's drawing attention to those references to the 'Parisian doctors' in Galileo's early writings were amply demonstrated by recent studies, especially by those of W. Wallace; see, for instance, his 'The Enigma of Domingo de Soto,' *Isis* 59 (1968):348-401.

77. *Etudes sur Léonard de Vinci*, 3:562.

78. *Ibid.*, p. 259.

January-March issue of the *Bulletin Italien*, he had been engaged for six years in a heroic pioneering study of the history of science in medieval and Renaissance centuries. He had six more years of work allotted to him, as he would have certainly put it, by Providence. His balanced view of Galileo's genius was, contrary to a rather slanted claim, not the product of his final and mature view, a sort of retraction.⁷⁹ As a historian, no less than as a philosopher, Duhem showed a surprisingly high degree of 'maturity' at a relatively early stage of his investigations — physical, philosophical, and historical. Nor was maturity ever lacking in his appraisal of the role of Christian creed and dogma in the rise of modern science. Of course, against the dark background produced, propagated, and imposed as a dogma since Francis Bacon and Condorcet agreed — for distinctly different reasons — that Catholicism in particular and Christianity in general were sworn enemies of learning and science,⁸⁰ any rejoicing over the medieval contribution to the rise of science could but appear in established circles an immoderate overreach, nay a sheer sacrilege, not to be tolerated.

Silence, as will be seen, has been one favorite weapon in this respect. Another has been the labeling of Duhem's interest in history as a thinly disguised apologetics to which scholarship is subordinate. There is no trace in Duhem's writings of such motivation whatsoever. His overriding interest was the completeness of the image of physical science. Nothing was, of course, more natural for him than to realize the broader significance of the emergence of science during the Middle Ages in virtue of Christian thought. Such a truth struck at the root of scientism, the unofficial ideology of the Third Republic. In the opening decade of this century, no less than today, the gullible public, including its academic sector, readily swallowed any claim, however unrelated to science and however unfounded, if offered in scientific wrapping. Dismissal of Christianity as an enemy of science and reason is still a chief strategy of her opponents, violent and polite. Only in this light will appear the true physiognomy of the resentment which in certain circles is still provoked by the rejoicing of Duhem, the historian of science, who neither mixed his Catholicism into his historical research, nor was ever ashamed of it. At any rate, unlike many modern historians who try to hide their agnosticism, if not their militantly anti-Christian outlook, under the cloak of 'scholarly objectivity' free of metaphysical presuppositions, Duhem was here too sincerity itself. Indeed, a *Christian* sincerity was needed that the fight of the Sorbonne during the 14th century on

79. A claim of E. Rosen, 'Renaissance Science as Seen by Burckhardt and His Successors,' in T. Helton (ed.), *The Renaissance: A Reconsideration of the Theories and Interpretations of the Age* (Madison: University of Wisconsin Press, 1961), p. 96, based on two rather transparent tactics. One is Rosen's keeping his readers in the dark about the fact that at most three years separate the publication of the third volume of the Leonardo studies from Duhem's writing of what became the tenth volume of the *Système du monde*. The second is Rosen's implicit suggestion that Duhem, who died at the age of 55, was not mature yet as a historian at the age of 52, after ten years of monumental and pioneering researches. More on the motivations of such tactics later; see also note 87 below.

80. For details, see 115 *The Origin of Science and the Science of its Origin*, pp. 7-12 (on Bacon) and pp. 36-39 (on Condorcet).

behalf of Catholic orthodoxy be recognized as the source or matrix out of which there emerged the epoch-making insights of a Buridan and an Oresme. And the *sincerity* of a Christian was needed to add that concluding note in the Preface Duhem penned on May 24, 1913, to the third volume of his Leonardo studies: 'And how could a Christian not give thanks for this to God!'⁸¹

Scholarship as apologetics

Or was a Christian, a Catholic, to remain forever silent about attacks on Christianity based on scientific history? As today, so in Duhem's time, some of those attacks were so many rhetorical exercises in pages reputedly reserved for scholarly exposition. G. Milhaud, future occupant in Paris of a chair created for intellectual history in reference to science,⁸² proved his unfamiliarity with the 'latest' (the first volume of Duhem's *Origines de la statique* published in 1905), as he wrote in 1906 that 'if the art of printing had been invented two centuries earlier it would have especially served the reinforcing of orthodoxy and the propagation of the *Summa* of St. Thomas and works of that kind, in addition to the bulls of excommunication and the decrees of the Holy Office.'⁸³ It was not 'apologetics' on Duhem's part but plain intellectual honesty based on an enormous grasp of factual evidence that made him write in 1913 with a view on Milhaud's dictum: 'If the art of printing had been invented two centuries earlier, there would have been printed, at the rate as they were written, the works which on the ruins of the physics of Aristotle, laid the foundations of a mechanics of which modern times are justly proud.'⁸⁴

Only because he was in command of a vast array of facts gathered with no apologetical motivations (which, even if covert, should seem to call for no apology whatever when aimed at the unearthing of facts), did Duhem feel justified in using the history of science for Christian apologetics. Indeed he urged that such a use be made of it. The major document in this respect is Duhem's letter of May 21, 1911, to the Père Bulliot, professor of philosophy at the Institut Catholique in Paris. The two, who had known one another for years, met on May 14 while Duhem visited Paris. Their conversation must have dealt a great deal with the relevance of the philosophy and history of science for an effective presentation of Catholic truth. The Père Bulliot must have been deeply impressed because next day he asked Duhem in a letter to put in writing his ideas on the subject.

81. *Etudes sur Léonard de Vinci*, 3:xiv.

82. The chair was established in 1908 for the Sorbonne.

83. G. Milhaud, *Etudes sur la pensée scientifique chez les Grecs et les modernes* (Paris: Société française d'imprimerie et de librairie, 1906), pp. 268-9. The statement was part of 'Science grecque et science moderne,' the last of Milhaud's previously published essays reprinted in that volume.

84. *Etudes sur Léonard de Vinci*, 3:xiii.

Duhem quickly complied with a long letter,⁸⁵ much more than a plea for the establishment in the philosophy department of the Institut Catholique of two chairs, one for the philosophy of science, another for the history of science. Such chairs, Duhem argued, could greatly help to counter at its nerve center the strategy of the opponents of Church and Christianity. The strategy, Duhem argued, was no longer about particulars, say, the agreement of this or that biblical verse with the findings of geology, but about fundamentals which determine the outcome of any and all debate. The fundamentals related to two major fields. One was the logical analysis of scientific knowledge as the only one which provides certainty. The other was a portrayal of intellectual history centered on the growth of science as the sole embodiment of rationality. 'As one living among those who profess doctrines contrary to ours and therefore well placed to know their plan of attack against us,' Duhem called the Père Bulliot's attention to the fact that both fields were exploited in order 'to deny, in the name of science as such, to all religion the very right to exist.' The strategy, whatever its intrinsic merit, found steady support in the fact that 'the value of science further asserts itself every day through thousands of marvelously useful inventions which only a blind man would call into doubt.'

The logical analysis of scientific knowledge was used either to advocate radical positivism for which 'the object of religious dogmas is absurd and void of sense,' or to advocate agnosticism which views the same object 'as one which escapes the demonstrations of science and is therefore incapable of being known with the slightest [degree of] certitude.' In the latter case, Duhem noted with striking anticipation of claims made by many philosophers and historians of science, one is asked 'to subscribe to an agnosticism for which all religion is a dream, more or less poetical and comforting.' Needless to say, they would also add that such a comfort was unworthy of a mind 'which had experienced the firm realities of science.' Moreover they would relentlessly resort to the historical argument:

They show us how all the sciences are born of the fertile Greek philosophy whose most brilliant exponents left to the vulgar the ridiculous concern of believing in religious dogmas. They depict to us shockingly that night of the Middle Ages during which the schools, subservient to the agencies of Christianity and exclusively concerned with

85. The full text of that letter is given in *Un savant français*, pp. 158-69. In his letter of May 15, 1911 to Duhem, the Père Bulliot expressed his hope that the pattern to be set by the Institut Catholique in emphasizing the teaching of the history and philosophy of science would be quickly followed by Catholic universities outside France, a hope still to be largely fulfilled. In thanking Duhem for his long letter, the P. Bulliot informed Duhem that his recommendations had been quickly acted upon by the P. Peillaube in the form of a long memorandum to the authorities of the Institut Catholique and that a copy of it had been sent confidentially to him. The P. Bulliot also expressed his regret that Duhem was the only one missing in 'the little cenacle of Clamart [a village 8 km southwest of Paris on the edge of the Meudon forest], a replica of the cenacle in the Montagnes Noires,' a nostalgic allusion to some summer gatherings already described in Chapter 6.

theological discussions, did not know how to gather the smallest parcel of the scientific bequest of the Greeks. They make shine into our very eyes the glories of the Renaissance where minds, liberated at long last of the yoke of the Church, have found again the thread of scientific tradition at the same time as they found the secret of scientific and literary beauty. They delight in contrasting from the 16th century on the always ascending march of science, the ever deeper decadence of religion. They believe themselves to be authorized to predict the imminent demise of religion and at the same time the universal and unchallenged triumph of science. This is what is being taught in a number of chairs, this is what is being written in a multitude of books.'

What sort of a reply was called for by such claims? The reply Duhem spelled out was that of an academic unafraid to vindicate truth from fallacy:

In the face of that teaching it is time that the Catholic teaching rise and hurl into the eyes of its adversary this word: lie! Lie in the domain of logic, lie in the domain of history. A teaching which pretends to have established the irreducible antagonism between the scientific spirit and the spirit of Christianity is the most colossal lie and the most audacious which has ever attempted to dupe the people.

As to the abuse of the analysis of knowledge Duhem stressed the unity of human intelligence. The same mind was at work in various fields although each of them required different presuppositions and objectives. Once this was recognized across the mathematical, experimental, and historical disciplines, it would easily be seen that the specificity of religious knowledge was but another variation on the same intellectuality. As to the portrayal of history on behalf of a narrow-minded analysis of scientific knowledge, Duhem started with a reference to the conditioning of Greek science, from its very birth on, by pagan theology. The various tenets of that theology, including the divinity of the heavens and the uncreatedness of the universe, proved in the long run so many harnesses preventing free intellectual movement and growth. 'If the human mind had not broken these harnesses, it would not have passed beyond Aristotle in physics and beyond Ptolemy in astronomy,' wrote Duhem, who could recite a long list of conceptual breakthroughs made in the Middle Ages as his answer to the questions: 'Who broke these harnesses? Who had first profited from the freedom thus gained in order to launch forward to the discovery of a new science?' The inference was blunt in its plainness: 'If therefore that science, of which we are so legitimately proud, could see birth, it was only because the Catholic Church was its midwife.'

If such was the case, the establishment of two chairs, one for the philosophy of science, another for the history of science, had to be of paramount importance for the Institut Catholique or for any Catholic institution of learning:

The chair devoted to the analysis of the logical methods by which the various sciences make their progress, would show us that one can, without contradiction and incoherence, pursue the acquisition of positive [scientific] knowledge and, at the same time, meditate on religious truths. The [instruction given from the] other chair would, by following the historical course of the development of human knowledge, lead us to recognize that in times when men were intent above all on the Kingdom of God and of His justice, God gave them for good measure the most profound and seminal thoughts concerning things of this world.

The proposition may have appeared daring to many though not to Duhem whose 'sole concern' in the matter was 'to see the Kingdom of God re-established among us' and who held that he dealt with an 'objective on behalf of which there was no daring which would not only be permissible but very much in order.'

Nothing would be more misleading about Duhem than this letter if read either with the sanguine eyes of a facile Christian apologist or with the resentful mind of someone bent on keeping science harnessed in the service of unscientific aims. None of Duhem's writings comes even remotely close to apologetical (or counter-apologetical) writings, a genre very much in vogue at that time. At Collège Stanislas, at the Ecole Normale, and in Lille, Duhem, as was already noted, stood apart from such involvements. He worked out a philosophy of physics to satisfy himself as a physicist. That such a philosophy could be useful for countering the claims of scientism was not something that motivated his work. For years he accepted with no discomfort the standard view of the history of science according to which there was nothing between the Greeks and Descartes. Not in the slightest did he espouse, as he wrote his *Evolution of mechanics* and the first installments of his *Origines de la statique*, anything of inept apologetic efforts which in the second half of the nineteenth century tried to rehabilitate scientifically the Middle Ages.⁸⁶ Only rank prejudice would see in Duhem's celebrated series of essays, *To Save the Phenomena*, a work motivated by the desire to undercut once and for all the anti-Catholic exploitation of the Galileo case. Duhem's interest in the motto, 'to save the phenomena,' was born out of his wrestling, while in Lille, with the nature of physical theory as an explanation. It was most natural for him to become interested in the whole history of that motto after it had become very clear to him, following his encounter with the writings of Jordanus Nemorarius and with the complex history of Leonardo the scientist, that large segments of scientific history were missing in the standard accounts.

The quest for completeness

To restore the completeness of the record was enough of a motivation for Duhem to write that famous essay. Historical completeness was a test of the truth of his theory of physics. Since it was the essence of physical science to be mathematical, the truth of physical theory, Duhem noted,⁸⁷ could not be illustrated from medieval physics which for all its insights remained essentially qualitative, even its science of weights, the discovery of which enthralled him so much. Quite different was the case with astronomy. It was the only part of physical science which already in the hands of the Greeks achieved a mature degree of exact, that is, quantitative treatment. In this special status of astronomy Duhem saw a major proof of his

86. The schoolman most often seized upon in that respect was Albert the Great, who was turned into the initiator of the experimental method by F. A. Pouchet, professor of zoology at Rouen, in his *Histoire des sciences naturelles au Moyen Age ou Albert le Grand et son époque considérés comme point de départ de l'école expérimentale* (Paris: J. B. Baillière, 1853).

87. *To Save the Phenomena*, 1969 (1), p. 3. This remark of Duhem should suffice to lay bare the hollowness of Rosen's claim discussed in note 79 above.

principal contention that physical theory was not an explanation but a quantitative systematization of data and that physical science advanced most when its cultivators have seen physical theory in such a light.

While this last point could readily be argued with respect to Ptolemy, whose system was not surpassed in accuracy by the heliocentrism of Copernicus, the latter, and especially Kepler and Galileo, to all of whom Duhem referred as 'Renaissance astronomers,' was a different matter. Could it be shown that their great achievements were done in virtue of the purely formalist motto, 'to save the phenomena,' in spite of their formal opposition to it, and in spite of the 'realism' to which they subscribed in the belief that physical theory was an explanation? It was this question which Duhem tried to answer by setting forth the history of that motto on a scale that went well beyond the level to which scholars like T.H. Martin, G. Schiaparelli, and P. Mansion, all of whose help Duhem generously acknowledged, had carried it.⁸⁸ Being fully conscious of why he was undertaking the history of that motto, he could benefit in full from the insights which that meaning, as he saw it, provided. The meaning enabled him to be eminently fair to the 'Renaissance astronomers' in spite of laying bare the superficiality of their 'realism.' It was not so much a realism based on common sense as the 'realism' of a spurious reification of geometry. (Galileo was too poor a 'realist' philosopher to realize the disastrous consequences for his 'realism' which followed from his rejection of the reality of secondary qualities.) Since a pivotal part of Duhem's theory of physics was that it should rigorously and consistently account for *all* phenomena, his story could end as an ecomium of 'Renaissance astronomers.' For, as Duhem put it, what the Renaissance astronomers, in spite of their spurious realism, were really requiring was

that the theory of the celestial motions rest upon bases that could support the theory of the motions we observe here below as well. The courses of the stars, the ebb and flow of the sea, the motion of projectiles, the fall of heavy bodies – all were to be saved by *one and the same* set of postulates, postulates formulated in the language of mathematics . . . Despite Kepler and Galileo, we believe today with Osiander and Bellarmine that the hypotheses of physics are mere mathematical contrivances devised for the purpose of saving the phenomena. But thanks to Kepler and Galileo, we now require that they save *all the phenomena* of the inanimate universe *together*.⁸⁹

Today when the equivalence of all reference systems is part and parcel of thinking in physics, the position of Osiander, Bellarmine, and Urban VIII appears far more than a poor defensive tactic of embattled theologians. In 1908, when Duhem wrote those words, Einstein's relativity still had to assert itself. Hence Duhem's

88. Their studies were of help to Duhem only in the first chapter dealing with hellenic science. For the remainder of the work – another six chapters dealing with the views of Arabic, Jewish, Scholastic, and Renaissance astronomers up to Galileo – his sole help was the *Bibliographie générale de l'astronomie* (1887) by Houzeau and Lancaster. He was indeed most entitled to point out that 'to the texts which they [Martin, Schiaparelli, and Mansion] brought to attention we shall be adding a good many others' (*ibid.*, p. 4).

89. *Ibid.*, pp. 116-17.

insight and articulation should seem all the more impressive and daring. Duhem did not wish to win particular battles. His strategy aimed at the entire dispute between formalists and realists and therefore had to cover the field as completely as possible. Canvassing the story from Plato to Copernicus issued in the ten volumes of the *Système du monde* and seems to have called for superhuman forces as its almost six thousand pages, bursting with material of astonishing richness, were written in a mere eight years that were not exclusively set apart for the undertaking. Aiming at completeness implied attention to all facets of the process under investigation, and therefore to its slowness, a principal facet if the growth was genuine, that is, organic. Thus Duhem took for the motto of the whole work a dictum of Roger Bacon: 'Never was any science invented at any particular time, but from the beginning of the world knowledge has grown slowly and is still not complete at this very age.'⁹⁰

Since Duhem's interest in the history of physical science was a function of his philosophy of physics, it should not be surprising that the *Système du monde* was from its first volume on a mine of information on the philosophies of those who discoursed on scientific matters from the time of Plato. The first two volumes of the *Système* dealing with the evolution of cosmology in classical antiquity from Plato to Philoponus would have done credit to a historian of Greek philosophy. The same volumes are still among the best accounts, and in a specific sense the very best account, of cosmological science in Hellenic and Hellenistic antiquity. Duhem's treatment of the subject was steeped in the belief that all science was a function of a world view. This is why Duhem devoted so much space to the question of tides as discussed by ancient Greek authors.⁹¹ For it was there that came most conspicuously to the fore within a scientific context the intellectually hopeless entanglement of the ancient Greek world view in astrological lore. There the specific sense, in which the ancient Greeks attributed unity to the world of things, also came fully to the fore. While the attribution of unity is at least an implicit requirement of any meaningful scientific work, the sense in which such an attribution is made is of decisive importance for the true quality of that work. The unity of all was for the Greeks the unity of a living organism. For them the world was an all-encompassing living entity, a view codified by Plato and Aristotle. Such a world view, in which everything was connected with everything as so many members of one living body, invited Aristotle's definition of motion that the mover and the moved had to be in continuous contact with one another during the whole duration of motion. Astrological discourse was part and parcel of that organismic view of the world which made the formulation of a correct science of dynamics impossible. Astrological preoccupations, so many threats to human freedom, including the freedom of inquiry, infiltrated and corrupted all scientific discourse

90. Duhem's admiration for Roger Bacon sharply contrasted with his strictures of Francis Bacon as one who did not understand a thing about the experimental method while singing its praises (*Système du monde*, 3:440).

91. *Ibid.*, 2:266-390.

whenever that discourse went beyond geometry or a purely geometrical astronomy to such topics as the tides. Thus in the same contexts, where the tides were spoken of as the effect of the mutual pull between two material bodies, the earth and the moon, there was the ubiquitous presence of the astrological exploitation of an idea which could in itself have propelled ancient Greek thought toward the recognition of universal gravitation and its mathematical formulation. The ancient Greek mind, for all its excellence in the sciences, which Duhem portrayed with astonishing mastery and detail, especially with respect to astronomy, could not free itself of the mirage of an astrological and organismic world view. The latter received its supreme expression in the doctrine or system of the Great Year. To make one of the greatest discoveries of all times, the recognition by Hipparchus of the precession of the equinoxes, subservient to that system, was taken for a meritorious task by all schools. Or as Duhem brought to a conclusion the over 900 pages he devoted to ancient Greek science:

To the construction of that system all disciples of Hellenic philosophy – Peripatetics, Stoics, Neo-Platonists – contributed; to that system Abu Masar offered the homage of the Arabs; the most illustrious rabbis, from Philo of Alexandria to Maimonides, have accepted it. To condemn it and to throw it overboard as a monstrous superstition, Christianity had to come.⁹²

Against this background it made eminent sense to discuss, as Duhem did in a way of a long conclusion to the second volume of the *Système*, the manner in which the Church Fathers reacted to the philosophy and science of pagan Greek teachers. Looking at it superficially, the manner was puerile and obscurantist on the part of not a few Fathers eager to vindicate the letter of the Biblical story of creation. Even more obscurantist would their attitude appear if viewed through scholarly sourcebooks on Greek science which readily give the impression that there traversed through the centuries of classical antiquity a tradition of ‘pure science’ untainted by any form of obscurantism. To be sure, in the dicta of the Fathers there are not lacking gems of ‘enlightened reason,’ such as Augustine’s warning that, since the heathen can know a number of things about the material world that can be ‘experimentally verified’ and supported by ‘unquestionable proofs,’ the faithful must be on guard against making a laughing stock of themselves and of the Bible.⁹³ Although undoubtedly familiar with that warning, Duhem did not quote it.⁹⁴ He wrote not apologetics but a history where he never

92. *Ibid.*, p. 390. This all-important point, made by Duhem, is further discussed in the context of the first two volumes of the *Système* in my article, ‘The Greeks of Old and the Novelty of Science,’ in *Artes mnéme: Aphiéroma eis mnémen tou Konstantinou I. Bourbére* [Vourveris Festschrift] (Athens: Elleniké Anthropolistiké Etaireia, 1983), pp. 263-77.

93. St. Augustine, *De genesi ad litteram*, Lib. 1, cp. 19. For English translation of the entire passage, see my *Science and Creation: From Eternal Cycles to an Oscillating Universe* (Edinburgh: Scottish Academic Press, 1974), p. 182.

94. In discussing the cosmological stance of the Church Fathers, Duhem quoted three times from the first book of *De genesi ad litteram*, though not from the 19th chapter; see *Système du monde*, 2:436-7 and 492.

lost sight of the basic issue. It related to the presence, beneath scientific particulars, of cosmologies which, as he put it, were so many theologies.⁹⁵ The Fathers did not have to be experts on science to oppose and reject those cosmologies and theologies. Yet, by doing so they cleared the ground for a better science and also provided the spark for it. Duhem was not the purist historian afraid of giving a foretaste of the grand conclusion:

In the name of Christian doctrine the Church Fathers attacked the pagan philosophers on points which today we judge to pertain more to metaphysics than to physics, such as the theory of eternal prime matter, the belief in the domination of planets on sub-lunary things, the belief in the periodic life of the world caught in the rhythm of the Great Year. By destroying through those attacks the cosmologies of Peripatetics, Stoics and Neoplatonists, the Fathers of the Church cleared the terrain for modern science . . . Modern science, one may say, will be born the day when one will dare to proclaim the truth: the same mechanics, the same laws govern the celestial motions and the sub-lunary motions, the motion of the sun, the ebb and flow of the sea, the fall of bodies. That such an idea may possibly be conceived it was necessary that the stars should be removed from the divine rank where Antiquity had put them; it was necessary that a theological revolution take place. This revolution will be the work of Christian theology. Modern science caught fire from the spark touched off by the clash between the theology of Hellenic paganism and the theology of Christianity.⁹⁶

Within that perspective it was no rhetoric to lament the demise of classical wisdom in the very lands which saw its birth and development and to recall the coming of new young nations eager to seize the last and almost dry seeds of that wisdom. Much more was at issue than to bring fresh forces to lands peopled by decadent nations where the power of invention was growing feeble. The soil itself, Duhem warned, had to be reworked to let a new vegetation arise.⁹⁷

Apart from this view in depth the *Système du monde* may appear useful only as a storehouse of data to satisfy the precepts of logical positivism according to which everything meaningful must be 'on the surface.'⁹⁸ Of course, the *Système* was bursting with such data. In addition to the long section on tides, its first two volumes are still a first-rate source on each and every discourse of the Greeks of old on homocentric spheres, on heliocentrism, on eccentrics and epicycles, and on the dimensions of the world. The subsequent volumes are bursting no less with 'positive' information. The third volume is a still unsurpassed documentation on such a 'positive' topic as the medieval reflections on Heraclides of Pontus' system of the world, a transition between geocentrism and heliocentrism. Duhem did not exaggerate in introducing that third volume with the remark: 'The desire to learn was intense among the young nations which invaded the Roman Empire.'⁹⁹

95. *Ibid.*, p. 453.

96. *Ibid.*, pp. 408 and 453.

97. *Ibid.*, p. 501.

98. As stated in the Manifesto of the Vienna Circle. See *Wissenschaftliche Weltauffassung: Der Wiener Kreis* (Vienna: Verein Ernst Mach 1929), p. 15.

99. *Système du monde*, 3:3.

No less intense was his own eagerness to learn and unearth everything possible about that desire. The third and fourth volumes, largely devoted to astronomy as cultivated in various medieval schools — secular clergy, Dominicans, Franciscans, Parisian and Italian doctors — would do credit to any historian of science for whom only positive data are of relevance. The same type of scholar would, of course, be dismayed by the ‘positivist’ Duhem’s resolve to consider the various metaphysical notions beneath the ‘positive’ crust. The second part of the *Système*, devoted to astronomical theories in the Latin Middle Ages, is followed by a vast discussion of the philosophical layers underlying those ‘positive’ systems, including their most fundamental or metaphysical kinds. But even a historian sensitive to the sweep of metaphysics probably did not guess what was ultimately in store as Duhem declared at the very outset: ‘The dominant ambition of human intelligence is the one which pushed him to comprehend the universe. To know what all things are, whence they come, whither they go, such is the curiosity of *infinite* amplitude which . . . gave birth to philosophy.’¹⁰⁰

Duhem went all the length philosophy called for as he considered first Neoplatonism, mostly transmitted by the Arabs, as one of the philosophies underlying astronomical theories which were discussed during the Middle Ages. Some Arabic commentators of the ‘Theology of Aristotle’, a chief source of Neoplatonism for the medievals, noted a strange contradiction there. On the basis of pure emanationism it was contradictory that a superior being should desire an inferior being and provide thereby its *raison d’être*. In fact the very concern of a superior being about any inferior being turned the former, if the logic of emanationism was strictly followed, into a being less worthy than the inferior being. Al-Ghazzali, the Muslim philosopher-mystic, aware of the dogma of creation which the Koran inherited from biblical revelation, accepted that contradiction. He did so with a reference to the concern of the shepherd for his sheep, of a prophet for his disciples: ‘The shepherd insofar as he is a shepherd [who cares for his sheep] is inferior to the sheep but superior to them insofar as he is a man.’ In commenting on this Duhem went all the length required by the facts of the history of human reflection: ‘Assuredly no philosophy outside the influence of Christianity could make intelligible the benevolence by which the superior being desires, without compromising [his own status], the good of the inferior being. No such philosophy could comprehend that the prophet loves his people, that the Good Shepherd loves his sheep to the point of giving his life for them.’¹⁰¹ A sectarian comment, the ‘non-sectarian’ historian would add in hinting about the presence of a debilitating bias irreconcilable with ‘objective’ scholarship. But is not there more bias in the positivist’s non-sectarianism, professedly in service of all facts, which shuns and positively excludes decisive facts of intellectual history because those facts witnessed an unlimited resolve to understand the world, that is, existence itself?

Not that Duhem was attuned to questions about existence, his commitment

100. *Ibid.*, 4:309 (italics added).

101. *Ibid.*, 4:453.

to the primacy of common sense notwithstanding. This is well attested by the fifth volume of the *Système*, which completes Duhem's treatment of the growing tide of Aristotelianism during the 14th century. He brings it to a close with Siger of Brabant's espousal of Aristotle. In Duhem's rendering, Siger's stance was an unintended warning that Peripatetic doctrine and Christian faith were irreconcilable. Duhem took the 1277 decision as a heeding of that warning. Christendom had to choose, and Duhem was obviously rejoicing over the choice made on behalf of faith against an unreconstructed Aristotelianism. That these were the real alternatives seemed to Duhem exemplified in Siger of Brabant's insistence that Aristotelianism demanded from Scholastic Christianity, unwilling to reject Catholic orthodoxy, the admission that two contradictory doctrines could both be true: 'One because the Church taught it, the other because it was rationally demonstrated by the philosophers.' But Duhem himself cast the alternative also in a form which he hardly thought over: 'Christianity was expected to sacrifice either its faith or its common sense. The side was quickly taken by Christianity which sacrificed pagan philosophy.'¹⁰² Duhem, a professed apostle of common sense and a convinced Catholic, can hardly be pictured as one relinquishing common sense to a philosophy which he held, in its fully rigorous form, to be an intrinsically pagan philosophy. But his apparent identification of common sense and pagan philosophy lays bare once more the pitfalls of his neglect to articulate the very foundations of his philosophy, a philosophy steeped in the validity of common sense and the metaphysics it invites. Not only the understanding of Duhem's philosophy was compromised by that neglect but also Duhem's understanding of medieval science and also his readers' understanding of what he said. This is however to anticipate.

A gamut of reactions

Reaction to Duhem's major publications in the history of science was not at all commensurate with the vastness of new material he submitted and to the revolutionary character of his interpretation of it. Curiously, the *Origines de la statique* was not reviewed in the *Revue des questions scientifiques* where it first appeared in installments. This was all the more surprising because Paul Mansion, professor of mathematics at the University of Ghent and a first-rate historian of mathematics, was a chief power behind the *Revue* and had acknowledged in a letter of June 10, 1910, to Duhem, that those installments greatly enhanced the reputation of the *Revue* abroad. Certainly more was in order if Duhem's treatment there of Leonardo prompted Charles Ravaisson-Mollien, the foremost Leonardo scholar in France, to send Duhem the following letter on November 27, 1905: 'I have not read anything more instructive, more interesting, and more original on the character of Leonardo da Vinci and on the proper part which must be attributed to him in that science [of mechanics] . . . This is what you have shown, Monsieur, in a superior manner, in a spirit of perfect equity and this is for me a

102. *Ibid.*, 5:580.

joy which compensates me for the boredom I endured on reading certain appraisals, as false as reckless, by men of recognized and incontestable merit.'

Ravaisson-Mollien's boredom may have been touched off by his reading books on Leonardo by E. Müntz¹⁰³ and by G. Séailles.¹⁰⁴ The latter, professor at the Sorbonne, presented his work on Leonardo the artist and scientist as an 'essay of psychological biography.' Duhem's attention was undoubtedly called to the second edition of Séailles' book (1905) and he must have been amused, perhaps also irritated, by the inept tactics of Séailles in the face of massive evidence. Leonardo was for Séailles above all a chief apostate from Christianity. While Duhem's thesis that Leonardo had medieval predecessors was mentioned in the preface of that second edition¹⁰⁵ and even the name of Jordanus Nemorarius appeared briefly as Séailles discussed Leonardo and the origins of modern science, Leonardo remained for Séailles the beginning of modern science and the medieval centuries an unqualified Dark Age. Séailles had no choice. He saw in Leonardo above all a freethinker who by the age of thirty was, as Séailles pointedly put it, 'no longer the sublime child of Christ's baptism.'¹⁰⁶

Even when anti-christianism was less virulent than that displayed by Séailles, it was sufficient to distort Duhem's message. A case in point was Jules Sageret's history of cosmology from ancient Babylon to Newton. While its chapter iii on the evolution of the science of dynamics was replete with references to Duhem, Sageret kept his readers in the dark about Duhem's insistence on the decisive theological contribution of the Middle Ages to matters scientific.¹⁰⁷ To the academic circles represented by Sageret that contribution was not such as to bring glory to the medieval French academic world, the Sorbonne in particular. The 'incomparable splendor of the University of Paris during the 13th, 14th, and 15th centuries,' of which no less an official representative of French academia than L. Liard boasted

103. E. Müntz, *Léonard de Vinci: l'artiste, le penseur, le savant* (Paris: Hachette, 1899); see English translation, *Leonardo da Vinci: Artist, Thinker, and Man of Science* (London: W. Heinemann, 1898), 2:70-80, on mathematics, mechanics, and physics. Müntz had no eyes for the importance of Leonardo's dicta on balance and virtual velocity, which he did not mention at all.

104. G. Séailles, *Léonard de Vinci. L'artiste et le savant (1452-1519): Essai de biographie psychologique* (Paris: Perrin, 1891).

105. Paris: Perrin, 1905, p. vii.

106. New, revised and enlarged edition; Paris: Perrin, 1919, p. 38. Jordanus Nemorarius' *De ponderibus* was described by Séailles as 'one of the rare works which continues the Greek scientific tradition' (p. 382). Duhem was not mentioned in the chapter, 'Léonard et l'origine de la science moderne' (pp. 369-94), as if Duhem had not been the originator of the phrase concluding that chapter: 'One has to renounce once and for all that prejudice that Bacon and Descartes invented science.'

107. In J. Sageret's *Le système du monde des Chaldéens à Newton* (Paris: F. Alcan, 1913), the decision of 1277 is mentioned (p. 247) as an incidental matter dealing solely with the plurality of worlds!

in his sumptuously printed book on the past and present of that university, did not include as much as a hint of the splendors laid bare by Duhem.¹⁰⁸

This was all the more curious because a year before Liard's book saw print there appeared in Paris in 1908 the first volume of a book in which the principles of mechanics were set forth not only in terms of its historical development but also documented with long excerpts from original sources, many of them medieval. Its author, E. Jouguet, future professor at the Ecole des Mines, heavily relied on Duhem's *Origines de la statique* throughout the first hundred pages of that volume which, as the second volume too, was pure science.¹⁰⁹ The strictly scientific merits of Duhem's historical investigations were indeed such as to prompt the highest encomiums on the part of scientists, especially abroad. The second volume of the *Origines de la statique* was greeted in the *Journal of Physical Chemistry* as a 'work particularly opportune at the present time when mechanics is undergoing its second great transformation.'¹¹⁰ In recalling the words, 'Eppùr si muove,' E. B. Wilson wrote in the *Bulletin of the American Mathematical Society*: 'It probably takes as much courage nowadays to maintain that 'the earth moves' means merely that 'it is more convenient to assume that the earth moves'.' One wonders what was the reaction of some at the Sorbonne and in France on reading Wilson's further remark: 'It is interesting to note that during the fourteenth, fifteenth, and sixteenth centuries the masters at the Sorbonne set forth views on physical theory which were better than any heard up to the middle of the last century.'¹¹¹ The first two volumes of Duhem's Leonardo studies gave rise to another incisive comment, again from the United States. According to David Eugene Smith, both a first-rate mathematician and a historian of mathematics, 'Duhem has not written a history of science but has composed a work of the kind that makes the history of science possible.'¹¹²

Clearly, unless one was resentful of historic Christianity, it was possible to perceive the immense scientific merits of Duhem's historical researches. To scholars with Christian convictions Duhem's findings could be most welcome news. Very typical in that respect was Mansion's reaction to *To Save the Phenomena* as stated in his letter of January 22, 1929, to Duhem: 'I have read it with the greatest interest and in closing it I said to myself: *Now the battle is won*. All those who read it will at long last know what *is* physical theory. One can now write a definitive history of the Galileo case and in general one will understand the history of the

108. L. Liard *L'Université de Paris* (Paris: Librairie Renouard – H. Laurens, Editeur: 1909), 1:14.

109. E. Jouguet, *Lectures de mécanique. La mécanique enseignée par les auteurs originaux. Première Partie. La naissance de la mécanique* (Paris: Gauthier-Villars, 1908). Jouguet's indebtedness to Duhem was noted in the *Revue du mois* by E. B. (Emile Borel, its director) as he concluded his brief review of Jouguet's work with the remark that 'it was unnecessary to recall the importance and the very personal tendencies of the historical researches of that learned theoretician' (7 [1909]:505), a subtly backhanded praise indeed.

110. *JPhCh* 11 (1907):422.

111. 16 (1909-10):325.

112. *Ibid.*, 17 (1910-11):488.

past.' Similarly enthusiastic was A. Dufourcq's widely read account of what Duhem accomplished in *To Save the Phenomena* as a sequel to his studies on the origin of statics and on Leonardo. The opening paragraph of that account in the July 15, 1913, issue of the *Revue des deux mondes* must have sounded ominous in the ears of all those on the side of Condorcet for whom the question of the origin of science had been settled once and for all:

The origins of science are less known than its discoveries. We profit from its conquests, enjoy its benefits without any concern about the source from which they derive. Yet there is no more interesting study. In no domain is human progress secured by some spontaneous and necessary evolution. It is important to know the conditions in which science was born, the conditions in which its progress accelerates so that our future procedures may be better oriented. For this reason the works of Duhem must be highly esteemed. They establish on the basis of vast evidence that the principles on which modern science rests were formulated before Newton, before Descartes, before Galileo, before Copernicus, before Leonardo himself, by the masters of the University of Paris during the 14th century.¹¹³

Readers familiar with Duhem's works could not be surprised by Dufourcq's recital of Duhem's documentation of the existence of a keen interest among medievals in observational evidence. Different must have been the case with Dufourcq's emphasis on the decision of 1277. The third volume of the Leonardo studies, in which, as already noted, he made his first explicit reference to that decision as marking the birth of modern science, was just about to appear. The sixth volume of the *Système du monde*, in which Duhem enthusiastically hailed that decision in the same sense,¹¹⁴ was not to be published for another forty years, and the same was true of its seventh volume in which he credited Dufourcq for making him see the importance of that decision.¹¹⁵ Dufourcq first argued at some length in the sixth volume of his great church history that the decision was an intellectual breakthrough because of its emphasis on divine omnipotence versus Aristotelian necessitarianism.¹¹⁶ It was an emphasis which only a religion, Christianity, steeped in God's miraculous deeds witnessing His omnipotence, could effectively generate. In Dufourcq's words, 'this double push of *believers* protesting in the name of faith and of *observers* protesting in the name of experience overthrows the Aristotelian science and raises that new Parisian science.'¹¹⁷ Dufourcq's concluding words put then the matter in its deepest perspective:

113. A. Dufourcq, 'Les origines de la science moderne d'après les découvertes récentes,' *RDM* 16 (1913):349-78.

114. There (*Système du monde*, 6:66) Duhem specified that 'one of the principal aims of the present work is to justify the assertion that modern science was born, so to speak, on March 7, 1277, from the decree issued by Msgr. Etienne, bishop of Paris.'

115. *Système du monde*, 7:4.

116. A. Dufourcq, *L'avenir du christianisme. Première partie. Le passé chrétien. Vie et pensée, VI. Epoque occidentale. Histoire de l'Eglise du XI^e au XVIII^e siècle. Le christianisme et l'organisation féodale. 1049-1300.* (3d rev. ed.; Paris: Bloud et Cie, 1911), pp. 360-63. The earlier editions of this volume were not available to me.

117. A. Dufourcq, 'Les origines de la science moderne ...,' p. 362.

Duhem's work tells how erroneous is the tradition which opposes the Middle Ages to the Renaissance. Undoubtedly the adepts of that tradition no longer dare to portray a barbaric art in the Gothic style, nor, for that matter, an arbitrary and fanatical regime in the civilization of the 12th and 13th centuries. But until the books of Duhem they could base the opposition between those two epochs on their different attitudes toward the experimental method and summarily describe the Renaissance as the rise of science and the collapse of faith. Today we see what one should think about all this: It is in the full Middle Ages that science was born.¹¹⁸

Such a message was a striking novelty for those on the side of Christ. In 1914 Father Bosmans introduced his review of the third volume of the Leonardo studies, subtitled 'the Parisian precursors of Galileo,' with the words: Here is one of the most novel topics one can imagine.¹¹⁹ To Duhem's words, 'until a few years ago the science of the Middle Ages was thought to be non-existent,' Bosmans, a Jesuit, added:

I remember, many years have gone by since, I was then a student of theology and philosophy, busy with things very different from the science of mechanics . . . In order to get respite from the metaphysics of the masters of the Middle Ages, or, to tell frankly, to have a laugh for a moment, my comrades and myself read aloud a page from the physics of those old scholastics. To laugh! And how right it seemed to be! The whole world thought the same. We have long since had second thoughts about these outbursts of hilarity. Duhem's book taught me how many prejudices still remain to be corrected.¹²⁰

It was the third volume of the Leonardo studies which made the historians of science, still hardly an identifiable group, recognize that Duhem was opening in their field a new epoch. Or as A. Mieli, of the University of Rome, wrote in the November 1914 issue of *Scientia*, then by far the leading periodical of the history of science:

Pierre Duhem is among all living scientists one of the vastest and most sympathetic minds. His enormous information permits him to write voluminous treatises, appreciated in physics as well as in physical chemistry, and to discuss in the most penetrating and customarily balanced manner questions of scientific philosophy since the times of the Greeks to modern times, and to publish in addition a long fragment of the *Opus tertium* of Roger Bacon. Moreover, very few are those who know the medieval science as well as the eminent professor of Bordeaux and this fact made him especially capable of pursuing the studies of which we speak . . . In pursuing those studies concerning in particular the concept of motion of free fall, scattered in the notebooks of Leonardo, Duhem gave us an insight, definitive in some respects, of the development of the principles of dynamics and kinematics, considered many new facts of the greatest importance for the history of science, and reached results which are very new and very interesting.¹²¹

118. *Ibid.*, p. 378.

119. *RQSc* 76 (1914) 529-37.

120. *Ibid.*, p. 530.

121. *Scientia* 15 (1914):440.

The next year Mieli wrote, à propos the first volume of the *Système du monde*:

We must congratulate ourselves that a work of this type has been undertaken by such a profound expert of these so-neglected Middle Ages which, however, offer such a great abundance of facts worthy of attention. And we must all the more rejoice because Duhem displays a truly historical sense, examines his subject from the vast perspective which we shall point out shortly. Most of the so-called modern philosophers would have been incapable, either because of incompetence or because of insufficient preparation, to treat such a subject. Or if they had developed its general theories, they would have misunderstood them in the belief that the evolution of thought coincides with what the modern philosopher thinks to be the evolution of his own thought.

After noting that a mere professional astronomer would be just as incapable of doing justice to the philosophical part of the story, Mieli added:

On the contrary, Duhem, who of course has personal ideas to which not everybody would subscribe, possesses a truly ingenious and wise intellect of a mathematician, a physicist, a philosopher, and a philologist.¹²²

A year later, in reviewing the second and third volumes of the *Système*, Mieli could not help having thoughts which retain a lasting validity for a proper estimate of Duhem, the historian of medieval science. The considerable lack of serious studies on the science of the Middle Ages had their cause in the fact, Mieli wrote,

that scientists had for long obstinately qualified as unworthy of scientific consideration the medieval works and works of ecclesiastical character . . . and this applies with particular force to the study of the world systems which superficial scientists could in particular find tainted with sectarian corruptions. A study like Duhem's has therefore an exceptional value, especially if one keeps in mind his vastly documented and complete method of exposition.¹²³

As one could expect, Italian scholars took exception to Duhem's tracing Galileo's ideas to Leonardo. In claiming that Galileo's *Juvenilia*, replete with Leonardo's ideas, in no way represented Galileo's own thought, Favaro made one of his rare blunders. Favaro hoped that Duhem would yield. But by the time Favaro corrected the proofs of his article, Duhem was dead. Favaro felt that the article still was to be published as a tribute to Duhem's memory: 'We have already stated so openly

122. *Ibid.*, 17 (1915):463-64.

123. *Ibid.*, 20 (1916):398. Mieli also noted that a minor part of the problem was posed by 'books written on medieval science by ecclesiastics with no competence whatever in matters scientific' (*ibid.*). Quite different was the reaction of G. Loria to the *Système du monde* as he reviewed its first five volumes in the *Bulletin des sciences mathématiques*, where ample space was given him on each occasion. He kept praising Duhem for his indefatigable researches, which in his view added nothing new to what had by then been known! He saw Duhem's chief, though partly useless, service, in his having spared other scholars from trying to find anything novel in boring medieval folios (*BScM* 39 [1915]:14; 40 [1916]:285; 43 [1919]:135). Loria found true merit only in vol. 4, but only inasmuch as the astronomical reflections of the 14th century prepared the reform of the calendar (*ibid.*, 41 [1917]:232). Not surprisingly, Duhem did not exist for Loria even as he discussed Leonardo in his *Storia delle matematiche. Vol. I, Antichità-Medio Evo-Rinascimento* (Torino: STEN, 1929).

our limitless admiration for this eminent scholar that any further statement, except that of our keen grief, would be superfluous.¹²⁴

The French responded to Duhem's major historical studies with only one significant essay, a two-part study by H. Lemonnier, professor of art history at the Sorbonne. The study, occasioned by Duhem's death, appeared in the *Journal des savants*¹²⁵ and had Duhem's Leonardo studies for its principal subject. Lemonnier's view that Duhem's discovery of medieval science added 'one century to the history of French science,'¹²⁶ was not novel. Duhem himself struck repeatedly a patriotic note, at times too patriotic. It did not make his work any more acceptable for most scholars within the 'Republican' establishment. The vindication of medieval Christian past on a strictly scientific level was unacceptable to them, even on the basis of patriotism. The restoration by Duhem of 'the continuity of our intellectual history paralleling the continuity of our political history,'¹²⁷ to quote another phrase of Lemonnier, was not an ingredient essentially different from the former. Not that Lemonnier insisted on it, though it was clearly impossible to pass it over in silence in any detailed review, sufficiently objective. Lemonnier's phrase, 'thus the rehabilitation of the Middle Ages is completed,'¹²⁸ was the reminder by an art historian to historians of science, and a sufficiently clear pointer to the heart of the matter. Lemonnier's chief interest was to compare Duhem's Leonardo studies with studies published during the previous ten years and he could not conceal his surprise over the extent to which serious scholarship on Leonardo confirmed Duhem's theses. Lemonnier also had an eye on works that preceded Duhem's Leonardo studies. That Leonardo voraciously read and studied authors of the 14th and 15th centuries had been largely realized by the time Duhem came to the scene. 'But one will not forget, especially we [historians], that Duhem was the first, or almost the first to emphasize it; that he carried his reflections to special points either neglected or ignored [until then]; that he established an argument which usually was very precise, and that at the same time he enormously extended research on Leonardo and on its implications . . . If others began at the same time tracing out that road, Duhem marked its direction more strongly and

124. A. Favaro, 'Léonard de Vinci a-t-il exercé une influence sur Galilée et son école?' *Scientia* 20 (1916):247-65; for quotation see p. 265. Favaro's defense of the importance of the Italian tradition, a defense no less suspect of that chauvinism of which Duhem was charged time and again, was echoed by other Italian scholars, such as Marcolongo (see his obituary of Duhem quoted in Ch. 8). They invariably referred to the works of Caverni and of G. Valiati (1863-1909). Duhem was one of the sponsors of the edition of Valiati's collected papers, *Scritti* (Leipzig: Barth, 1911), which contains (pp. 834-41) Valiati's criticism (1907) of Duhem's postulating a 'Precursor' of Jordanus Nemorarius.

125. H. Lemmonier, 'Les 'Etudes' de Pierre Duhem sur Léonard de Vinci,' *Journal des savants* 15 (janvier et mars 1917):25-34 and 120-32. The only noteworthy pages on the *Origines de la statique* and on the *Etudes sur Léonard de Vinci* that saw print in France prior to Lemonnier's essay were book reviews written, typically enough, by J. Tannery in the *Bulletin des sciences mathématiques* of which he was a co-editor.

126. *Ibid.*, p. 27.

127. *Ibid.*, p. 28.

128. *Ibid.*

also enlarged it.¹²⁹ Lemonnier could spot points where Duhem, carried away by enthusiasm, attributed too much to his heroes. Contrary to Duhem, Lemonnier wrote, Albert of Saxony nowhere spoke of fossils. But Duhem, Lemonnier argued, was right in insisting on the scientifically creative thinking of medieval figures, a thinking which could be seized upon and further developed by their Renaissance successors. By the fact that a Leonardo takes now his place in the historical continuity, 'he is not diminished but explained.' In that continuity which is history, Lemonnier added, 'there is now a new vision of things.'¹³⁰

Attitudes toward a new vision

Few visions could have conveyed more novelty than the one conjured up by Duhem, but no amount of historical scholarship could make it attractive to those committed to its very opposite. Their only alternative was to ignore scholarship. Anatole France, who could not be unaware of Duhem's election to the Académie, may have had Duhem the historian of science in mind as in his 'last thoughts' he declared defiantly: 'That Church, founded on disastrous illusions, had for eighteen centuries buried science and made torrents of blood flow. She dimmed the genius of peoples she had adopted. Christianity is a return to most primitive barbarism.'¹³¹ Such blindness, not only to the Middle Ages, but also to the latest and vastly increasing scholarship, has stoutly maintained itself during the more than half a century that elapsed since Duhem's death, and therefore, although not universal, its persistent reappearance should seem worth a brief glance. The three empty pages which an astronomer-author of a history of astronomy made to precede his pages on Copernicus would suggest deep emotions even to a mere bibliophile.¹³² No less telling is a footnote in *The Western Intellectual Tradition* where Duhem's Leonardo studies are quoted as a proof that 'Leonardo was not totally unlearned and, in fact, used and copied the writings of many ancient and medieval thinkers.'¹³³ That those studies were meant to prove something specially important concerning intellectual tradition in the West was carefully kept under cover by that book's authors. One of them, tellingly enough, was none other than J. Bronowski, author of the *Ascent of Man*, which, if its pages on the pre-Galilean history of science are considered, should have carried 'the saltation of man' for its title.¹³⁴

129. *Ibid.*, pp. 121 and 128.

130. *Ibid.*, p. 129.

131. M. Corday, *Dernières pages inédites d'Anatole France* (3d ed.; Paris: Calmann-Levy, 1925), p. 58.

132. H. S. Williams, *The Great Astronomers* (New York: Newton Publishing Co., 1932) pp. 97-99.

133. J. Bronowski and B. Mazlish, *The Western Intellectual Tradition: From Leonardo to Hegel* (1960; Harmondsworth: Penguin Books, 1963), p. 36 note.

134. The 'rationalist' thrust of *The Ascent of Man* (Boston: Little Brown, 1973) can readily be grasped from the fact that whereas a dozen pages are allotted there to a patently biased account of the Galileo trial, no mention is made of Leonardo, the scientist, to say nothing of Oresme and Buridan. Another, even ruder example of 'rationalist' propaganda is *Maps, Mirrors, and Mechanics* (New York: St. Martin's Press, 1974), by L. Hogben, who assures his readers (pp. 81-89) that there was no science whatever during the Middle Ages and that scholasticism is nonsense.

Some puzzlement may be in order when one considers surveys of medieval history which earned considerable repute and whose authors had the expertise of historians. Neither science nor Duhem can be found in the medieval volume, published in 1926, of the famed 'Legacy' series.¹³⁵ Science fared very poorly and with no mention of Duhem in the first volume of H. A. L. Fisher's *History of Europe* (1935) dealing with ancient and medieval times.¹³⁶ Vituperation was the tone of the ten pages devoted to science in the portrayal of medieval English panorama by G. C. Coulton.¹³⁷ While the two decades which by then had elapsed since Duhem's death were more than enough to let his findings trickle down to the niveau of high level popularization, they were obviously more than enough to provide scholarly veneer to silence about those findings. Such a silence would not have found much challenge even if historians in basic sympathy with Duhem's findings had done their best to keep them in focus. Christopher Dawson, with his short though emphatic references to the importance of Duhem's work,¹³⁸ was one of these historians. Another was H. Butterfield, who, however, was rather off the mark in claiming in 1949 that 'the work of Duhem . . . has been an important factor in the great change which has taken place in the attitude of historians of science to the Middle Ages.'¹³⁹

135. G. C. Crump & E. F. Jacob (eds.), *The Legacy of the Middle Ages* (Oxford: Clarendon Press, 1926, and many subsequent reprints). The omission of a chapter on science should seem all the more glaring, because such a chapter was a part of other volumes in the series dealing with the legacy of India, Egypt, Greece, China, and even of the Roman Empire.

136. H. A. L. Fisher, *A History of Europe. Volume One. Ancient and Medieval* (London: Eyre & Spottiswoode, 1935); see especially chs. xx and xxiv on intellectual and monastic movements and the Catholic mind.

137. Not even Grosseteste is mentioned in the section on science (pp. 433-43) in Coulton's *Medieval Panorama: The English Scene from Conquest to Reformation* (Cambridge: University Press, 1938). A full generation later only two pages were allotted to science in J. Dahmus' *The Middle Ages: a Popular History* (London: Victor Gollancz 1969). Buridan, Oresme, and Duhem are not to be found in *The Penguin Book of the Middle Ages* (1971), nor in its longer form, *The Horizon Book of the Middle Ages* (New York: American Heritage Company, 1968). The same is true of *The Rise of Christian Europe* (New York: Harcourt, Brace & World, 1965), a widely used textbook by H. Trevor-Roper, who deplores the lack of continuation of the 12th-century scientific renaissance in Chartres! Lack of attention to the intellectual side of the century of Buridan and Oresme is almost total in *A Distant Mirror: The Calamitous 14th Century* (New York: Alfred A. Knopf, 1971) by Barbara A. Tuchman. Christianity has nothing to do with science in P. Johnson's much publicized *A History of Christianity* (1976; Pelican Books, 1980). Many other examples could be quoted.

138. See his *Progress and Religion* (London: Sheed and Ward, 1929), p. 143; *Religion and Other Essays* (New York: Sheed and Ward, 1934), pp. 91-92; *Religion and the Rise of Western Culture* (London: Sheed and Ward, 1950), p. 16.

139. H. Butterfield, *The Origins of Modern Science 1300-1800* (1949; new ed.; London G. Bell & Sons, 1957), p. 15. In making that optimistic generalization Butterfield must have ignored, say, a Charles Singer, in whose *A Short History of Science to the Nineteenth Century* (Oxford: Clarendon Press, 1941) the Middle Ages, to say nothing of Buridan and Oresme, did not exist at all. A mere look in that book at p. 161 should make one wonder as to what could pass for unquestionable scholarship in the subject with a prestigious academic publishing house.

Here indeed attention should be focused on the attitude toward that new vision on the part of historians of science. In France few of them had for decades sufficient stature following the death of Duhem. Partly for this reason a professor of philosophy, A. Darbon, at the University of Bordeaux, had to take it upon himself to write an appraisal, hardly noteworthy,¹⁴⁰ of Duhem the historian in the second part of a commemorative volume on him published in 1927. Abel Rey, the leading French historian of science of the period between the two World Wars, was apparently unavailable for the assignment. No wonder. The silence on Duhem was complete for all practical purposes in a five-volume history of Greek science which Rey published between 1930 and 1938.¹⁴¹ A paradoxical fact though not without explanation. The paradox transpires from Rey's obvious familiarity with Duhem's writings and from his collaborating in 1937 with a group of French historians of science who wanted to rekindle interest in Duhem and in his *Système du monde*.¹⁴² The explanation is readily forthcoming from a recall of Rey's monograph on the history of the idea of eternal recurrence (Great Year) which he held to be the foundation of scientific thought.¹⁴³ Duhem, as was noted, described the idea of Great Year as the quintessence of the causes of the stillbirth of Greek science and also celebrated its overthrow by Christianity. Rey's com-

140. A. Darbon, 'L'histoire des sciences dans l'oeuvre de Pierre Duhem,' in *L'oeuvre scientifique de Pierre Duhem* (Paris: Blanchard, 1928), pp. 499-548. A chief shortcoming of Darbon's essay is his failure to portray the status of the historiography of science as Duhem found it with respect to the Middle Ages and the Renaissance. Darbon (1874-1943), a native of Bordeaux, began his teaching career at the University there in 1908. After serving with great distinction in World War I, he returned to Bordeaux as professor of philosophy, where he retired as dean in 1942. Most of his writings were published after his death and dealt with topics relating to basic questions of the philosophy of science.

141. Of those five volumes, published under the general title, *La science dans l'antiquité* (Paris: A. Michel), the first was devoted to science before the Greeks. Rey took up Duhem's ideas and main conclusions only in the fifth volume (pp. 271-74) and still held the view (see 4:170) that medieval science was not better than a resumption of the scientific decadence of late antiquity. He must have had in mind Duhem as he remarked earlier that 'the Middle Ages have been very much decried, and unjustly, . . . and have been rehabilitated, but perhaps with not much more justification' (4:164). Concerning Rey's remark that 'Duhem is evidently motivated in his judgment' (5:272), one comment should suffice which may be applicable also to many recent historians of science reticent about Duhem. While Duhem was fully aware that metaphysical and religious views (including his own Catholic convictions) can deeply influence scholarly work, Rey and those historians seem to be blissfully unaware that agnosticism, positivism, secularism, and last but not least Darwinism (as a creed distinct from a theory of evolution) can play a similar role in their own case.

142. See Ch. 7.

143. A. Rey, *Le retour éternel et la philosophie de la physique* (Paris: Flammarion, 1927). Rey, who aimed at vindicating the idea of eternal recurrence against the law of entropy, began and concluded his book with quotations from Nietzsche, who held that idea to be the touchstone of his philosophy and of the radical modern paganism he advocated. That Nietzsche and many other advocates of the idea of eternal recurrence were, by the same logic, also advocates of rudely antiscientific views, wholly escaped Rey, who also held high Blanqui's celebration of the same idea (for details see my book, *Science and Creation: From Eternal Cycles to an Oscillating Universe* [Edinburgh: Scottish Academic Press, 1974] pp. 314-28).

mitment to the opposite vision as the cause of his professional slighting of Duhem should seem especially reprehensible in view of the efforts of some, none of them historians of science, to remind the French reader of the 1920s and 1930s of Duhem's accomplishment as a historian of science. Duhem's discovery of the science of the Middle Ages was reported in 1920 in volume XIV devoted to the history of science in France, in the monumental *Histoire de la nation française*, directed by G. Hanotaux.¹⁴⁴ In 1931 a somewhat less extensive general history of civilizations carried the following phrase: 'The beginning of modern science is, according to Pierre Duhem's testimony, the date when the human mind was able to recognize the merit of the notion of impetus and held it for demonstrated.'¹⁴⁵ As one would expect, Duhem was amply recalled in the long lecture which E. Picard gave on the history of physical science as related to physical theories on December 16, 1929, at the Académie des Sciences.¹⁴⁶

The Middle Ages and Duhem were, however, nonexistent in the two large volumes on *Science* published by Larousse in the 1930s, of which the first dealt with sciences prior to 1900. Georges Urbain, a member of the Académie des Sciences and one of the organizers of the work, seemed to find no fault with entrusting the history of mechanics to a certain H. Volkringer, for whom even Leonardo was non-existent among the precursors of Galileo.¹⁴⁷ Duhem would not have been surprised about such countervision, obligatory in some circles, in his own country. Mindful of his often vain efforts to make his fellow Catholics aware of the importance of the history and philosophy of science, he would not have been surprised too much on seeing the meagre account on Buridan, Oresme and Albert of Saxony in the volume which in the massive *Histoire de l'Eglise* was dedicated to intellectual trends during medieval centuries. The director of the 20-volume work A. Fliche, once a younger colleague of Duhem in Bordeaux, was no longer alive when that volume saw print in 1956.¹⁴⁸ Those with very different persuasions did as expected. The printed record of the Colloque held in Royaumont in 1957 on sixteenth-century science contains only two, and rather

144. In that volume, entitled, *Histoire des sciences* (Paris: Plon-Nourrit, 1920) the article on the history of physics (pp. 167-420) was written by Charles Fabry, professor of physics at the Sorbonne; on Duhem see p. 170.

145. A. Renaudet, *La fin du moyen âge*, vol. VII in *Peuples et civilisations. Histoire générale*, ed. L. Halphen and Ph. Sagnac (Paris: F. Alcan, 1931), p. 261.

146. E. Picard, *Un coup d'oeil sur l'histoire des sciences et des théories physiques* (Paris: Gauthier-Villars, 1930); see pp. 42-44 on medieval physics and Duhem, and pp. 89-92 on his theory of physics.

147. *La Science: Ses progrès, ses applications. Tome premier. La science jusqu'à la fin du XIX^e siècle* (Paris: Librairie Larousse, 1933); see especially the section on mechanics and physics from the 10th century to Newton, pp. 37-45.

148. *Le mouvement doctrinal du XI^e au XIV^e siècle* (Paris: Bloud & Gay, 1956). In Livre II, 'Le XIII^e siècle,' written by M. de Gandillac, there is no hint about the pioneering character of Duhem's studies on Buridan, Oresme, and Albert of Saxony (pp. 494-502). Fliche died in 1951, at the age of 66.

slighting remarks on Duhem.¹⁴⁹ That Duhem's historiography was branded an apologetics in 1969 in a collection of French essays on the history of science¹⁵⁰ was almost a foregone conclusion. By the 1960s the cultivation of the history of science greatly revived in France though not in a direction hoped for by Duhem. In the four-volume *Histoire générale des sciences*, edited by R. Taton and published between 1957 and 1966, the sections on medieval and Renaissance science, written by G. Beaujouan and A. Koyré,¹⁵¹ were a repudiation of Duhem's scholarship and vision.

Such a repudiation had by then been a long-standing tradition for the majority of that easily identifiable professional group that historians of science had become by the mid-20th century. A convenient starting point of that tradition is an article which G. Sarton published in the May 1919 issue of *Scribner's Magazine* on the occasion of the 400th anniversary of Leonardo's death and which had Leonardo's relation to the birth of science as its chief topic.¹⁵² Sarton had no intention of making Leonardo shine against an unqualifiedly dark background, the Middle Ages. That 'everything was wrong and dark in the Middle Ages,' wrote Sarton, 'was a childish view . . . long exploded.' Nor were all the schoolmen so many dunces; . . . some of them were geniuses.' But, he added in the same breath, 'their point of view was never free from prejudice, theological or legal . . . They were

149. *La science au seizième siècle. Colloque International. Royaumont 1-4 juillet 1957* (Paris: Hermann, 1960). According to Koyré, Tartaglia was not, as Duhem would have it, influenced by the ideas of Leonardo, but by an empirico-technical tradition (p. 113), a curious remark indeed on the part of a champion of Platonism. For Santillana the parallel which Duhem drew between the languages of Cusa and Bruno was 'captious' (p. 234).

150. M. Fichant, L'idée de l'histoire des sciences,' in M. Fichant and M. Pécheux, *Sur l'histoire des sciences* (Paris: F. Maspero, 1969), p. 84. In Fichant's essay three types of histories of science, written respectively by philosophers, by historians, and by Duhem, are analysed. This putting of Duhem in a class by himself is clearly motivated by Fichant's heavy reliance on Koyré's criticism of Duhem, a point discussed below.

151. Duhem is not once mentioned in the more than seventy pages of ch. 7, 'Medieval Science in the Christian West,' written by G. Beaujouan in vol. 1 of the work's English translation, *History of Science: Ancient and Medieval Science from the Beginnings to 1450*, tr. A. J. Pomerans (New York: Basic Books, 1963), pp. 468-31. In view of this, the inclusion of the *Système du monde* in the 'additional' bibliography (p. 532) should seem rather unconvincing. In the more than eighty pages which A. Koyré could devote to the exact sciences during the Renaissance in vol. 2, *The Beginnings of Modern Science from 1450 to 1800* (pp. 11-104), there are eight references to Duhem. Koyré recognized that Duhem was right in equating the expression 'uniformly varying motion' with 'uniformly accelerated motion' (p. 84) and in singling out Jordanus Nemorarius as the first to solve the problem of the equilibrium of a body on an inclined plane (p. 101). Koyré flatly dismissed Duhem's interpretation of Leonardo as a man of science imbued with the ideas of medieval predecessors, though he also dismissed modern scholars who 'almost unanimously rejected that interpretation' (p. 24; see also pp. 84, 85 and 87). In Koyré's eyes Duhem was also wrong concerning the 'enigma of Domingo de Soto' (pp. 94-95). No reader, unfamiliar with Duhem, could gain a glimpse of the pioneering and magisterial character of his achievement as a historian of science from those contributions by Beaujouan and Koyré.

152. G. Sarton, 'The Message of Leonardo: His Relation to the Birth of Modern Science,' *Scribner's Magazine* 65 (1919):531-40.

cocksure . . . they knew everything except their own ignorance,' a strange ignorance, to be sure, because according to Sarton the interest of many schoolmen was intense in astronomy and physics!¹⁵³

Such was Sarton's way of allaying fears that he nurtured bias against the Middle Ages. He did not have to fear that most readers of *Scribner's Magazine* would notice the bias with which he extolled the 'New Humanism.'¹⁵⁴ He did his best to wrap science around that Humanism, and to make it appear the noble opposite to religion, namely, Christianity. Leonardo was for Sarton a kingpin in this pseudo-religious crusade, and therefore could not depend too much, if at all, on medievals, let alone on their vision. By the time, Sarton argued, Leonardo read 13th- and 14th-century authors, 'his mind was already proof against the scholastic fallacies; he was able . . . to filter through his own experience whatever medieval philosophy reached him either in print or by word of mouth.'¹⁵⁵ Sarton did not as much as hint at Duhem's studies on Leonardo. A vision had to be kept under cover.

The very few references of Sarton to Duhem over five decades amount to a practically complete silence which certainly helped keep at a low level awareness about Duhem during the first forty years following his death. While the first volume of the *Système du monde* was fairly reviewed by Sarton himself in the newly-born *Isis*,¹⁵⁶ no comments were offered there of the next four volumes. This was all the more a glaring inconsistency, because many publications of minor importance were reviewed by Sarton himself around 1920 in *Isis* which, following Sarton's arrival in 1916 in the United States, he reactivated and developed into the leading periodical on the history of science. On reading those four volumes Sarton could not help realizing that Duhem's reading of the history of science and the 'New Humanism' were irreconcilable. Such an interpretation is based not only on Sarton's sundry dicta on Christ and Christianity, but on the telling remark which he penned in 1951 in his reminiscences on five major historians of science whose collaboration he solicited around 1905 as he planned to launch *Isis*. Karl Sudhoff, Moritz Cantor, Paul Tannery, Johan Heiberg offered their assistance. 'The fifth,' Sarton wrote, 'declined to help me for religious reasons.'¹⁵⁷ He was Duhem, who refused assistance after obtaining from his friend, Paul Mansion, the information that Sarton, a graduate of the University of Ghent, where Mansion was a professor, followed in the footsteps of his father, a dedicated Freemason of the virulent Gallic brand. Sarton did not have the greatness, four decades after the event, either to appreciate utter consistency on Duhem's part,

153. *Ibid.*, p. 537.

154. *Ibid.*, p. 540.

155. *Ibid.*, p. 537.

156. *Isis* 2 (1914):203-04.

157. 'Acta atque Agenda,' in D. Stimson (ed.), *Sarton on the History of Science* (Cambridge: Harvard University Press, 1962), p. 25. Sarton portrayed Duhem as a very proud individual, unable to make enough friends and too synthetic a thinker for the modern specialized world (pp. 33-36). It is indeed sad, one may add, that in the field of scholarship recognition depends so much on the ability to 'make friends,' and a sufficient number of them!

or to see that his own interest in *Isis* and history of science was religious in substance if not in name, although the names Isis and Osiris, the respective titles of two periodic publications directed by Sarton, were suggestive enough to anyone familiar with freemasonic fondness for Egyptian lore and paraphernalia.

Any scholar, whether or not the *sapiens* who *de nominibus non curat*, must, however, wonder on taking a quick look at Sarton's *Appreciation of Ancient and Medieval Science during the Renaissance (1450-1600)*, the enlarged form of lectures he delivered at the University of Pennsylvania in 1953. Sarton kept complete silence on Duhem, which may appear outright scandalous in view of Sarton's introductory statement: 'My own interest in the history of science goes back to my student days in Ghent, before 1911, but it was kindled to a greater heat a few years later (in 1916) by the study of the MSS of Leonardo da Vinci. When I realized that Leonardo's knowledge was very largely of medieval origin, I decided to make a full survey of science from Homer's time to 1900.'¹⁵⁸ Such a phrase could easily suggest the most unlikely fact that Sarton had discovered the medieval provenance of many of Leonardo's dicta without first reading Duhem's Leonardo studies. In fact Sarton kept suggesting not only the utter independence of his scholarship from Duhem's writings, but even their non-existence, as he wrote that survey, a vast annotated bibliography on sciences and scientists of all ages and cultures.¹⁵⁹ By reaching the year 1400, Sarton progressed far enough to have countless occasions to refer to Duhem who in that massive work is mentioned only five times and invariably in an incidental manner. Such a procedure, unexplainable by oversight, could only be a matter of vision. That *Isis* carried in 1937 an appeal, signed by Sarton,¹⁶⁰ on behalf of the publication of the remainder, still in manuscript, of Duhem's *Système* seems to have been much more the concern of Paul Tannery's widow, who co-signed, than of Sarton. Possibly Sarton expected through that publication the coming to light of further data discrediting the scholarly reputation of Duhem, the historian. Earlier that year Sarton gave, in the bibliographical section of *Isis*, more than customary attention to an article published there the previous year. The article was not only summarized but also its concluding sentence was quoted: 'The episode of Jordanus, so far from proving medieval participation in modern science, as Duhem claims, proves in reality just the opposite thesis.'¹⁶¹

Such was a sentence which would have made matters immediately clear, had it contained the word vision instead of thesis. The same sentence not only disparaged Duhem more than any other sentence, but also was one which Sarton seems to have cherished. The article was significant in his eyes, to be mentioned by him in a very short bibliography on Duhem in which the only other study on Duhem was Lowin-

158. Philadelphia: University of Pennsylvania Press, 1955, p. x. Among the ten books on Leonardo cited there by Sarton one would look in vain for Duhem's Leonardo studies!

159. G. Sarton, *Introduction to the History of Science* (Baltimore: Publication of the Carnegie Institution, 1927-48).

160. *Isis* 26 (1937):302-03.

161. *Isis* 26 (1937):124.

ger's doctoral thesis.¹⁶² The author of that article, B. Ginzburg, was also a graduate student at Columbia University and the tone of his article anticipated the air of superiority which set the tone of Lowinger's thesis, a tone which is usually tolerated by mentors and editors who are driven by that 'deep-seated apologetical bias' of which Ginzburg charged Duhem at the very outset of his article. What Ginzburg did not spell out at the outset, although it could easily be guessed, was that enormously far-reaching revisions were in order if 'the evidence adduced by Duhem [on behalf of the medieval origin of modern science] really stands up,' because 'then indeed we must revise our customary ideas on the history and development of modern science.'¹⁶³ Those ideas were indeed more than customary. They were the chief support of Condorcet's vision of intellectual history and of all the Weltanschauung it implied. Adepts of that vision have for some time taken to the custom of not mentioning it, perhaps because it has already become a tacit foundation of established intellectual discourse, allegedly steeped in sheer objectivity.

Enforcing at least a style, which was not a patent violation of at least a semblance of objectivity, would have of course been the duty of the editor of *Isis* on reading a graduate student's manuscript which not only charged a towering scholar like Duhem with 'deep-seated apologetic bias' but in which, at the very outset, a wholesale doubt was cast on Duhem the historian: 'all his findings must be scrutinized with the same suspicion as a lawyer's brief for a client.'¹⁶⁴ Ginzburg's condescending and caustic style should have been bluepenciled by Sarton even if Ginzburg had demonstrated his specific claim that Duhem read into the writings of Jordanus Nemorarius crucial notions which were not there and that 'any scientifically informed person' could easily notice Duhem's confusion about the meaning of Torricelli's principle. To imply that Duhem was not 'scientifically informed,' was already a suggestion unworthy of any scholarly journal, to say nothing of other remarks of Ginzburg: 'It is easy to show,' Ginzburg claimed, that 'much of the evidence Duhem adduces in support of his thesis is palpably false and far-fetched.'¹⁶⁵ Ginzburg spoke of the 'abstruse nature of Duhem's theories,' and of Duhem's association of Albert of Saxony with the scientific development of statics as 'completely forced.'¹⁶⁶ According to Ginzburg there was 'an element of comedy'¹⁶⁷ in Duhem's speaking first of Jordanus Nemorarius alone, then later of him and of his hypothetical disciple. Duhem, according to Ginzburg, was so little a scholar as to cavort in rank arbitrariness: 'In short, he makes the rule of relative weight operate when he wants it to operate and not operate when he does not want it to operate.'¹⁶⁸ Duhem was also ridiculously

162. Discussed in the preceding Chapter.

163. B. Ginzburg, 'Duhem and Jordanus Nemorarius,' *Isis* 25 (1936):341-62.

164. *Ibid.*, p. 341.

165. *Ibid.* Ginzburg's secondary claim was that since there was no second Jordanus, Duhem's theory of continuity lacked foundation.

166. *Ibid.*, p. 342.

167. *Ibid.*, p. 344. 'Scarcely reasonable' was in Ginzburg's view Duhem's vision of a succession of medievals well versed in what was available on the science of mechanics (p. 351).

168. *Ibid.*, p. 350.

short-sighted, for he relied on a 'stultifying addition' and 'he himself destroys what little force there is to his whole argument.'¹⁶⁹ Last but not least, Duhem was highhanded with texts, the most unforgivable sin a historian can commit: 'The statements he does print are incidental statements extracted from the context of the false demonstration,' and he takes refuge in errors attributed to medieval copyists.¹⁷⁰ Finally, there is the blow at Duhem's acumen: 'The idea that Benedetti . . . might have been able to formulate these principles by himself does not seem to have entered his mind.'¹⁷¹ That there could be something very seriously wrong with an argumentation which systematically falls back on such shallows, did not seem to enter Sarton's mind. He must have felt comforted by Ginzburg's principal message, suggestive enough of what was really at stake: There was no need, Ginzburg assured his readers, 'to change our views about the intellectual climate of the Middle Ages.'¹⁷² Obviously, there was between Ginzburg and Sarton not so much a meeting of views on a particular question as a unity of vision in the center of which was the Renaissance as the imperative alternative to the Middle Ages.

The Renaissance threatened

The extent to which Duhem's unveiling of medieval science posed a threat to the 'received' vision of the Renaissance was amply revealed in 1948 by W.K. Ferguson, author of a still unsurpassed survey of the interpretations, which the notion of the Renaissance had been given over the past five centuries.¹⁷³ To Ferguson only the

169. *Ibid.*, p. 358.

170. *Ibid.*, p. 360.

171. *Ibid.*, p. 361. For all that, Ginzburg did not think that his strictures of Duhem were 'unnecessarily harsh' (p. 342).

172. *Ibid.*, p. 351. The appearance of a note of relief, in the middle of the article as well as at its start and conclusion, speaks all too clearly of Ginzburg's apologetics on behalf of the Renaissance. He did not suspect what an old and self-defeating idea he was advocating when he stated that in contrast to the Middle Ages, where there was only a 'low social level of interest' in the sciences, the new social climate of the Renaissance produced many scientists and this is why science arose there and then.

173. *The Renaissance in Historical Thought: Four Centuries of Interpretation* (Cambridge, MA: Houghton Mifflin, 1948). An attentive reading in that book (see note 28 above) of the denunciation of the Middle Ages by Protestant divines from Melancthon to Cotton Mather and beyond may give the clue to the almost systematic oversight of Duhem and of the Middle Ages in books written during the last two or three decades by Protestant scholars on the rise of science and Christianity. While they constantly refer to the essay, 'The Christian Doctrine of Creation and the Rise of Modern Natural Science' (*Mind* [1934] :446-68) by M. Foster, who not once referred to Duhem and for whom the medievals were all covertly pagan Averroists, they ignore the far better work, *Dieu dans l'univers. Essai sur l'action exercée sur la pensée chrétienne par les grands systèmes cosmologiques depuis Aristote jusqu'à nos jours* (Paris: Librairie Fischbacher, 1933) by V. Monod, maître de conférences at that time at the Protestant Faculty of Theology at the University of Strasbourg, who heavily relied on Duhem's *Système*. The boasting about 'the eventual victory of the Hebraic doctrine of God and nature over the scornful opposition of the Greco-medieval tradition' in *Science, Chance and Providence* (Oxford University Press, 1978, p. 11) by D. M. MacKay, who does not seem to know of Duhem, is typical of that pattern.

last few decades of that half a millennium seemed to have produced a real challenge to the hallowed idea of the Renaissance as the rise of human genius from the shackles of Christianity. It is difficult not to sense that in Ferguson's view challenges based on philosophy, ethics, sociology, arts, and letters could be coped with. He indeed felt so secure as to write in connection with the Neo-Thomist thesis on the Middle Ages as articulated by Maritain and Gilson, that 'full acceptance [of them] is difficult if not impossible for non-Catholics.'¹⁷⁴ Its converse, or the impossibility of the acceptance by Catholics of the 'established' thesis, carried no weight in Ferguson's eyes. Such brazen lack of impartiality, apparently acceptable in reference to philosophy, was obviously inappropriate when it came to science, namely, to the challenge to the Renaissance by historians of medieval science, above all Duhem, 'the great pioneer.' The only thing Ferguson could do with that 'impressive monument' of scholarship, the five volumes of the *Système du monde*, was to undermine its significance with the remark 'that there is a distinct note of patriotic as well as sectarian pride in Duhem's account.'¹⁷⁵ Ferguson did not explain why a Haskins and a Thorndike, neither French nor Catholic, to whom after Duhem medieval studies of science owed most prior to 1940, agreed in substance with Duhem's findings and even with his vision.

Ferguson might have found support in an article published by J. H. Randall Jr. on 'The Development of Scientific Method in the School of Padua,'¹⁷⁶ in which much was made of the 'freethinking and anticlerical' 15th-century Paduan scholars in whom Randall found a pivotal link in the pre-Galilean history of science. The link was a proof of continuity and Randall chastised Galileo, Descartes, and others for not having seen 'the countless bonds' which tied them to the medievals 'in materials, methods and even achievements.'¹⁷⁷ Yet, the nature of the link, freethinking and anticlericalism, was such as to save the Renaissance as a vision even if it was true that Galileo's science was 'the culmination of the cooperative efforts of ten generations of scientists' that preceded him.¹⁷⁸ Ferguson would have been helped even by D. B. Durand's 'Nicole Oresme and the Medieval Origins of Modern Science,' published in 1941.¹⁷⁹ Durand, who grudgingly acknowledged Duhem's pioneering greatness, tried to find a middle road between those who like Duhem saw precursors and his debunkers who would not see any of them. Durand's was an instructive try inasmuch as it forecast the failure of future efforts to resolve the problem of 'continuity issuing in novelty' in the absence of a genuine middle road between conceptual classification (*Ideengeschichte*) and sociological moulds, both of which Durand rejected. Yet, his solution was only a variation on conceptual classification. He urged that side by side with the notion of genius, at-

174. *The Renaissance in Historical Thought*, p. 339.

175. *Ibid.*, p. 337.

176. *Journal of the History of Ideas* 1 (1940):177-206.

177. *Ibid.*, p. 179.

178. *Ibid.*, p. 177.

179. *Speculum* 16 (1941):167-85; see especially pp. 172 and 184.

tention be given to the notion of virtuosi, or minor figures, who merely guessed the truth to be discovered. Oresme was such a virtuoso in Duhem's eyes.

Such was hardly a proof of philosophical perspicacity, which was also absent in Durand's reading of a 'group of important articles' by A. Koyré on pre-Galilean science, which Durand characterized as a 'somewhat different interpretation' from the one Duhem offered on the history of impetus theory. Two years later Durand still believed, although already in possession of the *Etudes galiléennes*, that Koyré 'qualifies but hardly contradicts' Duhem's thesis.¹⁸⁰ It is rather unfortunate that Koyré was not among those half a dozen scholars whom the editors of the *Journal of the History of Ideas* obtained to comment on Durand's paper and on the general topic of the originality of the Renaissance science.¹⁸¹ Koyré would have right there and then poured cold water on their efforts to reconcile somehow the hallowed idea of an absolute originality of Renaissance science and the view formulated and largely articulated by Duhem which attributed scientific creativity to Buridan and his successors. Of those half a dozen scholars only one, F. R. Johnson, referred, though indirectly, to Koyré's *Etudes*, not yet widely available in America because of wartime conditions. Johnson was also the one who upheld without any significant qualification the absolute originality of Renaissance science as epitomized in Galileo, and rejected the possibility of overcoming the division between Galileo and his predecessors.¹⁸² It should seem no less significant that L. Thorndike, the only one among the six to resolutely uphold the continuity thesis, also saw in full clarity its ultimate philosophical implication in the mirror of its opposite, a sheer vision:

The concept of the Italian Renaissance or Renaissance has, in my opinion, done a great deal of harm in the past and may continue to do harm in the future. It is too suggestive of a sensational, miraculous, extraordinary, magical, human and intellectual development, like unto the phoenix rising from its ashes after five hundred years. It is contrary to the fact that human nature tends to remain much the same in all times. It has led to a chorus of rhapsodists as to freedom, breadth, soaring ideas, horizons, perspectives, out of fetters and swaddling clothes, and so on. It has long discouraged the study of centuries of human development that preceded it, and blinded the French *philosophes* and revolutionists to the value of medieval political and economic institutions. It has kept men in general from recognizing that our life and thought is based more nearly and actually on the Middle Ages than on distant Greece and Rome, from whom our heritage is more indirect, bookish and sentimental, less institutional, social, religious, even less economic and experimental.¹⁸³

180. D. B. Durand, 'Tradition and Innovation in 15th century Italy,' *Journal of the History of Ideas* 4 (1943):1-20; see especially p. 17.

181. *Ibid.*, pp. 21-74.

182. *Ibid.*, p. 58. The other five were H. Baron, E. Cassirer, P. O. Kristeller, D. P. Lockwood, and L. Thorndike. Cassirer, certainly a great admirer of the Renaissance, admitted, with an eye on Duhem (p. 50), that the originality of Renaissance science must be sought not so much 'in the new content' which it engendered as in the new energies with which those contents were sought.

183. *Ibid.*, p. 74.

Such a message could hardly be welcome for many from a scholar whose expertise in medieval science has often been equated with that of Duhem and who, unlike Duhem, could not be charged with 'the animus of a Catholic.' The best one could do with that message was to ignore it. Thorndike's work, hardly less massive than Duhem's, was never dignified to any appreciable comment by Koyré whose thinking allowed no resolution to the problem noted by Durand. This was made all too clear to the readers of the *Journal*, most of them still unfamiliar in 1943 with the *Etudes*, in the last issue of the *Journal* for the same year:

What the founders of modern science, among them Galileo, had to do was not to criticize and to combat certain faulty theories, and to correct or to replace them by better ones. They had to do something quite different. They had to destroy one world and replace it by another. They had to reshape the framework of our intellect itself, to restate and to reform its concepts, to evolve a new approach for Being, a new concept of knowledge, a new concept of science – even to replace a pretty natural approach, that of common sense, by another which is not natural at all.

Those familiar with the capital importance attached by Duhem to common sense were not at all surprised then to hear Koyré continue:

The apparent continuity in the development of medieval and modern physics (a continuity so emphatically stressed by . . . Duhem) is an illusion.¹⁸⁴

The supreme illusion was, however, the hope of historians of science stepping in Koyré's footsteps that it was possible to profit from their field's 'exciting interest' opened up by the master¹⁸⁵ and remain reticent about the nature of truly human cognition and the metaphysics it involves. Their reticence trapped them time and again in the confusion and contradiction unwittingly spelled out in the *Etudes*. For the author of the *Etudes*, an advocate of a most unnatural idea of human cognition, which tries to understand man in terms in which some men try to understand animals,¹⁸⁶ could not deny his own human nature calling for common sense. On the surface Duhem, the historian, was the chief target of the *Etudes*. This would have become crystal clear from the outset had the *Etudes* appeared with a name index, where Duhem would have figured with over forty entries, far more than any modern scholar mentioned by Koyré. This would have alerted at least the more perspicacious readers of the *Etudes* that its real aim was the discrediting of Duhem's vision. Hardly commendable was Koyré's tactic which gave only four mentions of Duhem in the text, although no one else stated so forcefully and extensively the thesis of continuity which Koyré fiercely opposed

184. A. Koyré, 'Galileo and Plato,' *Journal of the History of Ideas* 4 (1943):405.

185. C. C. Gillespie, 'Koyré, Alexandre,' *Dictionary of Scientific Biography*, 7:486.

186. In Koyré's *Etudes galiléennes* (1939; Paris: Hermann, 1966) a biological (Darwinian) view of knowledge was, of course, merely hinted, though tellingly, at the very start, through the borrowing of Bachelard's view of scientific history as a sequence of intellectual mutations. On the unfolding by Koyré's disciples of the inner logic of such a start, see ch. 14 'Paradigms or Paradigm,' in my Gifford Lectures, *The Road of Science and the Ways to God* (Chicago: University of Chicago Press, 1978).

with a thesis that left nothing of real significance between the Greeks and Galileo. Galileo was turned by Koyré into a chief catalyst of a mutation, nay of a revolution of the human intellect, 'the most important since the invention of the Cosmos by the Greek mind.'¹⁸⁷ It was in such a perspective that one was to understand Koyré's claim that the study of scientific revolutions alone could secure meaning to 'the idea, so often glorified and so often decried, of progress.'¹⁸⁸ Enlightenment and New Humanism were waiting in the wings and with them, beneath the surface, a specific vision of human nature.

The articles composing the *Etudes* began to appear in 1935 and were a sort of mutation in the intellectual development of Koyré who, already over forty, had been previously busy with topics not at all related to physical science and its history.¹⁸⁹ One wonders if not more preparation was needed to dismiss Duhem's perplexity as to why Oresme did not apply his theory of latitudes to the fall of bodies with the remark: 'Oresme understood himself better than his historians did.'¹⁹⁰ Curiously, one of the very few cases when Koyré approved of Duhem, although even then the latter was upstaged with a glowing reference to Meyerson, concerned the long gestation of truth in a state of confusion.¹⁹¹ Clearly, there was something contradictory in Koyré's use of the notion of mutation, always a sudden process, as an *idée maitresse* to which all understanding of ideas and reality had to be subjected. Undoubtedly, not all of Duhem's writings displayed the wit and verve of most of Koyré's papers. But none of Duhem's passages trigger the feeling of contradiction which strikes the reader of Koyré's redefinition of his other favorite idea centering on a long process. That redefinition was the vengeance which human nature took in the name of common sense on Koyré's redefinition of understanding and human nature:

The principle of inertia did not come forth all ready made, like Athena from the head of Zeus, from the minds of Descartes and Galileo. The formation of the new conception of motion – implying as it did a new concept of physical reality – of which the principle of inertia is both the expression and support, was made precise by a long and painful work of the spirit. The Galilean and Cartesian revolution – which remains nonetheless a revolution – was prepared for a long time. It is this history which we propose to study here, a history which forms an indispensable preface to the work of Galileo, a history in which one sees the human spirit face up obstinately to the same problems, come to grips indefatigably with the same objections, the same difficulties, and forge slowly and painfully the instrument which will permit it to surmount them.¹⁹²

The first and last phrases could have been written by Duhem. The entire passage, resting as it did on the short middle phrase, was pregnant with the havoc wrought

187. *Etudes galiléennes*, p. 12.

188. *Ibid.*, p. 11.

189. In fact, they largely related to natural theologies of philosophers mostly with a pantheistic bent.

190. *Etudes galiléennes*, p. 66.

191. *Ibid.*, p. 165 note.

192. *Ibid.*, pp. 164-65.

by disregard for logic. It asserted itself in the measure in which a historiography of science steeped in mutations and revolutions, with meanings stretched beyond recognition, gained further converts. As their number grew, not only was there a drop in references to Duhem but also such an increase in the number of revolutions and mutations as to leave hardly a place for normalcy and permanence. Duhem's memory was not, of course, entirely exorcized either by Koyré or by those who did their best to restore credibility to the hallowed sleight-of-hand which starts everything with Galileo. Unlike Duhem, they hardly ever declared their vision or *Weltanschauung*, although they revealed enough of its driving force. Their prolific discourse obviated the precept according to which silence is the only way to avoid appearing a metaphysician. More 'positively,' early euphoria about Koyré made no room for suspicion about the nature of logic which forced Koyré to dispute any real role for a real inclined plane in Galileo's mental development. To lay bare the hollowness of that logic required in the end only a graduate student's resolve to construct a plane along the specifications of Galileo, and let balls roll down on it.¹⁹³ Others could easily watch Koyré's brand of Platonism go up in smoke with all its revolutions and mutations.

Duhem fared far better with those students of medieval science who carried on with their work free of prejudices about the question of the origin of modern science, although not unaware of its importance. Theirs was essentially an appreciation of the vast domains opened up by Duhem for study. In the 1920s the most significant of such studies came from the pen of K. Michalski, of the University of Cracow, who reported on the contents of a large number of 14th-century manuscripts in Cracow, Oxford, and the Vatican, manuscripts unavailable to Duhem. In the fourth and last of his major communications, which dealt with the physics of the century of Buridan, Oresme, and Albert of Saxony, Michalski reported a finding which added to Duhem's conclusions the kind of major corrective that only enhanced his pioneering genius and the solidity of his major message. The finding showed that Buridan, whatever his Ockhamist inspiration, was preceded in the advocacy of impetus theory by the realist school of which Francesco de Marchia was in 1320 a late representative.¹⁹⁴ The intrinsic significance of this finding relates to the scientific potentiality of the realist or Thomist strain of medieval philosophy. Its extrinsic significance emerges in relation to the researches of Anneliese Maier whose work, already begun in the early 1930s, made its impact only after the War and who is often spoken of as the discoverer of Francesco de Marchia as a spokesman of the impetus theory. The revisions Maier felt necessary to add to Duhem's main conclusions were not essential. 'Duhem

193. T. B. Settle, 'An Experiment in the History of Science,' *Science* 133 (1961):19-23.

194. K. Michalski, 'La physique nouvelle et les différents courants philosophiques au XIV^e siècle,' *Bulletin international de l'Académie polonaise des sciences et des lettres. Classe d'histoire et de philosophie et de philologie. Année 1927*, pp. 93-164; on Francesco da Marchia, see p. 158.

is fundamentally right,' she wrote.¹⁹⁵ Duhem, who bemoaned the intellectual decline of Buridan's university during the 15th century, would have easily accepted Maier's view that instead of a steady growth or development one should rather speak of a tide which, in sweeping over four centuries, produced two peaks, one in the 14th and another in the 17th century. Yet, Duhem also knew that the difference between the two peaks concerned more than mere size. For him the 17th century represented a surplus which he tried to convey with the analogy of a bud blossoming into a flower. Such was a perfect means for coping with the crucial problem of the analogy of being, which is present in any real growth, biological or intellectual. Duhem would have understood the groping of his outstanding successors with that problem by coining striking phrases. Maier was certainly in the grip of that problem as she described the 14th century as 'a classical century of science' which, though much more than Aristotelian science, was not yet 'a century of classical science.'¹⁹⁶ And so was M. Clagett who spoke of the medievals' 'not completely unsuccessful efforts to solve crucial problems' of mechanics.¹⁹⁷ But Duhem would be the first to point out that impressive antitheses and double negatives can easily run the risk of becoming an evasion of the issue¹⁹⁸ and even a mere negation of it as illustrated by Koyré's notion of a long prepared revolution which is a revolution nonetheless. No such risk was presented by two major books of A. C. Crombie, in both of which the continuity thesis was firmly upheld. One of those books was described by Koyré as the most important

195. A. Maier, *Die Vorläufer Galileis im 14. Jahrhundert* (Rome: Edizioni di Storia e Letteratura, 1949), p. 1.

196. A. Maier, *Zwischen Philosophie und Mechanik* (Rome: Edizioni di Storia e Letteratura, 1958), p. 382.

197. M. Clagett, *The Science of Mechanics in the Middle Ages* (Madison: University of Wisconsin Press, 1961), p. 682. In that book the conflict of accolades and strictures heaped on Duhem (pp. xx-xxi) seems to remain unresolved.

198. Such an evasion, however unintended, may be especially undesirable when it forms part of a book destined for large circulation, such as the *Physical Sciences in the Middle Ages* (New York: John Wiley, 1971) by E. Grant, who endorses the 'brilliant middle of the road view' of Maier (p. 115) without facing up to what is implied epistemologically and ontologically in such a 'middle road.' It is that lack of philosophical depth which weakens the distinction with which E. A. Moody tried to resolve the problem whether Duhem was right or wrong in his 'Galileo and His Precursors' (1966) (reprinted in his *Studies in Medieval Philosophy, Science, and Logic: Collected Papers 1933-1969* [Berkeley: University of California Press, 1975], pp. 393-408). While firmly upholding Duhem's claim about the formulation by Buridan and his disciples of the concept of inertial motion and momentum, Moody denied its impact on Galileo, the latter's awareness of it notwithstanding. According to Moody, Duhem failed to see that there was *no* application by Buridan and others of that concept, whereas it received a *universal* application in Galileo's dynamics. Such stark contrast between a *mere* idea and a *physical* theory should have seemed suspect even on its own merit, let alone with a view to facts. Buridan was fully aware of the physical bearing of various examples, ranging from the javelin-throw to the motion of stars, which he gave of that concept. Furthermore, Duhem's emphasis on the gradualness of conceptual development was very applicable also in the case of Galileo whose dynamics is a very inchoate structure compared with the one offered in Newton's *Principia*.

publication in a decade,¹⁹⁹ the other forced him to admit that there were several legitimate ways of presenting pre-Galilean science.²⁰⁰ Duhem the historian would not have asked more from his foremost antagonist in the form of a surrender.

Posthumous volumes

Meanwhile the manuscripts of the last five volumes of Duhem's *Système du monde* began to be typeset at long last. With the sixth volume published in 1954, his magnum opus entered its fourth part, a portrayal of the impact of the condemnation of 216 theses on March 7, 1277, a date which, as Duhem asserted, was the birth of modern science. 'One of the major aims of this work,' he added, was to substantiate this assertion.'²⁰¹ The date was a watershed. Before it the tide of Aristotelianism was coming in, beyond it a reflux became increasingly noticeable. Pursuing the development through the philosophical and theological writings of Henri of Ghent, the German Dominicans, Duns Scotus, Raymundus Lullus, Jean Jandun, Ockham, and Buridan, Duhem felt entitled to conclude after some 700 pages bursting with data and texts:

After many upheavals, the Christian faith and experimental science vanquished Aristotelian dogmatism as well as Ockhamist Pyrrhonism. Their combined efforts gave birth to Christian positivism whose rules were made known by Buridan. This positivism will not be practiced by Buridan alone, but also by his disciples, Albert of Saxony, Nicole Oresme, Marsilius of Inghen. Those are the men who will create the Parisian physics and they will create it by this very method.²⁰²

The seventh volume dealt with the *Système's* fifth part or the Parisian physics. Far from being a quick work, the new physics, Duhem warned, was a slow development and yet issued in a novelty which those who worked on it did not foresee. Duhem handled the problem of continuity and novelty with graphic force:

The demolition of Aristotelian physics was not a sudden collapse; the construction of modern physics did not take place on a terrain where nothing was left standing. From one to the other the passage takes place by a long sequence of partial transformations of which each pretended to retouch or enlarge some piece of the edifice without changing anything of the ensemble. But when all these modifications of detail had been made, the human mind perceived, as it sized up with a single look the result of that long work, that nothing remained of the ancient palace and that a new palace

199. See A. Koyré, *Etudes d'histoire de la pensée scientifique* (Paris: Presses Universitaires de France, 1966), p. 49, in reference to Crombie's *Robert Grosseteste and the Origins of Experimental Science 1100-1700* (Oxford: Clarendon Press, 1953), in which it is argued that the method practiced by Galileo and Newton was fully articulated, at least in its qualitative aspect, in the 13th century (pp. 1 and 9).

200. See Koyré, *ibid.*, p. 72, in connection with Crombie's *Augustine to Galileo* (London: Falcon Press, 1952), a book which is better known in its second revised edition under the title, *Medieval and Early Modern Science* (Garden City, NY: Doubleday, 1959). Crombie, who ignores Duhem's assertions of ontological order, turns him into a conventionalist.

201. *Système du monde*, 6:66.

202. *Ibid.*, p. 729.

rose in its place. Those who in the 16th century took stock of this substitution of one science for another were seized by a strange illusion. They imagined that this substitution was sudden and that it was their work. They proclaimed that Peripatetic physics had just collapsed under their blows and that on the ruins of that physics they built, as if by magic, the clear abode of truth. About the sincere illusion or arrogantly willful error of these men, the men of subsequent centuries were either the unsuspecting victims or sheer accomplices. The physicists of the 16th century were celebrated as creators to whom the world owed the renaissance of science. They were very often but continuers and sometimes plagiarizers.²⁰³

In that Volume VII, Duhem surveyed the discussions of such concepts as the infinitely small and large, place, movement, and time, before giving a two-hundred-page-long survey of the doctrine of the latitude of forms, the medieval mathematization of various physical parameters, including the all-important parameter of accelerated motion. 'Until the discovery of calculus,' Duhem concluded, 'no demonstration of the law of uniformly varied motion was better than that of Oresme.'²⁰⁴

In Volume VIII Duhem broached topics more specifically characteristic of physical science such as vacuum and motion in vacuum, projectile motion, free fall, and finally the insights provided by Christian resistance to astrology. Duhem's discussion of each of these topics is crowned with forceful remarks, such as the one closing Buridan's account of the beginning of celestial motions:

Buridan has the incredible daring to say: the motions of the heavens are subject to the same laws as the motions of things on earth. There is a single mechanics by which all created things are governed, the orb of the sun as well as the top driven by a child. Never perhaps has there been in the entire domain of physical science a revolution so profound and fruitful. One day Newton will write on the last page of his *Principia*: By the force of gravity I have given an account of all the phenomena which the heavens show and which our seas present. On that day Newton will announce the full blooming of a flower of which Buridan sowed the seed. The day when that seed was sown is, so to speak, the day when modern science was born.²⁰⁵

The chain of events connecting two such dates was invariably complicated if not confused to the highest degree. Duhem spoke of the 'meandering of the thought'²⁰⁶ of medieval students on projectile motion from Richard of Middleton to the 'ingenious' Galileo. Never to question Galileo's genius, Duhem questioned time and again the acumen of his medieval heroes. He singled out Oresme as the starting point of the decline of physics in the University of Paris,²⁰⁷ a decline which accelerated during the 15th century. This was the Oresme who had some very particular ideas about the very start of an accelerated motion though not the Oresme

203. *Ibid.*, 7:3-4.

204. *Ibid.*, p. 633. Much of that volume and sections from other posthumous volumes of the *Système* are now available in English in *Duhem on Medieval Cosmology* by R. Ariew (to be published by the University of Chicago Press).

205. *Ibid.*, 8:340.

206. *Ibid.*, p. 260.

207. *Ibid.*, p. 299.

who discoursed about the rotation of the earth. The latter was the culminating point of Volume IX, much of which is taken up by the 14th-century discussions of the tides. The significance which Duhem accorded to those discussions shows him once more the very opposite to that 'overenthusiastic' medievalist with far-fetched views he is often made out to be:

What is therefore proper to admire in the theory of the equilibrium of the dry land and of the seas as developed in the School of Paris is much less the outcome than the method, [much less] the almost exact proposition which it accomplished than the spirit which animates it. If one should celebrate Buridan, his followers, and his disciples as precursors of Newton and of Newton's successors, it is not because they had the good luck of guessing a proposition which the theory of gravity will justify. Rather because they have rejected all recourse to final causes and all astrological considerations in order to draw their entire doctrine from mechanical reasons.²⁰⁸

The issue about which Duhem is most often mentioned, disputed, and maligned is, of course, the rotation of the earth as discussed by Oresme. Duhem, as is now well known, had access only to a rather faulty and incomplete text of Oresme's commentary to Aristotle's *On the Heavens*. When Duhem first published in 1909 the famed section from Oresme's commentary, his comments to it did not go beyond the suggestion that Copernicus may very well have been influenced by Oresme's detailed consideration of the earth's rotation as a hypothesis.²⁰⁹ In reinserting the same section in full in Volume IX, Duhem analyzed its meaning at length and he did so in a sense which would have needed no correction had he had access to a better manuscript containing Oresme's declaration: 'However, everyone maintains, and I think myself, that the heavens do move and not the earth.'²¹⁰ For, as Duhem noted, Oresme and others were faced with the utility of the hypothesis of the earth's rotation. Not knowing Archimedes' *Sand Reckoner*, in which an account given of Aristarchus of Samos postulating an orbital motion too for the earth, they had to find the earth's rotation wanting in usefulness. While it could cope with the apparent daily rotation of the sphere of stars, it helped not a whit with respect to the principal problem of astronomy, the irregular motion of planets. Last but not least it created enormous problems for dynamics:

It was this reason that prevented François de Mayronnes from casting his vote for the hypothesis of the earth's rotational motion. The same reason checked also Jean Buridan, Albert of Saxony, and Pierre d'Ailly, and above all Nicole Oresme held it to be valid. The choice it counseled appears pedestrian to us who, in order to appraise it, take our insights from the beacon of a science developed across the ensuing centuries. In the 14th century the choice [against the earth's motion] was most sensible. Those who eventually abandoned that choice yielded to the admirable imprudence of divining intuitions.²¹¹

208. *Ibid.*, 9:234-35.

209. 'Un précurseur français de Copernic,' 1909 (6).

210. For that phrase and the description of six manuscripts of Oresme's commentary, see *Nicole Oresme, Le livre du ciel et du monde*, edited by A. D. Menut and A. J. Denomy, translated with an introduction by A. D. Menut (Madison: University of Wisconsin Press, 1968), pp. 32-36 and 537.

211. *Système du monde*, 9:539.

Duhem, whose vast discourse as a historian of science was governed by his ideal of physical theory, would have once more taken exception to Galileo's realism à propos heliocentrism, his telescope notwithstanding. In Duhem's view heliocentrism was an obligation only as a mathematical formalism insofar as physical theory had to account for *all* the data available. But there was a further obligation set by Duhem, an obligation overlooked by him in this connection. According to him it was obligatory that there should be a growing correspondence between a successful mathematical formalism and natural classification, which in turn was supposed to be an ever more faithful reflection of ontological order, that is, reality. Duhem seemed at least to recognize that in order to cope with Copernicus' boldness the role assigned by him to mathematics had to be deepened. That such would have been the direction taken by Duhem may be gathered from the tenth and last volume of the *Système*, which carries his story only to the threshold of the century of Copernicus. In that volume, largely devoted to the status of universities in the 15th century, Duhem had to register a complete lack of progress beyond what had been achieved by Buridan, Oresme, and their disciples. This stalling was inevitable for two reasons, which Duhem set forth in clear indication of the note on which the *Système* was to come to a close:

In order to unfold all the riches which the teaching of Oresme, Buridan, and their contemporaries implicitly contained, it was above all necessary to have of mathematics a knowledge more complete and profound than the one with which those masters had to be satisfied. It was moreover necessary to have at one's disposal instruments and experimental methods which would allow one to study with greater precision the material bodies and their motions. The Parisians of the 14th century had, in almost every domain, pushed ahead as much as was possible for people who possessed only the elements of arithmetic and geometry and who had but five naked senses for making observations. Poorly equipped as they were, their 15th-century heirs could not go farther than they did. If one was to see the doctrines, whose seeds Buridan and Oresme sowed in the soil, flourish and bring fruit, it was necessary, first, that knowledge of Euclid's *Elements* be enlarged with the more advance methods created by Archimedes. It will be the work of the 16th century to recover them and to find again their use. It will then be necessary that physicists acquire the art of making, with the help of instruments, exact and refined measurements. Galileo's century will reveal this art to them. As long as these two advances have not been achieved, the physics of the School cannot transcend the limits which the Parisians of the 14th century let it reach.²¹²

This passage, which Duhem must have written not later than the winter of 1915-16 or perhaps even earlier, is almost as tantalizing as the passage relating to Copernicus. It suggests Duhem's plan to explore the impact made by the writings of Archimedes once they become available to Western Christendom. The exploration of this most important subject was denied to him by Fate (in Duhem's eyes Providence), an outcome on which A. Leboeuf, director of the Observatory of Besançon, offered the most appropriate remark as he reviewed in 1919 the fifth volume of the *Système*:

212. *Ibid.*, 10:45.

In Volume IV Duhem showed the necessity of a theological revolution [symbolized by the decree of 1277] in order to arrive at the laws of the universe. Volume V confirms not only that necessity, but, by the vivid and vigorously enhanced portrayal of the intellectual discussions among the great minds of the epoch, Duhem made us feel profoundly the magnitude of the effort which Copernicus and his successors would have to expend in order to accomplish the scientific revolution of the 16th century. But which historian will restore us a Duhem? He is rarely in agreement with his predecessors and justifies his judgments with arguments not within the reach of everybody. Does not his work show us long eclipses between master and disciples? . . . And is not there, in that brutal rupture of a work of gestation, a melancholy image of the fragility of our efforts, of the inexorable slowness imposed on the march of truth?²¹³

Comments touched off by the publication of the entire *Système* rarely reached the level of these remarks. Indeed they often fell below its elevated standard. A touch of begrudging, nay slighting, makes itself felt time and again when Duhem is evaluated by precisely those who half a century after his death saw farther and more accurately than he did, but only because they had the good fortune of standing on his shoulders. On reading a massive work of one of them, a judicious reader felt that in spite of its author's massive erudition

it might still be better to counsel the physicist to read Duhem, exaggerations and inaccuracies and all. It would of course be unfair to expect of any historian the genius which shines from behind Duhem's writings. Duhem was not only the discoverer of medieval mechanics; he was also a creator himself, and a great one, in rational mechanics and theoretical physics. Such a man will sometimes jump to a conclusion that must later be abandoned; he may commit slips in translation, and he will not edit texts. He gives us, however, a depth and a grasp that comes from the habits of creative thought; sometimes, because he knows how scientists think, he comes closer to the creator than does a more painstaking, scrupulous historian.²¹⁴

Not that Duhem ever longed to be spoken of as a genius. As a historian who traced so many meanderings and hesitations of scientific advance, he was all too aware of the vast amount of improvement that can be added to any work, however perfect. Mindful of the sharp criticism in store for anyone joining the intellectual arena with novel facts and interpretations, Duhem would not have been upset by remarks which charge him with 'overenthusiasm,' 'extravagant claims,' and with 'Duhemisms,' when such remarks are balanced with references to his 'gigantic' work, to the 'extraordinary freshness' of his approach, and to the 'inestimable debt' which all students of the history of medieval science owe to the great pioneer.²¹⁵ Quite different would have been Duhem's reaction to reviews in which the

213. *RGS&PA* 30 (1919):321-22.

214. C. Truesdell in his review (*Speculum* 36 [1961]:121) of M. Clagett's *The Science of Mechanics in the Middle Ages* (Madison: University of Wisconsin Press, 1961).

215. See M. Clagett's reviews of Volumes VI-IX of the *Système du monde* in *Isis* 49 (1958): 359-62 and 53 (1962):251-52. Duhem would be wholly in his right to request that Clagett's charge, according to which he had kept quoting out of context and quoted texts only in part, should either be fully documented or not made at all.

Système was recognized as a storehouse unimaginably rich in information but hopelessly void of valid ideas. Typically, the latter appraisal came from Koyré as he needled Crombie about the otherworldliness of medievals.²¹⁶

An age in the middle

Being part of a profoundly Christian matrix the medievals certainly had abiding interest in matters beyond this world, a fact which made them see in this world things which other cultures could not see, not even that classical Greece which the Renaissance wanted to reinstate with all its paganism and succeeded in doing so in the long run. Yet, even this century of ours, which witnesses pagan mores flaunting the very basics of Christian ethics, this last vital remnant of medieval heritage, the complete paganization of thought remains an impossibility. The admission of Benedetto Croce, a noble pagan by any measure, that 'it is impossible for us to call ourselves completely non-Christians,'²¹⁷ is a grudging recognition of the endurance of an age, the Middle Ages, which stands between two paganisms, ancient and modern. Primarily evocative of mores, paganism, ancient as well as modern, must be seen above all as a view of reality. In ancient paganism reality was viewed as self-explaining in the sense that no explanatory idea, however lofty, was given a truly transcendental status. Aristotelian and Averroist necessitarianism should come here to mind as the intellectually most sophisticated elaborations of that view. The view of reality in modern paganism is equivalent to a thorough disdain for explanation itself, whose place is taken by mere description, be it apparently as close to (and in fact as distant from) metaphysics as phenomenology. The philosophically much less refined paradigm shifts and survival values fall far short of the thinking of an Age steeped in metaphysical realism. Their spokesmen deserve the same warning which Fustel de Coulanges once addressed to Romanist and Germanist medievalists: 'Nothing resists more your narrow explanatory devices

216. Koyré's two reviews of Volume VI of the *Système*, (*Revue d'histoire des sciences* 9 [1956]:178-9 and *Archives internationales d'histoire des sciences* 35 [1956]:250-52) are the muted echo of his stringent strictures of Duhem in 'Le vide et l'espace infini au XIV^e siècle,' *Archives d'histoire doctrinale et littéraire du Moyen Age* 17 (1949):37-92. Concerning his remark on Crombie, see his *Etudes d'histoire de la pensée scientifique*, p. 60. Koyré's professed puzzlement about the long delay of the full publication of the *Système* is rather baffling in view of his close ties with the very circles whose resentment of Duhem must have been an open secret to him. It could hardly be unknown to Koyré that in 1936 Abel Rey was doing his very best (on behalf of Hélène Duhem!) to persuade Mr. Hermann to publish the remainder of the *Système*. Rey was not supposed to keep secret Hélène Duhem's fears, of which she had written to him on June 6, 1936, that the manuscript might perish in fire. It was also well known that there were not a few who wished, as Hélène Duhem put it in her letter of June 14, 1936, to Albert Dufourcq, that the rest of the *Système* with its expectedly vast portrayal of Buridan and Oresme 'not become a thing to be read in print.'

217. See the chapter, 'We Cannot Help but Call Ourselves Christians,' in B. Croce, *My Philosophy and Other Essays on the Moral and Political Problems of Our Times*, selected by R. Klibansky, translated by E. F. Carritt (London: George Allen & Unwin 1949), pp. 37-47.

than the Middle Ages.’²¹⁸ It was in that age that the view of existence, cosmic and human, as something created, has become a cultural matrix which cannot be exorcised from historical consciousness. No reflection on history can escape that view which represents the most radical contrast to the modern disregard for the createdness of existence and for its inherent purpose.

Unintended depths are therefore lurking beneath pleas such as the one by Fustel de Coulanges, a plea now more than a hundred years old, ‘for a knowledge of the Middle Ages which is accurate and scientific, sincere and non-partisan, as something of primary importance for our society because such knowledge is the best means of putting an end to the senseless yearnings of some, to the hollow utopias of others, and to the hatred of many.’²¹⁹ Such a plea is for scholars respectful of all facts regardless of their provenance and perspective. Concerning the Middle Ages no fact is so towering as the impact exercised by that Christian faith which stands or falls with its very first tenet, the one professing belief in the Father Almighty, Maker of Heaven and Earth, of all things visible and invisible. While the pagan Greeks of old could, in their few references to the idea of a creation ex nihilo, dismiss it with facile scorn,²²⁰ their modern counterparts have no such liberty as long as they want to be scholars as well. Unless this is recognized, debates about the question whether modern science owed its birth to the Middle Ages or to the Renaissance will run out in sheer evasions or in rank acrimony. To face up to the Christian past of the modern world as a past even potentially useful for the rise of that science, which was raised to the status of divinity in the modern post-Christian world, is therefore a task which, more than any other intellectual task, must breed uneasiness.

218. N. D. Fustel de Coulanges, ‘De l’analyse des textes historiques,’ *Revue des questions historiques* 42 (Jan. 1887):35. This warning should seem particularly relevant when one pages through *The Cultural Context of Medieval Learning. Proceedings of the First International Colloquium on Philosophy, Science and Theology in the Middle Ages – September 1973*, edited with an introduction by J. E. Murdoch and E. D. S. Murdoch (Dordrecht: D. Reidel, 1975). There it is claimed that the success of properly grasping medieval science ‘demands much more than the constant dipping into theological and ostensibly philosophical sources . . . something that Duhem himself had already done with considerable expertise’ (p. 16) and that as a Catholic Duhem ‘might be suspected of bias in favor of medieval Churchmen’ (p. 376). One wonders whether the long-standing neglect, nay contempt, of medieval learning on the part of professedly agnostic historians of science should not make one far more suspicious of a virulent bias at work. More importantly, one need not be a Catholic, as correctly argued in the foregoing context (p. 376), in order to agree with the *Théorie physique*. But when one becomes concerned with its foundation, the realism of common sense, is one not driven precisely toward a metaphysical view, the cultivation of which (as Duhem himself pointed out in his famed reply to A. Rey about the physics of a believer) has been largely confined to Catholics and which, in addition, inescapably implies the acceptance of the tenet of creation as again understood mainly by Catholics?

219. N. D. Fustel de Coulanges, ‘L’organisation de la justice dans l’antiquité et les temps modernes. III. La justice royale au moyen âge,’ *RDM* 94 (1871):538.

220. For details and documentation, see my *Cosmos and Creator* (Edinburgh: Scottish Academic Press; Chicago: Regnery-Gateway, 1980), pp. 73-74.

This is one of the two factors which turn Duhem into an uneasy genius. That Duhem overemphasized a strain of medieval Christianity, the trend behind the 1277 decision, is a secondary matter. On closer reading Duhem might have found the Great Scholastics, a Thomas in particular, to be no less an inspiring source about the decisive significance for philosophy, including 'natural philosophy,' of the dogma of creation. As a result, Duhem might then have developed a metaphysical basis for his animated insistence on the pivotal role of common sense which, he finally realized, was threatened by the Pyrrhonism of his beloved Ockhamites. For it is there, in the doctrine of the analogy of being, that lies the only solution to a problem whose ontological character is invariably overlooked or blatantly ignored, the problem of continuity issuing in novelty. It is rather revealing that an age like ours, steeped in the notion of biological evolution, has become insensitive to the philosophical lesson of a seed growing into a flower, a fruit, a plant – Duhem's favorite analogy. Duhem would only have added another factor to his being taken for an uneasy genius had he articulated an ontology implied in his insistence on commonsense realism. His failure to do so, when coupled with his negative utterances on metaphysics, make him easy reading for those who in their unease about philosophical depths want to see only patterns and throw common sense to the winds. Galileo and Descartes certainly claimed to see things as mere patterns. That patterns were present in things could hardly upset those who had a special predilection for the biblical phrase, 'God arranged *everything* according to measure, number, and weight,' the most often quoted biblical phrase in medieval times.²²¹ But the phrase implied that patterns made sense only if they were embodied in things. The depths which things conjure up is all too well attested by the uneasiness of logical positivists, who want to restrict all intellectual validity and respectability 'to the surface,' the invariable level of mere patterns.

To fight things is one thing, to claim they cannot be seen is another. It is still to be demonstrated that any human being, be he a Galileo or a Descartes, is unable to see *things*. If those two saw *only patterns*, they were certainly a very new breed, a really sudden and very large mutation, which, as evolutionary theory tells us, has no survival value. Four hundred years after Descartes and Galileo man's very survival is at stake, not so much on account of his scientific ability to blow up the globe but because of his insensitivity, fostered by the Galilean and Cartesian heritage, to the *purpose* of that most marvelous thing which is science. But if Galileo and Descartes saw things too, whatever their unwillingness to admit this, they were then part of the continuum of common sense, the very core of Duhem's vision and of the heritage which his genius wanted to serve as an apostle. Being rooted in reality, that sense finds ever new votes cast on its behalf, especially when another genius comes along. The following passage is such a vote:

221. E. R. Curtius, *European Literature and the Latin Middle Ages*, translated from the German by W. R. Trask (London: Routledge & Kegan Paul, 1953), p. 504.

Creating a new theory is not like destroying an old barn and erecting a skyscraper in its place. It is rather like climbing a mountain, gaining new and wider views, discovering unexpected connections between our starting point and its rich environment. But the point from which we started out still exists and can be seen although it appears smaller and forms a tiny part of our broad view gained by the mastery of the obstacles on our adventurous way up.²²²

Uncannily Duhemian in its ring, this passage has for its co-author none other than Einstein, a most reluctant discoverer in modern times of the realism of common sense²²³ and of the perspectives – scientific, philosophical, and historical – which it imposes in final analysis. Duhem served those perspectives with insights and efforts worthy of the genius whose inventiveness, to recall a phrase of Goethe, owes much less to unusual talents than to unremitting labor. Not surprisingly, while all too often Duhem's insights are dismissed as far-fetched, willful, and even fanatical, the magnitude of his work invariably makes such critics uneasy. Yet, rugged positivists or secularist historians as they may be, they can hardly conceal their satisfaction whenever they can appeal to Pierre Duhem's immense work, undoubtedly the mark of a genius.

222. A. Einstein and L. Infeld, *The Evolution of Physics* (New York: Simon and Schuster, 1938), p. 152.

223. See ch. 12 on Einstein in my Gifford Lectures, *The Road of Science and the Ways to God* (Chicago: University of Chicago Press, 1978).

LIST OF DUHEM'S PUBLICATIONS

Abbreviations:

<i>AChPH</i>	<i>Annales de Chimie et de Physique</i>
<i>AFH</i>	<i>Archivum Franciscanum Historicum</i>
<i>AFScT</i>	<i>Annales de la Faculté des Sciences de Toulouse</i>
<i>ANScEN</i>	<i>Archives Néerlandaises des Sciences Exactes et Naturelles</i>
<i>AGNT</i>	<i>Archiv für die Geschichte der Naturwissenschaften und der Technik</i>
<i>AJM</i>	<i>American Journal of Mathematics</i>
<i>APC</i>	<i>Annales de Philosophie Chrétienne</i>
<i>ASScB</i>	<i>Annales de la Société Scientifique de Bruxelles</i>
<i>ASScF</i>	<i>Acta Societatis Scientiarum Fennicae</i>
<i>AScENS</i>	<i>Annales Scientifiques de l'Ecole Normale Supérieure</i>
<i>BAAEEN</i>	<i>Bulletin de l'Association des Anciens Elèves de l'Ecole Normale</i>
<i>BATMA</i>	<i>Bulletin d l'Association de Technique Maritime et Aéronautique</i>
<i>BH</i>	<i>Bulletin Hispanique</i>
<i>BI</i>	<i>Bulletin Italien</i>
<i>BM</i>	<i>Bibliotheca Mathematica</i>
<i>BMSNY</i>	<i>Bulletin of the Mathematical Society of New York</i>
<i>BSChNF</i>	<i>Bulletin de la Société Chimique du Nord de la France</i>
<i>BScM</i>	<i>Bulletin des Sciences Mathématiques</i>
<i>CE</i>	<i>Catholic Encyclopaedia, The (New York: R. Appleton), 1907-14, 16 vols.</i>
<i>CR</i>	<i>Comptes Rendus des Séances de l'Académie des Sciences (Paris)</i>
<i>EE</i>	<i>L'Eclairage Electrique</i>
<i>JChPh</i>	<i>Journal de Chimie Physique</i>
<i>JMPA</i>	<i>Journal de Mathématiques Pures et Appliquées</i>
<i>JPhCh</i>	<i>Journal of Physical Chemistry</i>
<i>JPhThA</i>	<i>Journal de Physique Théorique et Appliquée</i>
<i>MARB</i>	<i>Mémoires présentés par Divers Savants Etrangers et Mémoires couronnés par l'Académie Royale de Belgique</i>
<i>MSScPhNB</i>	<i>Mémoires de la Société des Sciences Physiques et Naturelles de Bordeaux</i>
<i>PVSScPhNB</i>	<i>Procès-verbaux des Séances de la Société des Sciences Physiques et Naturelles de Bordeaux</i>
<i>RDM</i>	<i>Revue des Deux Mondes</i>
<i>RGScPA</i>	<i>Revue Générale des Sciences Pures et Appliquées</i>
<i>RM</i>	<i>Revue de Mathématique</i>
<i>RdM</i>	<i>Revue du Mois</i>
<i>RMM</i>	<i>Revue de Métaphysique et de Morale</i>
<i>RP</i>	<i>Revue de Philosophie</i>
<i>RPBSOu</i>	<i>Revue Philomathique de Bordeaux et du Sud-Ouest</i>
<i>RQSc</i>	<i>Revue des Questions Scientifiques</i>
<i>RRAL</i>	<i>Rendiconti della Reale Accademia dei Lincei</i>
<i>RSc</i>	<i>Revue Scientifique</i>
<i>RScPT</i>	<i>Revue des Sciences Philosophiques et Théologiques</i>
<i>TMFL</i>	<i>Travaux et Mémoires des Facultés de Lille</i>

The following list includes only such book reviews which have the character of an essay-review. The date in parentheses immediately following a title indicates the day of its presentation to a Society or Academy.

The day and/or month in parentheses at the end of an entry indicate the particular issue of a periodical.

1884

1. Sur le potentiel thermodynamique et la théorie de la pile voltaïque, *CR* 99:1113-15 (22 décembre)

1885

1. Sur la théorie de l'induction électrodynamique, *CR* 100:44-46 (5 janvier)
2. Sur le renversement des raies du spectre, *JPhThA* 4:221-25
3. Applications de la thermodynamique aux phénomènes capillaires, *AScENS* 2:207-54
4. Applications de la thermodynamique aux phénomènes thermo-électriques et pyro-électriques, *AScENS* 2:405-24

1886

1. *Le potentiel thermodynamique et ses applications à la mécanique chimique et à l'étude des phénomènes électriques*, (Paris: A. Hermann), xi+247pp
2. Sur les vapeurs émises par un mélange de substances volatiles, *CR* 102:1449-51 (21 juin)
3. Sur la condensation des vapeurs, *CR* 102:1548-49 (28 juin)
4. Sur la tension de vapeur saturée, *CR* 103:1008-09 (22 novembre)
5. Sur la loi d'Ampère, *JPhThA* 5:26-29
6. Sur les corps hygrométriques, *JPhThA* 5:103-16
7. Sur la capacité calorifique des combinaisons gazeuses dissociables, *JPhThA* 5:301-23
8. Translation, G. Kirchoff, 'Sur la théorie des rayons lumineux,' *AScENS* 3:303-41

1887

1. Sur la pression électrique et les phénomènes électrocapillaires *CR* 104:54-56 (3 janvier)
2. Sur quelques formules relatives aux dissolutions salines, *CR* 104:683-85 (7 mars)
3. Sur la chaleur spécifique d'une dissolution saline, *CR* 104:780-81 (14 mars)
4. Sur une relation entre l'effet Peltier et la différence de niveau potentiel entre deux métaux, *CR* 104:1606-09 (6 juin)
5. Sur le phénomène de Peltier dans une pile hydro-électrique, *CR* 104:1697-99 (13 juin)
6. Sur l'aimantation par influence, *CR* 105:749-51 (24 octobre)
7. Sur l'aimantation par influence, *CR* 105:798-800 (31 octobre)
8. Sur la théorie du magnétisme, *CR* 105:932-34 (7 novembre)
9. Sur l'aimantation par influence, *CR* 105:1113-15 (5 décembre)
10. Sur l'aimantation par influence, *CR* 105:1240-41 (19 décembre)
11. Sur la hauteur osmotique, *JPhThA* 6:134-47
12. Sur une théorie des phénomènes pyro-électriques, *JPhThA* 6:366-73
13. Sur la pression osmotique, *JPhThA* 6:397-414

14. Sur les vapeurs émises par un mélange de substances volatiles, *AScENS* 4:9-60
15. Sur quelques formules relatives aux dissolutions salines, *AScENS* 4:381-405
16. Etude sur les travaux thermodynamiques de J. Willard Gibbs, *BScM* 11:122-48, 159-76
17. Sur la relation qui lie l'effet Peltier à la différence de niveau potentiel de deux métaux en contact, *AChPh* 12:433-470

1888

1. *De l'aimantation par influence* (Paris: Gauthier-Villars), 138pp; also in *AFScT* 2:L1-L138
2. Sur les équilibres chimiques, *CR* 106:485-87 (13 février)
3. Sur l'aimantation des corps diamagnétiques, *CR* 106:736-38 (12 mars)
4. Sur les lois de l'équilibre chimique; réponse à M. H. Le Chatelier, *CR* 106:846-49 (19 mars)
5. Application de la thermodynamique aux actions qui s'exercent entre les courants électriques, *ASScF* 16:229-332
6. Sur quelques propriétés des dissolutions, *JPhThA* 7:5-25
7. Sur un mémoire de M. Robert von Helmholtz: 'Sur la variation du point de congélation,' *JPhThA* 7:122-23
8. Sur un mémoire de M. Max Plank [sic] ayant pour titre: 'Sur le principe de l'accroissement de l'entropie,' *JPhThA* 7:124-27
9. Sur la liquéfaction de l'acide carbonique en présence de l'air, *JPhThA* 7:158-68
10. [Sur une formule de M. Frowein], *JPhThA* 7:316-21
11. De l'influence de la pesanteur sur les dissolutions, *JPhThA* 7:391-419
12. Etude historique de la théorie sur l'aimantation par influence, *AFScT* 2:1-40
13. Einige Bemerkungen über die Lösungs- und Verdünnungswärme, *ZPhCh* 2:568-84
14. Sur la pression électrique et les phénomènes électrocapillaires. Première Partie. De la pression électrique, *AScENS* 5:97-146

1889

1. Sur la transformation et l'équilibre en thermodynamique, *CR* 108:666-67 (1 avril)
2. Sur l'impossibilité des corps diamagnétiques, *CR* 108:1042-43 (20 mai)
3. Sur la pression électrique et les phénomènes électrocapillaires. Deuxième Partie. Des phénomènes électrocapillaires, *AScENS* 6:183-256
4. Quelques remarques sur les mélanges de substances volatiles, *AScENS* 6:153-56
5. Sur l'équivalence des courants et des aimants, *AScENS* 6:297-326
6. Des corps diamagnétiques, *TMFL* Mémoire N^o 2, 71pp
7. Notice sur Bronislas-Etienne Wasserzug, *BAAEEN* (1884-89):57-62

1890

1. Sur les dissolutions d'un sel magnétique, *AScENS* 7:289-322
2. Analyse de l'ouvrage de E. Mathieu *Théorie de l'élasticité des corps solides*, *BScM* 14:161-84
3. Des principes fondamentaux de l'hydrostatique, *AFScT* 4:C1-C35
4. Sur le déplacement de l'équilibre, *AFScT* 4:N1-N9

1891

1. *Leçons sur l'électricité et le magnétisme* (Paris: Gauthier-Villars et Fils), Tome I, *Les corps conducteurs à l'état permanent* (viii+560pp)

2. *Hydrodynamique, Elasticité, Acoustique*. Cours professé à la Faculté des Sciences de Lille (in 4° lithographed; Paris: Hermann), Tome Premier, *Théorèmes généraux, les corps fluides* (iv+378pp); Tome Second, *Les fils et les membranes, les corps élastiques, l'acoustique* (iv+310pp)
3. Sur la continuité entre l'état liquide et l'état gazeux et sur la théorie générale des vapeurs, *TMFL* Mémoire N° 5, 105pp
4. Sur la pression à l'intérieur des milieux magnétiques ou diélectriques, *CR* 112:657-58 (31 mars)
5. Ueber ein Theorem von J. Willard Gibbs, *ZPhCh* 8:337-39
6. Ueber den dreifachen Punkt, *ZPhCh* 8:367-82
7. Application de la thermodynamique aux actions qui s'exercent entre les courants électriques et les aimants, *ASScF* 17:1-100

1892

1. *Leçons sur l'électricité et le magnétisme* (Paris: Gauthiers-Villars et Fils), Tome II, *Les aimants et les corps diélectriques* (474pp); Tome III, *Les courants linéaires* (vi + 528pp)
2. Sur la dissociation dans les systèmes qui renferment un mélange de gaz parfaits, *TMFL* Mémoire N° 8, 215pp
3. Sur la détente des vapeurs, *JPhThA* 1:470-74
4. Sur la déformation électrique des cristaux, *AScENS* 9:167-76
5. Sur le déplacement de l'équilibre, *AScENS* 9:375-79
6. Quelques réflexions au sujet des théories physiques, *RQSc* 31:139-77
7. Notation atomique et hypothèses atomistiques, *RQSc* 31:394-457
8. Emile Mathieu, His Life and Works, *BNYMS* 1:156-69
9. Commentaire aux principes de la thermodynamique – Première partie. Le principe de la conservation de l'énergie, *JMPA* 8:269-330
10. Review of H. Poincaré, *Cours de physique mathématique. Thermodynamique* (Paris: Georges Carré, 1892), *RQSc* 31:603-06

1893

1. *Introduction à la mécanique chimique* (Paris: George Carré), 177pp
2. Dissolutions et mélanges – Premier mémoire: Equilibre et mouvement des fluides mélanges, *TMFL* Mémoire N° 11, 136pp
3. Dissolutions et mélanges – Deuxième mémoire: les propriétés physiques des dissolutions, *TMFL* Mémoire N° 12, 138pp
4. Le potentiel thermodynamique et la pression hydrostatique, *AScENS* 10:183-230
5. Sur les lois générales de l'induction électrodynamique, *AFScT* 7:B1-B28
6. Les actions électrodynamiques et électromagnétiques – Première partie: Les forces électrodynamiques, *AFScT* 7:G1-G52
7. Une nouvelle théorie du monde inorganique, *RQSc* 33:99-133
8. Physique et métaphysique, *RQSc* 34:55-83, also in *APC* 127:461-86
9. L'école anglaise et les théories physiques, à propos d'un livre de W. Thomson, *RQSc* 34:345-78
10. Note sur les conditions de fusion de la glace en présence du chlorure de sodium *BSChNF* 3:55-60
11. Commentaire aux principes de la thermodynamique – Deuxième partie: Le principe de Sadi Carnot et de R. Clausius *JMPA* 9:293-359
12. Sur les phénomènes de volatilisation apparente, *ASScB* 17:93-102

1894

1. Dissolutions et mélanges – Troisième mémoire: Les mélanges doubles, *TMFL* Mémoire N° 13, 138pp
2. Commentaire aux principes de la thermodynamique – Troisième partie: Les équations générales de la thermodynamique, *JMPA* 10:207-85
3. Théorèmes généraux sur l'état des corps en dissolution, *JPhThA* 3:49-64
4. Les actions électrodynamiques et électromagnétiques – Seconde partie: Les actions électromagnétiques, *AFScT* 8:A1-A57
5. Quelques réflexions au sujet de la physique expérimentale, *RQSc* 36:179-229
6. Fragments d'un cours d'optique – Premier fragment: Le principe d'Huygens, *ASScB* 18:95-123
7. Les théories de l'optique, *RDM* 123:94-125
8. Lettre de M. P. Duhem, *APC* 128:91-92

1895

1. *Le potentiel thermodynamique et ses applications à la mécanique chimique et à l'étude des phénomènes électriques* (Paris: A. Hermann), xi + 247pp, 2d printing of 1886 (1)
2. De l'influence que les actions capillaires exercent sur un corps flottant, *AScENS* 12:211-26
3. Sur la stabilité de l'équilibre des corps flottants, *JMPA* 1:91-180
4. Fragments d'un cours d'optique – Deuxième fragment: Coup d'oeil sur l'optique ancienne. L'optique de Young, *ASScB* 19:27-94
5. Les théories de la chaleur. – I. Les précurseurs de la thermodynamique, *RDM* 129:869-901
6. Les théories de la chaleur. – II. Les créateurs de la thermodynamique, *RDM* 130:379-415
7. Les théories de la chaleur. – III. Chaleur et mouvement, *RDM* 130:851-68
8. Sur la pression dans les milieux diélectriques ou magnétiques, *AJM* 17:117-67
9. Sur l'interprétation théorique des expériences hertziennes, *EE* 4:494-502
10. Quelques remarques au sujet de l'électrodynamique des corps diélectriques proposée par J. Clerk Maxwell, in *Compte rendu du Troisième Congrès Scientifique International des Catholiques tenu à Bruxelles du 3 au 8 septembre 1894. Septième Section – Sciences mathématiques et naturelles* (Bruxelles: Société Belge de Librairie, 1895), pp. 260-69.

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1. Sur la propagation des actions électrodynamiques, *AFScT* 10:B1-B87
2. Sur la stabilité d'un navire qui porte du lest liquide, *JMPA* 2:23-40
3. De l'influence qu'un chargement liquide exerce sur la stabilité d'un navire, *BATMA* 7:43-50
4. Sur les déformations permanentes et l'hystérésis – Premier mémoire: Sur les déformations permanentes et l'hystérésis (13 octobre, 1894), *MARB* 54, 61pp
5. Sur les déformations permanentes et l'hystérésis – Deuxième mémoire: Les modifications permanentes du soufre (2 mars, 1895), *MARB* 54, 86pp
6. Sur les déformations permanentes et l'hystérésis – Troisième mémoire: Théorie générale des modifications permanentes (3 août, 1895), *MARB* 54, 56pp
7. Sur l'électrodynamique des milieux diélectriques. – Premier mémoire: Propriétés fondamentales des courants de déplacement, *MSScPhNB* 1:233-85
8. Sur l'électrodynamique des milieux diélectriques. – Second mémoire: Les équations générales de l'électrodynamique dans les milieux qui sont à la fois magnétiques et diélectriques, *MSScPhNB* 1:287-93
9. Théorie thermodynamique de la viscosité, du frottement et des faux équilibres chimiques, *MSScPhNB* 2:1-207

10. Sur l'équivalence des flux de conduction et des flux de déplacement, *EE* 8:110-12
11. L'évolution des théories physiques du XVII^e siècle jusqu'à nos jours, *RQSc* 40:463-99
12. Fragments d'un cours d'optique – Troisième fragment: L'optique de Fresnel, *ASScB* 20:27-105

1897

1. *Traité élémentaire de mécanique chimique fondée sur la thermodynamique* (Paris: A. Hermann), Tome I, viii + 299 pp
2. Die dauernden Aenderungen und die Thermodynamik. – I. Die dauernden Aenderungen der Systeme weiche von einer einzigen normalen Veränderlichen abhängen, *ZPhCh* 2: 545-89
3. Die dauernden Aenderungen und die Thermodynamik. – II. Die Umwandlungen des Schwefels, *ZPhCh* 23:193-266
4. Die dauernden Aenderungen und die Thermodynamik. – III. Allgemeine Theorie der dauernden Aenderungen, *ZPhCh* 23:497–541
5. Thermochemie, à propos d'un livre récent de M. Marcelin Berthelot, *RQSc* 42:361-92
6. Sur la stabilité de l'équilibre d'une masse fluide dont les éléments sont soumis à leurs actions mutuelles, *JMPA* 3:151-93
7. Sur la stabilité de l'équilibre d'un corps flottant à la surface d'un liquide compressible, *JMPA* 3: 389-403
8. Conditions nécessaires et suffisantes pour la stabilité de l'équilibre des corps flottants (7 janvier), *PVSScPhNB* (1896-97):21-25
9. Sur les déformations permanentes du verre. Etude théorique (4 mars), *PVSScPhNB* (1896-97):45-50
10. Sur les faux équilibres chimiques (1 avril), *PVSScPhNB* (1896-97):75-84
11. Théorèmes sur la distillation (17 juin), *PVSScPhNB* (1896-97):112-15
12. Sur le problème général de la statique chimique (1 août), *PVSScPhNB* (1896-97):118-24
13. On the Liquefaction of a Mixture of Two Gases, *JPhCh* 1:273-97
14. Review of G. Koenigs, *Leçons de cinématique. Tome I. Cinématique théorique* (Paris: Hermann), *RQSc* 42:279-84

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2. La loi des phases, à propos d'un livre récent de M. Wilder D. Bancroft, *RQSc* 44:54-82
3. L'intégrale des forces vives en thermodynamique, *JMPA* 4:5-19
4. Sur les déformations permanentes et l'hystérésis. – Quatrième mémoire: Etudes de divers systèmes dépendant d'une seule variable (7 août, 1897), *MARB* 56:1-16
5. Sur les déformations permanentes et l'hystérésis. – Cinquième mémoire: Etudes de divers systèmes dépendant de deux variables (7 août, 1897), *MARB* 56:117-99
6. Sur l'intégrale des équations des petits mouvements d'un solide isotrope, *MSScPhNB* 3: 319-42
7. Sur les aciers au nickel irréversibles, *MSScPhNB* 4:443-64
8. Sur la formation des hydrates et les points quadruples (25 novembre, 1897) *PVSScPhNB* (1897-98):2-8
9. Sur l'équation des forces vives en thermodynamique et les relations de la thermodynamique avec la mécanique classique (23 décembre, 1897) *PVSScPhNB* (1897-98): 23-27
10. Remarques touchant les lois du résonateur hertzien, établies par M. A. Turpain (20 janvier), *PVSScPhNB* (1897-98):64-67

11. Sur l'équation des petits mouvements dans un milieu fluide (20 mai), *PVSScPhNB* (1897-98):180-84
12. On the General Problem of Chemical Statics, *JPhCh* 2:1-42 and 91-115
13. Une soutenance de thèse de doctorat à la Faculté des Sciences de Bordeaux, *RPBSOu* 244-50 (avril)
14. A propos d'une thèse de physique, *RPBSOu* 483-92 (septembre) and 516-23 (octobre)

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2. Die dauernden Aenderungen und die Thermodynamik. – IV. Ueber einige Eigenschaften der Systeme, welche von einer einzigen normalen Variablen abhängen, besonders über die Zerreiſung der elastischen Körper, *ZPhCh* 28:577-618
3. Die dauernden Aenderungen und die Thermodynamik. – V. Untersuchungen der Systeme, welche von zwei Veränderlichen abhängen, von denen die eine keine Hysteresis besitzt, *ZPhCh* 28:641-97
4. Zur Frage von den 'falschen Gleichgewichten,' *ZPhCh* 29:711-15
5. Sur l'égalité de Clausius, *JMPA* 5:175-90
6. Sur la viscosité magnétique, *MSScPhNB* 5:1-29; see 1908 (12)
7. Un point d'histoire des sciences: La tension de dissociation avant H. Sainte-Claire Deville, *MSScPhNB* 5:67-83
8. Sur un théorème approché concernant les systèmes affectés d'hystérésis (16 mars), *PVSScPhNB* (1898-99):68-71
9. Sur l'allongement spontané d'un fil soumis à une tension constante (18 mai), *PVSScPhNB* (1898-99):90–93
10. Sur l'écroutissage (29 juin), *PVSScPhNB* (1898-99):149-51
11. A propos des faux équilibres chimiques (20 juillet), *PVSScPhNB* (1898-99):157-62
12. Dissociation Pressure before H. Sainte-Claire Deville, *JPhCh* 3:364-78 (English translation of 7 above)
13. Une science nouvelle: La chimie physique, *RPBSOu* 205-19 (mai et juin)
14. Usines et laboratoires, *RPBSOu* 385-400 (septembre)
15. Discours de Mr. Pierre Duhem aux Anciens Élèves de l'École et l'Institution Sainte-Marie (Bordeaux) comme Président de leur Fête Annuelle, *Le Nouvelliste* (Bordeaux), mercredi, 28 juin, 1899, p. 3. cols 4-5

1900

1. La notion de mixte. Essai historique et critique, *RP* 1:69-99, 167-97, 331-57, 430-67, 730-45
2. Sur le théorème d'Hugoniot et quelques théorèmes analogues, *CR* 131:1171-73 (24 décembre)
3. Sur un point du calcul des variations, *AFScT* 2:115-36
4. Die dauernden Aenderungen und die Thermodynamik. – VII. Ueber einige Annäherungsmethoden, nach welchen man ein System untersuchen kann, welches von zwei Variablen mit Hysteresis abhängt, *ZPhCh* 34:683-700
5. Bemerkungen über eine Abhandlung des Herrn J.-V. Zawidski, *ZPhCh* 35:483
6. Sur la déformation des diélectriques polarisés, *JPhThA* 9:28-29
7. Sur la généralisation d'un théorème de Clebsch, *JMPA* 6:215-59
8. On the Emission and Absorption of Water-vapor by Colloidal Matter, *JPhCh* 4:65-122
9. Théorie et pratique, *RPBSOu* 250-62 (juin)
10. Un doctorat de l'Université de Bordeaux, *RPBSOu* 385-98 (septembre)

11. Archimède connaissait-il le paradoxe hydrostatique? *BM* 1:15-19
12. Sur la théorie électromagnétique de Helmholtz et la théorie électromagnétique de la lumière, *ANScEN* 5:227-36 (*Recueil de travaux offerts par les auteurs à H. A. Lorentz, professeur de physique à l'Université de Leiden à l'occasion du 25^{me} anniversaire de son doctorat le 11 décembre 1900* [Le Haye: Martinus Nijhoff, 1900])
13. Les théories électriques de J. Clerk Maxwell. Etude historique et critique. Introduction, *ASScB* 24:239-53; also in *RQSc* 49:5-21
14. L'oeuvre de J.-H. van't Hoff, à propos d'un livre récent, *RQSc* 47:5-27

1901

1. Sur la condition supplémentaire en hydrodynamique, *CR* 132:117-20 (21 janvier)
2. Sur la stabilité isentropique d'un fluide, *CR* 132:244-246 (4 février)
3. Sur les chaleurs spécifiques des fluides dont les éléments sont soumis à leurs actions mutuelles, *CR* 132:292-95 (11 février)
4. De la propagation des ondes dans les fluides visqueux, *CR* 132:393-96 (18 février)
5. Sur les ondes du second ordre par rapport aux vitesses, qui peut présenter un fluide visqueux, *CR* 132:607-10 (11 mars)
6. De la propagation des discontinuités dans les fluides visqueux, *CR* 132:658-62 (18 mars)
7. De la propagation des discontinuités dans un fluide visqueux. Extension de la loi d'Hugoniot, *CR* 132:944-46 (22 avril)
8. Sur la stabilité d'un système animé d'un mouvement de rotation, *CR* 132:1021-23 (29 avril)
9. Sur les théorèmes d'Hugoniot, les lemmes de M. Hadamard, et la propagation des ondes dans les fluides visqueux, *CR* 132:1163-67 (13 mai)
10. Sur les ondes longitudinales et transversales dans les fluides parfaits, *CR* 132:1303-06 (5 juin)
11. Des ondes qui peuvent persister en un fluide visqueux, *CR* 133:579-80 (14 octobre)
12. Analyse de l'ouvrage de G. Robin: *Thermodynamique générale*, *BScM* 25:174-203
13. Sur les équations de l'hydrodynamique. Commentaire à un mémoire de Clebsch, *AFScT* 3:379-431
14. Ueber die Verdampfung eines Gemisches zweier flüchtigen Stoffe für den Fall, dass der eine Dampf sich dissociiren kann, *ZPhCh* 36:227-31
15. Ueber die Verdampfung binärer Gemische, *ZPhCh* 36:605-06
16. Die dauernden Aenderungen und die Thermodynamik. – VIII. Die Ungleichung von Clausius und die Hysteresis, *ZPhCh* 37:91-99
17. Sur quelques extensions récentes de la statique et de la dynamique, *RQSc* 50:130-57
18. Sur la stabilité de l'équilibre relatif d'une masse fluide animée d'un mouvement de rotation, *JMPA* 7:331-50
19. Sur la fusion et la cristallisation, et sur la théorie de M. Tammann, *ANScEN* 6:93-102
20. Les théories électriques de J. Clerk Maxwell. Première Partie: Les électrostatiques de Maxwell, *ASScB* 25:1-90
21. Les théories électriques de J. Clerk Maxwell. Seconde Partie: L'électrodynamique de Maxwell, *ASScB* 25:293-417
22. Recherches sur l'hydrodynamique. Première Partie: Sur les principes fondamentaux de l'hydrodynamique, *AFScT* 3:315-77
23. Recherches sur l'hydrodynamique. Deuxième Partie: Sur la propagation des ondes, *AFScT* 3:379-431
24. On the Liquefaction of a Mixture of Two Gases. Composition of the Liquid and of the Vapor, *JPhCh* 5:91-112

1902

1. *Thermodynamique et chimie: Leçons élémentaires à l'usage des chimistes* (Paris: Hermann), x + 496pp
2. *Le mixte et la combinaison chimique. Essai sur l'évolution d'une idée* (Paris: C. Naud), 208pp. Text of articles 1900 (1) printed under a new title.
3. *Les théories électriques de J. Clerk Maxwell. Etude historique et critique* (Paris: Hermann), 228pp. Text of articles 1900 (13) and 1901 (20, 21).
4. Stabilité, pour des perturbations quelconques, d'un système animé d'un mouvement de rotation uniforme, *CR* 134:23-34 (6 janvier)
5. Sur les conditions aux limites en hydrodynamique, *CR* 134:149-52 (20 janvier)
6. Sur certains cas d'adhérence d'un liquide visqueux aux solides qu'il baigne, *CR* 134:265-67 (3 février)
7. Sur l'impossibilité de certains régimes permanents au sein des fluides visqueux, *CR* 134:456-58 (24 février)
8. Sur l'extension du théorème de Lagrange aux liquides visqueux, *CR* 134:580-81 (10 mars)
9. L'extension du théorème de Lagrange aux liquides visqueux et les conditions aux limites, *CR* 134:686-88 (24 mars)
10. Sur les fluides compressibles visqueux, *CR* 134:1088-90 (12 mai)
11. La viscosité au voisinage de l'état critique, *CR* 134:1272-74 (2 juin)
12. Sur les quasi-ondes, *CR* 135:761-63 (10 novembre)
13. Sur l'analogie entre les rayons X et les oscillations hertziennes, *CR* 135:845 (17 novembre)
14. Sur les conditions nécessaires pour la stabilité de l'équilibre d'un système visqueux, *CR* 135:939-41 (1 décembre)
15. Sur la stabilité de l'équilibre et les variables sans inertie, *CR* 135:1088-91 (15 décembre)
16. Des conditions nécessaires pour qu'un fluide soit en équilibre stable, *CR* 135:1290-93 (29 décembre)
17. Sur la stabilité, pour des perturbations quelconques, d'un système animé d'un mouvement de rotation uniforme, *JMPA* 8:5-18
18. Sur la stabilité de l'équilibre relatif, *JMPA* 8:215-27
19. Notice sur la vie et les travaux de Georges Brunel, *MSScPhNB* 2:i-1xxxix; reprinted also as a booklet with pagination in Arabic numerals (Bordeaux: Gounouilhou)
20. Notes sur quelques points des théories électriques et magnétiques, *MSScPhNB* 2:45-81
21. Recherches sur l'hydrodynamique. Deuxième partie (suite et fin): Sur la propagation des ondes, *AFScT* 4: 101-69
22. Actions exercées par des courants alternatifs sur une masse conductrice ou diélectrique, in *Comptes rendus de l'Association Française pour l'Avancement des Sciences – Congrès de Montauban. 1902* (Paris: Secrétariat de l'Association), pp. 280-304

1903

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2. *Recherches sur l'hydrodynamique. – Première Série* (Paris: Gauthier-Villars), 212pp in 4°. Text of memoirs 1901 (22, 23) and 1902 (21).
3. Recherches sur l'hydrodynamique. Troisième partie: Des quasi-ondes, *AFScT* 5:5-24
4. Recherches sur l'hydrodynamique. Quatrième partie: Des conditions aux limites, *AFScT* 5:25-61 and 197-255
5. Recherches sur l'hydrodynamique. Cinquième partie: Le théorème de Lagrange et les conditions aux limites, *AFScT* 5:353-76

6. Recherches sur l'hydrodynamique. Sixième partie: Sur les deux coefficients de viscosité et la viscosité au voisinage de l'état critique, *AFScT* 5:377-404
7. L'évolution de la mécanique. – I. Les diverses sortes d'explications mécaniques, *RGSsPA* 14:63-73 (30 janvier)
8. L'évolution de la mécanique. – II. La mécanique analytique, *RGSsPA* 14:119-32 (15 février)
9. L'évolution de la mécanique. – III. Les théories mécaniques de la chaleur et de l'électricité, *RGSsPA* 14:171-90 (28 février)
10. L'évolution de la mécanique. – IV. Le retour à l'atomisme et au cartésianisme, *RGSsPA* 14:247-58 (15 mars)
11. L'évolution de la mécanique. – V. Les fondements de la thermodynamique, *RGSsPA* 14:301-14 (30 mars)
12. L'évolution de la mécanique. – VI. La statique générale et la dynamique générale, *RGSsPA* 14:352-65 (15 avril)
13. L'évolution de la mécanique. – VII. Les branches aberrantes de la thermodynamique, *RGSsPA* 14:416-29 (30 avril)
14. *L'évolution de la mécanique* (Paris: A. Joanin), 348pp. Text of 1903 (7-13)
15. Ewolucya Mechaniki, *WM* 7:113-36, 137-68, 244-88. Polish translation of 1903 (7-9)
16. Les origines de la statique—Ch. I. Aristôte et Archimède; Ch. II. Léonard de Vinci; Ch. III. Jérôme Cardan; Ch. IV. L'impossibilité du mouvement perpétuel, *RQSc* 54:462-516 (octobre)
17. Sur quelques formules de cinématique utiles dans la théorie générale de l'élasticité, *CR* 136:139-41 (19 janvier)
18. Sur la viscosité en un milieu vitreux, *CR* 136:281-83 (2 février)
19. Sur les équations du mouvement et la relation supplémentaire au sein d'un milieu vitreux, *CR* 136:343-45 (9 février)
20. Sur le mouvement des milieux vitreux, affectés de viscosité, et très peu déformés, *CR* 136:592-95 (9 mars)
21. Sur les ondes au sein d'un milieu vitreux, affecté de viscosité et très peu déformé, *CR* 136:733-35 (23 mars)
22. Des ondes du premier ordre par rapport à la vitesse au sein d'un milieu vitreux, doué de viscosité et affecté de mouvements finis, *CR* 136:858-60 (6 avril)
23. Des ondes du second ordre par rapport à la vitesse au sein des milieux vitreux, doués de viscosité, et affectés de mouvements finis, *CR* 136:1032-34 (4 mai)
24. Sur la propagation des ondes dans un milieu parfaitement élastique affecté de déformations finies, *CR* 136:1379-81 (8 juin)
25. Sur la propagation des ondes dans les milieux élastiques selon qu'ils conduisent ou ne conduisent pas la chaleur, *CR* 136:1537-40 (22 juin)
26. Sur les ondes-cloisons, *CR* 137:237-40 (27 juillet)
27. Sur la suppression de l'hystérésis magnétique par un champ magnétique oscillant, *CR* 137: 1022-25 (14 décembre)
28. Remarques sur la mécanique générale et la mécanique électrique, *JPhTA* 2:686-89
29. Etude sur l'oeuvre de George Green à l'occasion de la réimpression des *Mathematical Papers of the late George Green*, *BScM* 27:237-56
30. Analyse de l'ouvrage de Ernst Mach: *La mécanique, étude historique et critique de son développement*, *BScM* 27:261-83; also as 1904 (26)
31. Die dauernden Aenderungen und die Thermodynamik. – IX Die Hysteresis und die umkehrbaren Aenderungen, *ZPhCh* 43:696-700
32. Sur la stabilité et les petits mouvements des corps fluides, *JMPA* 9:233-328
33. Stabilité et viscosité, *MSScPhNB* 3:121-40
34. Sur la viscosité et le frottement au contact de deux fluides (19 février), *PVSScPhNB* 27-31

35. Sur les conditions nécessaires pour la stabilité initiale d'un milieu vitreux (2 avril), *PVSSc-PhNB* 52-58
36. Sur une généralisation du théorème de Reech (7 mai), *PVSScPhNB* 63-73
37. Considérations sur la stabilité et, particulièrement, sur la stabilité des corps élastiques (25 juin), *PVSScPhNB* 98-104
38. Sur certains milieux élastiques considérés par M. J. Boussinesq (9 juillet), *PVSScPhNB* 105-09
39. Sur l'énergie utilisable d'un système dont la surface est maintenue à une température invariable (23 juillet), *PVSScPhNB* 121-28
40. Les points d'eutexie et de transition pour les mélanges binaires qui peuvent donner des cristaux mixtes, *JChPh* 1:34-56, 97-120
41. Léonard de Vinci et la composition des forces concourantes, *BM* 4:338-43

1904

1. *Recherches sur l'hydrodynamique. – Second Série* (Paris: Gauthier-Villars), 153 pp in 4°. Text of 1903 (3-6)
2. *Ewolucya Mechaniki*, *WM* 8:1-72, 191-222, 223-53, 254-86; Polish translation of 1903 (10-13)
3. *Recherches sur l'élasticité. – Première Partie: De l'équilibre et du mouvement des milieux vitreux*, *AScENS* 21:99-139
4. *Recherches sur l'élasticité. – Deuxième Partie: Les milieux vitreux peu déformés*, *AScENS* 21:375-414
5. D'une condition nécessaire pour la stabilité initiale d'un milieu élastique quelconque, *CR* 138:541-45 (29 février)
6. Sur quelques formules utiles pour discuter la stabilité d'un milieu vitreux, *CR* 138:737-41 (21 mars)
7. D'une condition nécessaire pour la stabilité d'un milieu vitreux illimité, *CR* 138:844-47 (5 avril)
8. Modifications permanentes sur les propriétés des systèmes affectés à la fois d'hystérésis et de viscosité, *CR* 138:942-45 (18 avril)
9. Effet des petites oscillations sur les systèmes affectés d'hystérésis et de viscosité, *CR* 138:1075-76 (2 mai)
10. Effet des petites oscillations de la température sur un système affecté d'hystérésis et de viscosité, *CR* 138:1196-99 (16 mai)
11. Effet des petites oscillations des conditions extérieures sur un système dépendant de deux variables, *CR* 138:1313-16 (30 mai)
12. Influence exercée par de petites variations des actions extérieures sur un système que définissent deux variables affectées d'hystérésis, *CR* 138:1471-73 (13 juin)
13. La théorie physique – Introduction, *RP* 4:387-402 (avril)
14. La théorie physique – Première Partie, *RP* 4:542-56 (mai), 643-71 (juin), 5:121-60 (août), 241-63 (septembre)
15. La théorie physique – Seconde Partie, *RP* 5:536-69 (octobre), 635-62 (novembre), 712-37 (décembre)
16. Les origines de la statique – Ch. V. Les sources alexandrines de la statique du Moyen Age, *RQSc* 55:560-96 (avril)
17. Les origines de la statique – Ch. VI. La statique du Moyen Age. Jordanus de Nemore, *RQSc* 56:9-66 (juillet)
18. Les origines de la statique – Ch. VII. La statique du Moyen Age (suite). L'École de Jordanus; Ch. VIII. La statique du Moyen Age et Léonard de Vinci; Ch. IX. L'École de Jordanus au XVI^e siècle; Ch. X. La réaction contre Jordanus, *RQSc* 56:394-473 (octobre)

19. Preface à *Thermodynamique. I. Notions Fondamentales*, par L. Marchis, (Grenoble: A. Gratier & J. Rey, 1904), pp. 1-13
20. Sur les déformations permanentes et l'hystérésis. – Sixième mémoire: L'inégalité de Clausius et l'hystérésis (7 mai, 1901), *MARB* 62:32 pp
21. Sur les déformations permanentes et l'hystérésis. – Septième mémoire; L'hystérésis et viscosité (7 mai, 1901), *MARB* 62:33-136 (pagination continues that of preceding).
22. Un ouvrage perdu cité par Jordan de Nemore: Le Philotechnes, *BM* 5:321-25
23. [Lettre à l'éditeur] A propos de la déformation des solides, *RGScPA* 15:217-18
24. Review of A. Dufourcq, *L'avenir du christianisme. Introduction. La vie et la pensée chrétienne dans le passé* (Paris: Bloud, 1904), *RQSc* 55:252-60
25. Review of J. Hadamard, *Leçons sur la propagation des ondes et les équations de l'hydrodynamique* (Paris: Gauthier-Villars, 1903), *BScM* 28:14-28
26. Reprint of 1903 (30), *RQSc* 55:198-217

1905

1. *L'évolution de la mécanique* (Paris: A. Hermann), 348 pp; reimpression of 1903 (14)
2. De l'hystérésis magnétique produite par un champ oscillant superposé à un champ constant, *CR* 140:1216-19 (8 mai)
3. De l'hystérésis magnétique produite par un champ oscillant superposé à un champ constant. Comparaison entre la théorie et l'expérience, *CR* 140:1370-73 (22 mai)
4. Sur les origines du principe des déplacements virtuels, *CR* 141:525-27 (25 septembre)
5. Sur l'impossibilité des ondes de choc négatives dans les gaz, *CR* 141:811 (20 novembre)
6. Recherches sur l'élasticité. – Troisième Partie: La stabilité des milieux élastiques, *AScENS* 22:143-217
7. La théorie physique – Seconde Partie (suite), *RP* 6:25-43 (janvier), 267-92 (mars), 377-99 (avril), 519-59 (mai), 619-41 (juin)
8. Physique de croyant, *APC* 151:44-67 (octobre), 133-59 (novembre); also as a brochure (Paris: Bloud), 52pp
9. Les origines de la statique – Ch. XI. Galileo Galilei; Ch. XII. Simon Stevin, *RQSc* 57:96-149 (janvier)
10. Les origines de la statique – Ch. XIII. La statique française – Roberval; Ch. XIV. La statique française (suite) – René Descartes, *RQSc* 57:462-543 (avril)
11. *Les origines de la statique. Tome Premier* (Paris: A. Hermann), iv + 360 pp. Text of 1903 (16), 1904 (16-18) and 1905 (9-10), with additional Notes A-C (pp. 352-58)
12. Les origines de la statique – Ch. XV. Les propriétés mécaniques du centre de gravité d'Albert de Saxe à Evangelista Torricelli. Première Période. D'Albert de Saxe à la révolution copernicaine, *RQSc* 58:115-201 (juillet)
13. Les origines de la statique – [Ch. XV. Les propriétés mécaniques du centre de gravité, d'Albert de Saxe à Evangelista Torricelli] Seconde Période. De la révolution copernicaine à Torricelli, *RQSc* 58:508-58 (octobre)
14. Sur l'équilibre de température d'un corps invariable et la stabilité de cet équilibre, *JMPA* 1:77-94
15. Sur l'algorithmus demonstratus, *BM* 6:9-15
16. Le principe de Pascal: Essai historique, *RGScPA* 16:599-610 (15 juillet)
17. Paul Tannery 1843-1904, *MSScPhNB* 4:269-94, also *RP* 6:216-30
18. Paul Tannery et la Société des sciences physiques et naturelles de Bordeaux, *MSScPhNB* 4:295-98
19. Albert de Saxe et Léonard de Vinci, *BI* 5:1-33, 113-30
20. Léonard de Vinci et Villalpand, *BI* 5:237-48
21. Léonard de Vinci et Bernardino Baldi, *BI* 5:314-48
22. Souvenirs de l'Ecole préparatoire (1878-1882), in *Centenaire du Collège Stanislas (1804-1905)* (Paris: Imprimerie de J. Dumoulin), pp. 101-122

1906

1. Les origines de la statique – Ch. XVI. La doctrine d'Albert de Saxe et les géostaticiens, *RQSc* 59:115-48 (janvier)
2. Les origines de la statique – Ch. XVII. La coordination des lois de la statique, *RQSc* 59:383-441 (avril), 60:65-109 (juillet)
3. *Les origines de la statique. Tome II* (Paris: A. Hermann), viii + 364 pp. Text of 1905 (12-13) and 1906 (1-2), with additional Notes A-S (pp. 291-351)
4. *La théorie physique: son objet et sa structure* (Paris: Chevalier & Rivière), 450 pp. Text of 1904 (13-15) and 1905 (7)
5. Recherches sur l'élasticité. – Quatrième Partie: Propriétés générales des ondes au sein des milieux visqueux et non visqueux, *AScENS* 23:169-223
6. *Recherches sur l'élasticité* (Paris: Gauthier-Villars), 218 pp in 4°. Text of 1904 (3-4), 1905 (6), 1906 (5)
7. Bernardino Baldi, Roberval et Descartes, *BI* 6:25-53
8. Thémon Le Fils du Juif et Léonard de Vinci, *BI* 6:97-124 and 185-218
9. Léonard de Vinci, Cardan et Bernard Palissy, *BI* 6:289-319
10. *Etudes sur Léonard de Vinci: Ceux qu'il a lus et ceux qui l'ont lu. Première Série* (Paris: A. Hermann) vii + 355 pp. Text of 1905 (19-21) and 1906 (7-9); with previously unpublished chapters VII and VIII, 'La Scientia de ponderibus et Léonard de Vinci,' 'Albert de Saxe,' Notes A-D (pp. 255-349), and Preface (pp. iii-vii)
11. Sur les quasi-ondes de choc et la distribution des températures dans ces quasi-ondes, *CR* 142:324-27 (5 février)
12. Quelques lemmes relatifs aux quasi-ondes de choc, *CR* 142:377-80 (12 février)
13. Sur une inégalité importante dans l'étude des quasi-ondes de choc, *CR* 142:491-93 (26 février)
14. Sur les quasi-ondes de choc au sein des fluides mauvais conducteurs de la chaleur, *CR* 142:612-16 (12 mars)
15. Sur les quasi-ondes de choc au sein d'un fluide bon conducteur de la chaleur, *CR* 142:750-52 (26 mars)
16. Sur les deux chaleurs spécifiques d'un milieu élastique faiblement déformé; formules fondamentales, *CR* 143:335-39 (13 août)
17. Sur les deux chaleurs spécifiques d'un milieu élastique faiblement déformé; extensions diverses de la formule de Reech, *CR* 143:371-74 (27 août)
18. Sur l'histoire du principe employé en statique par Torricelli, *CR* 143:809-12 (26 novembre)
19. Sur quelques découvertes scientifiques de Léonard de Vinci, *CR* 143:946-49 (10 décembre)
20. L'hystérésis magnétique. Première Partie: L'aimantation dans un champ qui varie très lentement, *RGScPA* 17:8-17 (15 janvier)
21. L'hystérésis magnétique. Seconde Partie: L'aimantation dans un champ qui varie rapidement, *RGScPA* 17:64-73 (30 janvier)
22. Le P. Marin Mersenne et la pesanteur de l'air. – Première Partie: Le P. Mersenne et le poids spécifique de l'air, *RGScPA* 17:769-82 (15 septembre)
23. Le P. Marin Mersenne et la pesanteur de l'air. – Seconde Partie: Le P. Mersenne et l'expérience de Puy-de-Dôme, *RGScPA* 17:809-17 (30 septembre)
24. Sulla origine della statica, *RRAL* 15:697-99 (2 décembre)
25. De l'accélération produite par une force constante: Notes pour servir à l'histoire de la dynamique, in *II^e Congrès International de Philosophie. Comptes rendus* éd. E. Claparède (Geneva: Kundig et fils, 1906), pp. 859-915

1907

1. Nicolas de Cues et Léonard de Vinci, *BI* 7:87-134, 181-220, 314-29
2. Sur la propagation des quasi-ondes de choc, *CR* 144:179-81 (28 janvier)
3. Josiah-Willard Gibbs, à propos de la publication de ses Mémoires scientifiques [*The Scientific Papers of J. Willard Gibbs*], *BScM* 31:1-31; also as a separate brochure (Paris: A. Hermann), 43 pp
4. Leonardo da Vinci, *RRAL* 16:34 (6 gennaio)
5. Le mouvement absolu et le mouvement relatif – I. Il appartient à la métaphysique de fixer le sens de ces mots: La Terre est immobile, la Terre tourne; II. Le mouvement du Ciel et le repos de la Terre d'après Aristôte, *RP* 11:221-35
6. Le mouvement absolu et le mouvement relatif – III. Les philosophes grecs et l'immobilité du lieu, *RP* 11:347-62
7. Le mouvement absolu et le mouvement relatif – IV. Les commentateurs arabes d'Aristôte, Averroes; V. Albert de Grand; VI. Saint Thomas d'Aquin; VII. Gilles de Rome, *RP* 11:548-73

1908

1. Le mouvement absolu et le mouvement relatif – VIII. Jean Duns Scot; IX. L'Ecole scotiste. Jean le Chanoine, *RP* 12:134-65
2. Le mouvement absolu et le mouvement relatif – X. Guillaume d'Occam; XI. Walter Burley, *RP* 12:246-65
3. Le mouvement absolu et le mouvement relatif – XII. Jean de Jandun, *RP* 12:386-400
4. Le mouvement absolu et le mouvement relatif – XIII. Albert de Saxe, *RP* 12:486-98
5. Le mouvement absolu et le mouvement relatif – XIV. L'Ecole de Paris: Marsile d'Inghen. Pierre d'Ailly. Nicolas de Orbellis. Pierre Tartaret; XV. La théorie du lieu dans les universités allemandes. Conrad Summenhard. Grégoire Reisch. Frederic Sunczel, *RP* 12:607-23
6. Le mouvement absolu et le mouvement relatif – XVI. L'influence parisienne à l'école de Padoue: Paul Nicoletti de Venise; Gaétane de Tiène, *RP* 13:143-65
7. Le mouvement absolu et le mouvement relatif – XVII. La philosophie réactionnaire de l'école de Padoue. Les humanistes. Giorgio Valla; XVIII. La philosophie réactionnaire de l'école de Padoue (*suite*). Les Averroistes. Agostino Nifo, *RP* 13:275-87
8. Le mouvement absolu et le mouvement relatif – XIX. Nicolas Copernic et Joachim Rheticus, *RP* 13:515-19
9. Le mouvement absolu et le mouvement relatif – XX. Coup d'oeil sur les temps modernes, *RP* 13:635-65
10. *Ziel und Struktur der physikalischen Theorien*, autorisierte Übersetzung [de *La Théorie physique*] von Dr. Friedrich Adler, mit einem Vorwort von Ernst Mach (Leipzig: Johann Ambrosius Barth), xii + 367 pp; translation of 1906 (4)
11. Josiah Willard Gibbs. A propos de la publication de ses Mémoires Scientifiques, *RQSc* 63:5-43 (janvier); reimpression of 1907 (3)
12. Sur les isothermes d'un mélange de deux gaz et sur une extension du théorème de Maxwell, *MSScPhNB* 3:331-42 (published in 1899; added in proofs)
13. La valeur de la théorie physique, à propos d'un livre récent, *RGScPA* 19:7-19 (15 janvier)
14. Ce qu'on disait des Indes occidentales avant Christophe Colomb, *RGScPA* 19:402-06
15. Sur un fragment, inconnu jusqu'ici de l'*Opus Tertium* de Roger Bacon, *CR* 146:156-59 (27 janvier); also published in *AFH* 1:238-40
16. Sur la découverte de la loi de la chute des graves, *CR* 146:908-13 (4 mai)
17. Nicolas de Cues et Léonard de Vinci (*suite*), *BI* 8:18-55, 116-47
18. Léonard de Vinci et les origines de la géologie, *BI* 8:212-52, 312-46
19. ΣΩΖΕΙΝ ΤΑ ΦΑΙΝΟΜΕΝΑ, *Essai sur la notion de théorie physique de Platon à Galilée*, *APC* 156:113-39 (mai), 277-302 (juin), 352-77 (juillet), 482-514 (août), 561-92 (septembre). – Also as a separate volume (Paris: A. Hermann), 144pp

1909

1. *Un fragment inédit de l'Opus Tertium de Roger Bacon, précédé d'une étude sur ce fragment* (Ad Claras Aquas [Quaracchi] prope Florentiam, ex typographia Collegii S. Bonaventurae), 197 pp
2. *Etudes sur Léonard de Vinci: Ceux qu'il a lus et ceux qui l'ont lu. Seconde Série* (Paris: A. Hermann), iv + 474 pp. Text of 1907 (1) and 1908 (17, 18), with previously unpublished chapters I and II, 'Léonard de Vinci et les deux infinies' and 'Léonard de Vinci et la pluralité des mondes' (pp. 3-96), Notes A-J (pp. 363-455), and Preface (pp. iii-iv)
3. Jean I. Buridan (de Béthune) et Léonard de Vinci, *BI* 9:27-57, 96-130, 227-71
4. La tradition de Buridan et la science italienne au XVI^e siècle, *BI* 9:338-60
5. Sur la propagation des ondes de choc au sein des fluides, *ZPhCh* 69:169-86
6. Un précurseur français de Copernic: Nicole Oresme (1377), *RGSsPA* 20:866-73
7. Du temps où la Scolastique latine a connu la Physique d'Aristôte, *RP* 15:163-78
8. Thierry de Chartres et Nicolas de Cues, *RScPT* 3:525-31
9. A propos du ΦΙΛΟΤΕΧΝΗΣ de Jordanus de Nemore, *AGNT* 1:380-84; also in *Festschrift Moritz Cantor*, ed. S. Gunther and K. Sudhoff (Leipzig: Veit) pp. 88-92
10. Le mouvement absolu et le mouvement relatif – Appendice, *RP* 14:149-79, 306-17, 436-58, 499-508
11. *Le mouvement absolu et le mouvement relatif* (Montligeon, Orne: Imprimerie-librairie de Montligeon) 284 pp. Text of 1907 (5-7), 1908 (1-9), and 1909 (10)
12. Sur la découverte de la loi de la chute des graves, in *Atti del IV Congresso Internazionale dei Matematici (Roma, 6-11 Aprile 1908)*, vol. III (Rome: Reale Accademia dei Lincei, 1909), pp. 432-35
13. Review of E. Jouguet, *Lectures de mécanique* 2 vols (Paris: Gauthier-Villars, 1908-09), in *BScM* 33:124-38

1910

1. *Thermodynamique et chimie. Leçons élémentaires*. Seconde édition entièrement refondue et considérablement augmentée (Paris: A. Hermann et Fils), xii + 579 pp
2. La tradition de Buridan et la science italienne au XVI^e siècle, *BI* 10:24-47, 95-133, 202-31
3. Dominique Soto et la scolastique parisienne, *BH* 12:275-302, 357-76
4. La physique néo-platonicienne au Moyen Age, *RQSc* 68:10-60 (juillet), 385-430 (octobre)
5. Sur les Meteorologicorum libri quatuor, faussement attribués à Jean Duns Scotus, *AFH* 3:626-32
6. Les colloïdes et les modifications permanentes en chimie, in *Gedenkboek aangeboden aan J. M. van Bemmelen* (Helder: C. de Boer), pp. 1-6
7. La mécanique expérimentale, à propos d'un livre récent, *RGSsPA* 21:462-65 (15 juin)
8. [Analyse de l'ouvrage de] H. Bouasse, *Cours de mécanique rationnelle et expérimentale*, (Paris: C. Delagrave), *BScM* 34:144-76
9. Le jubilé du Professeur van Bemmelen, *RGSsPA* 21:802

1911

1. *Traité d'énergetique ou thermodynamique générale. Tome I. Conservation de l'énergie. Mécanique rationnelle. Statique générale. Déplacement de l'équilibre – Tome II. Dynamique générale. Conductibilité de la chaleur. Stabilité de l'équilibre* (Paris: Gauthier-Villars), 528 and 504 pp
2. La tradition de Buridan et la science italienne au XVI^e siècle (suite), *BI* 11:1-32
3. Dominique Soto et la scolastique parisienne (suite), *BH* 13:157-94, 291-305, 440-67
4. Sur les petites oscillations d'un corps flottant, *JMPA* 7:1-84

5. Le temps selon les philosophes hellènes, *RP* 19:5-24, 128-45
6. Un document relatif à la réforme du calendrier, in *Hommage à Louis Olivier* (Paris: Imprimerie de la Cour d'Appel), pp. 97-104
7. Nemore (Jordanus de), *CE* 10:740-41
8. Oresme (Nicole), *CE* 11:296-97
9. Physics (History of), *CE* 12:47-67
10. Review of Sir William Thomson, *Mathematical and Physical Papers. Volume V. Thermodynamics, Cosmical and Geological Physics, Molecular and Crystalline Theory, Electrodynamics* (Cambridge: University Press, 1911), *BScM* 35:221-32

1912

1. *Die Wandlungen der Mechanik und der mechanischen Naturerklärung*. Autorisierte Uebersetzung [de *L'Evolution de la mécanique*] von Dr. Philipp Frank, unter Mitwirkung von Dr. Emma Stiasny (Leipzig: Johann Ambrosius Barth), viii + 242 pp. Translation of 1903 (14)
2. Dominique Soto et la scolastique parisienne (suite), *BH* 14:60-76, 127-39
3. La dialectique d'Oxford et la scolastique italienne, *BI* 12:6-26, 93-120, 203-223, 289-98
4. La précession des équinoxes selon les astronomes grecs et arabes, *RQSc* 72:45-89 (juillet), 465-510 (octobre)
5. Sur le principe d'optique géométrique énoncé par Fermat, *JMPA* 8:1-58
6. La nature du raisonnement mathématique, *RP* 21:531-43
7. Saxe (John of), *CE* 13:493
8. Saxony (Albert of), *CE* 13:504-05
9. Thierry (of Freiburg), *CE* 14:635
10. Préface to A. Maire, *L'oeuvre scientifique de Blaise Pascal. Bibliographie. Critique et analyse de tous les travaux qui s'y rapportent* (Paris: A. Hermann), pp. i-ix
11. Review of Sir William Thomson, *Mathematical and Physical Papers. Volume VI. Voltaic Theory, Radioactivity, Electrons, Navigation and Tides, Miscellaneous* (Cambridge: University Press, 1911), *BScM* 36:105-12
12. Review of Rayleigh (John William Strutt), *Scientific Papers, Vol. V* (Cambridge: University Press, 1912), *BScM* 36:270-79

1913

1. *Notice sur les titres et travaux scientifiques de Pierre Duhem* (Bordeaux: Imprimeries Gounouilhau), 125 pp
2. *Le système du monde. Histoire des doctrines cosmologiques de Platon à Copernic. Tome I. La cosmologie hellénique* (Paris: A. Hermann et Fils), 512 pp
3. La dialectique d'Oxford et la scolastique italienne (suite), *BI* 13:16-36, 128-46, 297-318
4. *Etudes sur Léonard de Vinci: Ceux qu'il a lus et ceux qui l'ont lu. Troisième Série. Les précurseurs parisiens de Galilée* (Paris: Hermann), xiv + 605 pp. Text of 1909 (3, 4), 1910 (2, 3), 1911 (2, 3), and 1912 (2, 3), with a new Preface (pp. v-xiv)
5. Sur la stabilité adiabatique de l'équilibre, *CR* 156:181-84 (20 janvier)
6. La croissance adiabatique de l'entropie, *CR* 156:285-86 (27 janvier)
7. Sur deux inégalités fondamentales de la thermodynamique, *CR* 156:421-25 (10 février)
8. Sur la stabilité de l'équilibre thermique, *CR* 156:597-99 (24 février)
9. Remarques élémentaires sur le problème des ondes sphériques, *CR* 156:1727-30 (9 juin)
10. Sur la formule de la vitesse du son, *CR* 157:269 (28 juillet)
11. Sur la vitesse du son, *CR* 157:426-28 (1 septembre)
12. Sur le diamagnétisme, *JMPA* 9:89-164
13. Le temps et le mouvement selon les scolastiques, *RP* 22:453-78

14. François de Meyronnes O. F. M. et la question de la rotation de la terre, *AFH* 6:23-25
15. Examen logique de la théorie physique, *RSc* 51:737-40 (14 juin). Text of Seconde Partie (pp. 108-114) of 1913 (1)

1914

1. *Le système du monde. Tome II. La cosmologie hellénique* (suite et fin) – *L'astronomie latine au Moyen Age* (Paris: A. Hermann et Fils), 522 pp
2. *La théorie physique. Son objet – Sa structure*, deuxième édition, revue et augmentée (Paris: Marcel Rivière & Cie), viii + 514 pp (see 1906 [4]). Contains also 'Physique de croyant' (1905 [8]) and 'La valeur de la théorie physique, à propos d'un livre récent' (1908 [13])
3. Sur le paradoxe hydrodynamique de d'Alembert [sic], *CR* 159:592-95 (19 octobre)
4. Remarque sur le paradoxe hydrodynamique de d'Alembert, *CR* 159:638-40 (9 novembre)
5. Sur le paradoxe hydrodynamique de M. Brillouin, *CR* 159:790-92 (14 décembre)
6. Le problème général de l'électrodynamique pour un système de corps immobiles, *JMPA* 10:347-416
7. Le temps et le mouvement selon les scolastiques (suite), *RP* 23:5-15, 136-49, 225-41, 361-80, 470-80, 24:109-52
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