Pierre Duhem: Between the Historiography of Science and Philosophy of History

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Abstract

This chapter initially analyzes Pierre Duhem's incursions in the direction of medieval science, delineating both (a) the genesis of historiographic research brought about by his discoveries regarding medieval statics, which occurred at the end of 1903, and (b) his persistence in that direction resulting from a new set of discoveries, this time associated to medieval dynamics and the names of John Buridan and Nicole Oresme, which occurred in mid-1908. In a second moment, the chapter argues that the Duhemian thinking supports itself on a philosophic vision of historical development present ever since the beginning, in 1892, of his epistemological publications. It underscores that his philosophy of history, essential for sustaining an understanding of the methodology itself, is (a) optimistic insofar as it reveals that the historical events are ruled by a providence that makes

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even the sincere errors of the theoreticians fruitful and that (b) the author embraces a teleological, almost determinist conception of historical evolution as being governed by laws that make predictions of the future of theories possible. Lastly, based on the preceding considerations, the intention is to draft a synthetic and coherent position regarding the supposed (dis)continuism attributed to our historian.

Keywords

Continuism · Determinism · Historical laws · Medieval science · Methodology · Philosophy of history · Physical theory · Pierre Duhem · Providence · Scientific revolution

Introduction

As a qualified physicist, Pierre Maurice Marie Duhem (1861–1916) found that his scientific activities naturally inspired him to produce a philosophy of science. In turn, he was always pensative about having recourse to history as the means of illustrating or materializing his main philosophical theses. Indeed, prior to the initial publication of *Les origines de la statique* in the second half of 1903, that was basically the role which the historical narrative performed in his publications. Everything took place as if the history of science could legitimize his philosophy and, *a ulteriori*, his scientific conception. However, during and after his writing of *Les origines*, Duhem's history acquired a certain degree of autonomy in relation to his scientific project, no longer being a mere epistemological "test laboratory," but becoming largely independent and endowed with an agenda of its own. (More precisely, in practically all Duhemian historiographic works, his theses on the development of science, especially their conclusions and prefaces, end up being used in the defense of positions transcendent to the history itself, be it apologetic (Duhem 1905–1906/1991: 438–448), nationalist (Duhem 1906–1913/1984, v. 3: xiii–xiv), or methodological (Duhem 1913–1959, v. 2: 50–179), etc. That observation reinforces the unity of Duhemian thought.) New concerns arose such as with dating and certifying the authenticity of various medieval manuscripts, studies on inheritance and the dissemination of specific editions among European universities, as well as the affiliation of ideas that would make it possible to establish research priorities and traditions. Examples of early publications that sought to reveal innovative medieval contributions are *Études sur Léonard de Vinci* and the later works *Le mouvement absolu et le mouvement relatif* and *Le système du monde*, along the same lines. What we might call his "historiographic turn" took place in a very specific way: it was the (re)discovery of medieval manuscripts, forgotten by tradition, but in which the historiographer discerned contributions heralding the advent of modern statics that made him start the production of a revisionist reading worthy of the attention of genuine historians. Thus, the relative autonomy of history actually came about as result of the discovery of a medieval science in the form of statics. It is impossible for us to describe the former without referring to the latter.

However, we should not suppose that Duhem's discoveries were limited to those first moments insofar as between April and June of 1908 a new set of discoveries, this time related to dynamics, took our historian by surprise. While he was writing *Le mouvement*, *Sauver les apparences*, and the second volume of *Études*, Duhem came across John Buridan's version of the *impetus* theory, in which Duhem descried a rudimentary anticipation of the Law of Inertia and the unification of terrestrial and celestial mechanics, announcing a rupture with the peripatetic *cosmos*. Parallel to those events, he devoted unprecedented attention to the thinking of Nicole Oresme. Duhem lost no time in relating the emergence of Buridan and Oresme's theoretical essays with the recently discovered impact of the condemnations of March 7, 1277, promulgated by Bishop Stephen Tempier in Paris, against pagan necessitarism, considering it a milepost in the occidental thinking's liberation from the yoke of Aristotelianism and expanding the scope of his astronomical analyses to theological and cosmological contexts.

That being said, we can sum up his ways of dealing with medieval science as follows: in an initial period, it was practically absent, mainly consisting of marginal and negative comments; in a second, he addressed it in depth and exalted its fecundity. This second moment can be divided into two: a first moment of genesis in which Duhem exhibits the medieval anticipations in regard to statics and a second moment of persistence in which he attributes seminal importance to the dynamics and the astronomy of the Parisian masters. We will now pass on to brief portrayal of the first of those three stages.

Shared Prejudice up Until *Les origines de la statique*

On various occasions in his early articles, Duhem unabashedly propagated the predominant prejudice of his day in regard to medieval science. In his work *Les théories de l'optique*, he starts his historical narrative with Descartes and insists that with the exception of astronomy, hydrostatics, and the great principles of statics, nothing was obtained in the Middle Ages and in Antiquity "other than incoherent and poorly observed facts" (Duhem 1894: 94). To him, the end of the Renaissance marks the adolescence of the modern world, the moment in which ideas spring up on every side to form the modern tradition. Again, in *Les théories de la chaleur*, the exposition only goes back a mere "three centuries" into the past. In it, the scholastics are negatively described as obstinate defenders of peripatetic qualitativism in regard to heat, thereby making its quantification and transformation into the modern theoretical concept of temperature all the more difficult (Duhem 1895/2002: 126–127). A more explicit example can be found in *L'évolution des théories physiques*, in which the opening paragraph proffers these words: "The theories of modern physics are born of a reaction against scholastic philosophy" (Duhem 1896/2002: 193). Modern physics, Duhem declares, is born against scholastic philosophy, not due to it. On various occasions, he describes scholastic thinking as being like an ancient incoherent building, his commentaries as being strange and narrow, his explanations puerile, and his set of themes, riddled with all sorts of personal affinities

and antipathies, as bizarre (Duhem 1896/2002: 196). Only with Galileo, the true founder of modern physics was man to learn how to study nature, to conduct an experiment adequately interpreting its results, and to use the apparat of mathematics in a precise and scientific manner (Duhem 1896/2002: 197).

Even in the main works that preceded *Les origines de la statique*, albeit he did not summarily ignore them altogether, he described the Middle Ages as being scientifically unfruitful. In *L'évolution de la mécanique*, he resumed his criticism of the Scholastics: "The renaissance of the sciences at the beginning of the 17th century was a violent reaction against such explanations" based on occult qualities (Duhem 1903: 13). The period distinction seems to be quite clear: up until the end of the sixteenth century, the influence of the decadent scholasticism was still decisively felt, whereas modern science, born in opposition to it, began in the seventeenth century. In regard to that change, the historian Duhem went so far as to elaborate a study project that consisted of tracing the moon's antics in the light of the struggle between the old scholasticism and the new physics, the Newtonian physics (Duhem 1903: 32). The medieval development of statics continued to be missing up to that point.

The Historiographic Turn: From *Les origines de la statique* Until Mid-1908

Many authors have analyzed the chronology of the example that represents the liberation of Duhemian thinking from the ideology of the positivist/enlightenment tradition. Jaki (1984: 384–388), Martin (1991: 147–162), Brenner (1990: 144–146), Patapievici (2015: 203–206), and Leite (2015) have all discoursed on the case from similar points of view. Thus, a succinct account of that subject should be sufficient for us to calibrate the extent to which the French author's perspective changed.

The first article of the series that would eventually compose the first four chapters of *Les origines de la statique* was published in October 1903 in the *Revue des questions scientifiques*. Very few mentions of medieval statics can be found in it, and that was justified by the declaration that the scholastic comments on statics "added nothing essential to the ideas of the Stagirite" and that "to see these ideas develop new branches and bear new fruits, one must wait for the beginning of the 16th century" (Duhem 1905–1906/1991: 16). The next number of the *Revue* came out in January 1904, but, significantly, without the expected article by Duhem. The series was only resumed in the April number and in its fifth chapter took a chronological step back from the sixteenth century to address *The Alexandrian sources of Medieval statics*. In it, the enigmatic figure of Jordanus de Nemore and of his *Elementa Jordani Super Demonstrationem Ponderis* emerged. After historically introducing that treatise, the sixth chapter entitled *Statics During the Middle Ages – Jordanus de Nemore* makes an unhurried analysis of Jordanus's originality, and he is portrayed as the inheritor of one tradition and the initiator of another (Duhem 1905–1906/1991: 75). Creator of a veritable school, Jordanus's ideas, according to Duhem, gave rise to an intense intellectual movement in the Middle Ages (Duhem 1905–1906/1991: 92). In the preface to the first volume of *Les origins*, Duhem (1905–1906/1991: 7)

registers the "unforeseen observations" of his research and adds "little did we know that our research would lead to a complete rethinking of the entire history of statics." With the modifications brought about by "totally unforeseen conclusions," Duhem felt the need to justify the work's disorderly structure. It was necessary, he felt, to get back to the Middle Ages to demonstrate how the thirteenth century had been a century of intellectual activity at the heart of which an autonomous statics developed that was independent of any ancient acquisitions (Duhem 1905–1906/1991: 8). In the wake of that discovery of the figure of Jordanus de Nemore, Duhem devoted unpremeditated attention to a new character, Albert of Saxony, and to him, Duhem dedicated an initially unplanned second volume of *Les origines*.

Ever since the beginning of *Les origins*, Duhem (1905–1906/1991: 12) had been anxious to publish a work on the history of dynamics in which he intended to delineate the main stages of the "gigantic" intellectual efforts that had led to the rejection of the peripatetic dynamics and the consequent adherence to the Galilean dynamics, paying special attention to the thinking of Leonardo da Vinci and Cardano (Duhem 1905–1906/1991: 34). Initially, that intention gave rise to an article, *De l'accélération produite par une force constante: Notes pour servir a l'histoire de la dynamique*, and later to the *Études sur Léonard de Vinci*. However, it should be noted that even after he had exhibited the originality of medieval statics in his work *Les origines*, Duhem (1905–1906/1991: 91) felt comfortable in stating that the peripatetic axiom that established the proportionality between force and velocity would only come to be surpassed with the "revolution which took place in dynamics in the 16th century." Thus, while in 1904 Duhem's conceptions regarding the history of statics had already altered, his views on the history of dynamics remained practically unshaken:

> Ancient dynamics was condensed in this law: the velocity of a moving body is proportional to the force that propels it. Modern dynamics states that the force is proportional to the acceleration. More than any other cause, the works of Galileo contributed to the revolution that replaced the ancient dynamics with modern dynamics. (Duhem 1904: 901)

Two factors stand out in the above paragraph. The first, more general one, is the use of the concept "revolution." Duhem never denied the possibility of the existence of revolutions in the history of science. His continuism was not so exclusive that it led him to completely abandon the category of revolution in areas such as optics, chemistry, dynamics, and astronomy, among others (Leite 2012: 337–348; Stoffel 2017). Generally speaking, there is a real epistemological rupture between peripatetic physics and modern physics, a revolution of grandiose proportions. What the historian did was to attribute importance to the thinking of Buridan and Oresme and push back the birth of modern science, the beginning of the scientific revolution, to the fourteenth century. That also proved to be a way of valorizing his findings. The second, more specific factor, is that the historian still preserved the idea of the existence of a revolution in the sixteenth century. It is his earlier unawareness of Buridan and Oresme's contributions that explains Duhem's conservatism. His discovery of Nemore was not sufficient to make Duhem abandon his idea of a

revolution in Galileo's century. Nemore achieved advances in statics but not in dynamics. There was nothing in his first discovery that implied the second, given that it would have been considered incapable of generating an ample "research Program" that included the latter. At the time, Duhem was merely sketching out the history of dynamics, and there is nothing that would lead us to believe that he expected any further impacting novelties.

The Persistence Toward Medieval Dynamics: The Attribution of Importance to John Buridan and Nicole Oresme and Its Consequences

It seems to have been through the intermediation of George Lokert (1485–1547) that Duhem (1905–1906/1991: 290) obtained his first information regarding Buridan's influence. However, unlike the contributions of Albert of Saxony, those of the philosopher of Béthune did not receive the slightest attention in *Les origines de la statique*. The attention paid to Oresme, albeit greater than that devoted to Buridan, was nevertheless scanty. In the final pages of that work, there are two explanatory notes, but only the second one briefly mentions the thinking of the Norman philosopher insofar as he is respected as he "to whom we owe our first notions on coordinates" and as being the author of the work *Treatise on the sphere*, which was supposed to have contributed to the diffusion of the ideas of the German (Duhem 1905–1906/1991: 486–487). In effect, the Bordeaux professor's focus was still on Albert.

We know that in the impetus theory's explanatory and unifying potential, Duhem (1913–1959, v. 8: 340) would later discern one of the greatest if not the greatest revolutions that ever shook the science of physics. Thus, it behooves us to seek out the earliest references to the said theory in his texts. In *De l'accélération produite par une force constante*, which traces the historical evolution in the period from antiquity to the seventeenth century, that led to the abandonment of the peripatetic relation of proportionality between the force applied to a body and its velocity, Duhem occupied himself with some of the medieval versions of *impetus*, but Buridan's name does not appear associated to any of them. In the first volume of *Études sur Léonard de Vinci,* he (1906–1913/1984, v. 1: 111) leaves no room for doubt that Albert of Saxony was the first to formulate and clarify the theory and completely ignores the figures of Buridan and Oresme. An examination of the methodological works of the same period reveals that the Picardian philosopher is not even the object of analysis in *La théorie physique* albeit, in that work, Duhem elaborates a long historical reconstruction of the formation of the universal gravitation theory asserting that it emerged from a "millenary evolution" (Duhem 1991: 222). We are also aware that one of the main methodological theses in *Le système du monde* consists of a defense of the idea that seeds of modern science planted in the fourteenth century developed under the guardianship of what Duhem (1913–1959, v. 6: 728–729) designated as "Christian positivism." Only his lack of knowledge of the thinking of the Parisian masters could explain why he, always so anxious to

historically justify his representationalist method, could have failed to draw on such a large body of support in his major philosophical work.

Let us move forward a couple of years. As had been the case with *Les origines de la statique*, the composition of *Le mouvement absolu et le mouvement relatif* was not uniform. However, unlike what he had done before, Duhem chose to preserve the chronological order of the chapters, only presenting the results of his more recent research at the end in the form of a long appendix (Duhem 1909a: 208–272). The appendix consists of eight sections and a note, all published between February and March of 1909, that is, after the publication of the conclusion, printed in December 1908. It is worth noting that the order in which the various authors appear in the appendix is not the chronological order of their respective discoveries but instead, as Duhem himself explains, the order in which they should have appeared in the work if they had been written at the appropriate moment (Duhem 1909a: 208). As each of those appendix sections follows a pattern that gives a precise indication of the place they should have occupied in the body of the work, we can determine that the section on Buridan should have been the 12th one. We know that the section in question was actually published on April 1, 1908 (Duhem 1906–1913/1984, v. 3: 247, note 1), and so we can conclude that Duhem did not attribute any importance to Buridan and Oresme until mid-March of that same year. In Sect. XIII (May 1), dedicated to Albert of Saxony, we come across a single, but revealing, paragraph on Oresme which means that at that time, he was already leafing through a manuscript in which the bishop of Lisieux discoursed on the geometric measurement and representation of all quantities and qualities (Duhem 1909a: 111). In Sect. XIV (June 1), dedicated to the Paris School, there is the marginal appearance of the name of the philosopher Béthune, but once again, there is a note explaining that the historian had "consulted" a manuscript Buridan's in Latin (Duhem 1909a: 128). Those are some of the indications that, for the first time, Duhem was frequenting the thinking of that pair of Parisian theologians. However, given that there had been no mention of the Buridan *impetus* theory up until that moment, we should not be surprised that it does occur in the following month in another work, *Sauver les apparences*, published in parallel with the earlier one.

In regard to *Sauver les apparences*, we should be able to find an analysis of the positions of that duo of Parisian masters in the third section on *Medieval Christian Scholasticism*, but in fact we only find it in the last four paragraphs of the following chapter dedicated to *The Renaissance Before Copernicus*. Not only is the insertion of the Parisians misplaced but the very manner in which it was produced announces the circumstances in which it emerged. After addressing the influence of the University of Paris in Vienna and in Padua, Duhem ends the said section with the following words:

> To account for Luiz Coronel's point of view we do not have to appeal to the influence of Nicholas of Cusa. It would be sufficient to invoke the traditions of the University of Paris; Coronel was merely formulating a rule of procedure constantly observed at that university from the middle of the fourteenth century on, as can be seen from the works of John Buridan, Albert of Saxony, and Nicholas of Oresme, which supply many examples. (Duhem 1969: 60)

The rule in question conditions the principles of physics to being understood as fictions or abstractions that, albeit incessantly perfectible, were not aimed at achieving the true essence of things. A quick consultation enables us to confirm that the highlighted paragraph interrupts the expositive sequence. Three others follow it, all equally elucidative, in which (i) Buridan's *impetus* theory appears linked to the representationalist use that Buridan confers on it; (ii) the tradition of the University of Paris is exalted as having been, for centuries, the depository of the most profound methodological analyses; (iii) Duhem defends the thesis that the Parisian Scholastics adopted the principle that the physics of the sub-lunar and celestial world were of the same nature and therefore should be addressed using the same method, that which seeks exclusively to save the phenomena treated.

The introduction of Buridan is extraordinary for various reasons: (a) it is outside of the natural thematic section; (b) even in the section where it occurs, it is in chronological misalignment; (c) the preceding section implied the nonexistence of any other University of Paris professor other than those it mentioned for in the section Duhem established the following generalization:

> The end of the Middle Ages slips by without that university's [of Paris] providing us, through its teaching, with any new documents concerning the value of astronomical hypotheses. Astronomy was going through one of those periods of quiet possession when no need is felt to discuss the principles that underlie theory, when all are directing their effort to working out the applications of theory. In the fourteenth century, at Paris, the system of Ptolemy was accepted without argument. (Duhem 1969: 44)

Assuming that what Duhem means by "the end of the Middle Ages" is the period after the writings of John of Jandun (†1328), then it can be concluded that up until that moment, Buridan and Oresme, whom in the following year Duhem referred to as the precursors of Copernicus insofar as they defended the idea of the Earth's daily rotation, did not represent even the slightest deviation from the general tendency.

The strange section that introduces the thinking of Buridan and Oresme was published in the July 1908 edition of *Annales de philosophie chrétienne*. That July article contained sections 4 and 5 of *Sauver les apparences*, and in them, there is evidence of the author's acknowledgment of the value of the Buridanian ideas. As the articles were published monthly, it can be concluded that up until the finalization of the June article, the second in the series, Duhem did not set much value on Buridan's theories. Intercalating the chronology of the two publications, *Le mouvement* and *Sauver les apparences*, we arrive at the conclusion that the historian began to attribute scientific importance to the thinking of the two medieval philosophers in the period between the beginning of April and the end of June 1908. There can be no doubt that Duhem dedicated part of the second half of 1908 to exploring the consequences of his recent discoveries. The long notes added on to the end of the second volume of *Études* stem from that period during which the fourteenth-century philosopher was the object of some study. In at least three opportunities, two in the notes and one in the preface, there are allusions to the recent nature of those examinations (Duhem 1906–1913/1984, v. 2: 380, 420, iii, respectively).

Thus, the transition from the first two volumes of *Études* to the third was not without surprises and resulted in the abandonment of theses and the rearranging of projects in progress. Indeed, it was through the intermediation of that second set of discoveries, this time related to dynamics and astronomy, that Duhem made his name as a historian of medieval science (most of his historiographic works were in fact written from 1909 onward). The new discoveries illuminated important occurrences among which we can name the following: (1) the beginning of publications specifically on Buridan and Oresme. It should be noted that the 1909 article *Un précurseur français de Copernic: Nicole Oresme (1377)* displayed for the first time Oresme's precociousness regarding the Earth's daily movement of rotation; (2) the introduction of the paragraphs upsetting the internal order and coherency of *Sauver les apparences*; (3) the insertion of the long appendix to *Le mouvement absolu et le mouvement relatif* whose articles appeared simultaneously with the preceding work; (4) the alterations to the subtitle and arrangement of the third tome of *Études sur Léonard de Vinci* from *Ceux qu'il a lus et ceux qui l'ont lu* to *Les précurseurs parisiens de Galilée*, with the aim of announcing Buridan and Oresme's medieval anticipations; (5) the course that Duhem began to give, already in 1909, on the "History of the theories of physics and in particular the formation of the Copernican system"; (6) his reassessment of his initial *Le système du monde* project resulting in the reorientation of his thematic scope from astronomy to cosmology (Duhem had had *Le système* in mind ever since 1906 (Stoffel 2002: 241). In his initial project, the work was to have been dedicated to the history of the theories of physics up until Copernicus, and it was to be in eight volumes altogether (Duhem 1913–1959, v. 6: v). If, as Jaki (1984: 195) stated, the History course Duhem intended to give in Bourdeaux served to prepare for his work *Le système*, then we must conclude that there was a change of direction because the subtitle of the published work refers to "The History of the Cosmological Doctrines from Plato to Copernicus." That redirection sprang from the need to insert into what were merely astronomical questions a cosmological substrate that had sustained them from ancient times through to the Middle Ages. It would not have been possible to describe the astronomic or purely theoretical discussions without their due metaphysical-theological contextualization, and among those was the theory of *impetus*. The incorporation of cosmological questions to the initial project led Duhem to increase the number of volumes which he then stipulated as 12 of which ten were actually written.); (7) the alteration of his judgment of Albert of Saxony who went from being described as an original thinker in the second volume of *Études* to being considered as "more of a disciple than a master" insofar as "his thinking very rarely offers any proof of originality" (Duhem 1913–1959, v. 4: 152; Lemonnier 1917: 31); (8) his argument, common from them on, that the revolution that propitiated the birth of modern science took place in the mid-fourteenth century with the unification of mechanics as tentatively delineated by Buridan and concretized by Newton (Duhem 1913–1959, v. 2: 453; v. 8: 340; 1917: 165; 1906–1913/1984, v. 3: ix; 1913: 537; 1916b: 670); and (9) the predominance, starting in 1909, of Duhemian publications of a historical nature and the decline (at least up until when they were taken up again

in 1914) of those with a philosophical orientation, in addition to lesser dedication to scientific issues.

Thus, Duhem's great historiographic work, dedicated to extracting the consequences of the two sets of discoveries mentioned above, was no longer to be characterized by that summarized history, directed at physicists, that defended a specific methodological vision to the detriment of opposing visions. Albeit continuing to underscore the links of continuity among the ideas involved and the conditions in which the main concepts that would come to form modern science emerged, his writings would actually come to compose a complex historiography, leaving aside expositive linearity. Reconstructing those conditions was to involve acknowledging seminal discontinuities: the "theological revolution" provoked by the 1277 condemnations (Duhem 1913–1959, v. 2: 453; v. 4: 316), the emphasis on the rupture with peripatetic cosmology that imprisoned human intellect in the spherical and divided universe of the ancient thinkers, and all the metaphysical framework that served as the backdrop for the emergence of modern science were themes to be addressed in depth. In one stroke, the Duhemian historiography operates an examination that illuminates the science of the past but, even so, examines topics which, at first sight, would be dispensable in a history of victorious theories. While it is true that the screening of the themes was to some extent retroactive, the requirement of understanding the ancient texts defined the method to be followed: it was necessary to avoid precipitation, and to make *tabula rasa* of the studies of past theories (Duhem 1905–1906/1991: 12), and to seek out the knowledge, methods, and instruments that were available to those authors, the errors they were liable to and which were almost inevitable for them (Duhem 1913–1959, v. 2: 54). Furthermore, it would be important to know the doctrines among which a given idea springs up in order to be able to properly determine its worth. Hence, Duhem's criticism of anachronic readings (Duhem 1905–1906/1991: 506, note 42) and his precaution when indicating medieval anticipations of modern concepts (Duhem 1913–1959, v. 8: 336). In a way, Duhem criticizes the type of narrative that he had composed himself up until 1903.

The Philosophy of History

Insofar as medieval science was a relative latecomer in Duhem's work, a veritable philosophy of history accompanies it from the primordial moments through to the last of his publications. We will see how that philosophy has some notable features from which we can derive a strictly continuist vision of physics theories, namely, the unificationism of its development, given that science would pass from diversity toward an ever-increasing unity; continuity through the complexity, in the sense that the science of physics progresses, despite all the mishaps and regressions, in the direction of that unity; and philosophical optimism, whereby the historical evolution would supposedly be regulated by a superior, providential plane. Let us turn to this last point at once.

The Idea of Providence as the Ruler of History

We know that the Duhemian concept of physics theory, at least in a statics analysis, is close to the positivist vision insofar as both of them set out to drain the theories of their ontological content. On that point, the main difference between them is that instead of the elimination of metaphysics or its relegation to the ambit of pure irrational faith, Duhem was concerned, above all, to guarantee the autonomy of physics' hypotheses in the face of the cosmological systems. From then on, redirected to outside of the theoretical justification context, metaphysics would find an appropriate place for its development in history. Duhem's rupture with positivism intensified as much at the level of the history of sciences, by underscoring the fecundity of medieval science and refusing to see the progress as essentially revolutionary, as at the level of the philosophy of history, by introducing the notion of divine Providence as the ruler of the historical process. Let us examine this aspect further.

In short, the description Duhem offered of the evolution of physics from the seventeenth century on was that after the mechanism revolution that Descartes and his followers conducted, there was a gradual restauration of the qualities they had sought to banish from physics. Atomism salvaged the primitive notion of mass from its Cartesian exclusion as one of matter's primary qualities. The advent of Newtonianism restored the notions of force and in the nineteenth century came thermodynamics. This last conceded ample space to qualities that had been framed as being irreducible to exclusively mechanical qualities. In generalized versions, like the one Duhem envisaged, thermodynamics came to serve as the base for mechanics itself, inverting the former relationship of subordination. The French historian insisted, however, that it does not follow from the above that the devotees of mechanism worked in vain: generalized thermodynamics would be equally indebted to Cartesian mathematics, inheritor of the Newtonian synthesis and of the experimental method of Galileo and Pascal. To Duhem, all that was best in the earlier approaches had flowed into it so that in all that immense effort:

> there is not a traveler whose work has been lost, even if this work has not always been used as the author intended; it often plays a different role in today's science than the role he attributed to it. It has taken up the place assigned in advance by He who leads all this activity. (Duhem 1896/2002: 213)

Duhem's philosophy of history enables us to see how, behind all the agitations that make demands on human intellect, there is a progressive order in their development. Thanks to a "guiding idea," the diversions, the mistakes, in relation to that order, end up being corrected, compensated for, even though it may not be by what their authors had imagined: "The creator of a mechanical doctrine is also unconsciously the precursor of those doctrines that will replace it" (Duhem 1903: 345–346). In the general framework of the evolution of physics theories, men work unconsciously, as if they were serving a "strange" purpose unknown to them: "It seems as if a mysterious force is watching over the progress of statics

and is able to render beneficial both truth and error alike" (Duhem 1905–1906/1991: 445).

In spite of all the individual, disperse, and heterogeneous nature of the efforts, the harmonious convergence to increasingly perfect and unified theories observed in the theoretical evolution is fortified by a set of maneuvers that its actors are not conscious of:

> Even more than the growth of a living being, the evolution of statics is the manifestation of the influence of a guiding idea. Within the complex data of this evolution, we can see the continuous action of a Wisdom which foresees the ideal form towards which science must tend and we can sense the presence of a Power which causes the efforts of all thinkers to converge towards this goal. In a word, we recognize here the work of Providence. (Duhem 1905–1906/1991: 447–448)

Duhem presents his argument using an analogy between the developments of a living being and that of physical theory insofar as, despite the contrasts of their superficialities, the complexity and continuity of the theoretical evolution are wonderfully well ordered. They lead us to suspect the existence of a conducting thread, a specific end toward which all the isolated works tend. Well, he argues, if there is indeed a finality that guides (tutors) the exact fitting together of apparently disconnected contributions, it cannot possibly reside in the minds of the physicists themselves, unaware as they always are of the place of their work will occupy in the yet to be theoretical scheme. Given that the future is unknown to them, it follows that the executors of the planning that historically materializes are not the planners themselves. Some are the bricklayers, but the architect will be another. Therefore, total knowledge of the plan is held exclusively by its formulator whose place is above that of ignorant common men. Being wise, that architect knows the plan to be carried out; being powerful, he conducts and causes to converge the individual efforts; being kind, he rewards even those who err, ensuring, for their work, provided it is elaborated with a "sincere" desire to achieve the truth, a worthy place in the science of the future. That author is Providence.

Just as the naturalist cannot desist from searching for a "*je ne sais quoi*" that directs cells' unconscious efforts toward the composition of the mature living being, in the development of theories, the attentive historian discerns an emerging order that leads to a constantly updated finality. For that reason, Duhem did not hesitate to state that one small demonstration of Jordanus de Nemore's contained "potentially" the doctrines of Lagrange, Gibbs, and Helmholtz (Duhem 1905–1906/1991: 446). The difference between the two states is astonishing; nothing in the latter suggests anything of the former and the complexity of the latter is glaringly apparent, but a highly attentive history reveals the existence of an affiliation between them. Skilled in the use of metaphors, it was among them that our author found the means to exhibit his philosophy of history, and all of them tend to reinforce the idea of continuity.

In the final paragraph of *Les origines*, Duhem offers (theist) Christian Apologetics a variant of the Design argument, similar in form and different in material, drawn

from the history of science (Leite 2016). In that history, nothing is lost and even the mistakes contribute toward progress. On another occasion, without having recourse to the existence of a superior intelligence, we find him stating that

> The history of science offers us a good number of discoveries suggested by erroneous doctrines [. . .]; when the engendering theory has exhausted its illegitimate fecundity it still obliges those that seek to overthrow it to gather a new harvest of discoveries.
>
> What a subject of profound and consolidating meditations the spectacle of scientific progress and the contemplation of the ways in which the truth frees itself little by little is! It draws to itself the fruits laboriously acquired by thousands of researchers, whose sincerity was lost in the ways of error; it inserts each discovery in its due place in the chain of ideas and not in the one its author had designated for it; to the incessant efforts of the human spirit, it decrees: *per falsa, ad verum*. (Duhem 1900: 4)

Optimistic, the Duhemian philosophy of science unveils the existence of a purpose that assumes the role of filtering out the errors and the truth and aggregating the initially isolated truths, causing them to flow toward a common plane on which each one will find what one could call its "natural place."

The Positive Role of Errors

Given that, as Duhem always took pains to make clear, all hypotheses have both a relative and an approximative domain (Duhem 1914/1991: 168–174), it is easy to see that the representative extension and the improvement of the empirical adaptation of the theories take place along a path that starts from error. Thus, error, in its aspect as a condition of theoretical work, is also the way to correctness. Indeed, in Duhem's enormous historiographic production, he does not fail to consider the importance of the errors, hesitations, obstacles, and declines suffered in the perfecting of knowledge. Descartes shows us that error may be genial: in regard to the thesis that light travels with instantaneous velocity, he imagined cases in which his hypothesis would be invalidated, thereby contributing to enabling him to acknowledge his error more readily and thus being able to rectify it (Duhem 1894: 98). Insofar as it is not a linear progression, the description of historical development must include all achievements including outdated theories. On showing the ways in which the theories of place evolved in his work *Le mouvement absolu et le mouvement relatif*, the deviations receive special attention, not for having been condemned but, in some cases, to be exalted as auxiliaries of progress. While on the one hand, medieval Averroism with its persistence in maintaining peripatetic dynamics and astronomy represented a brusque interruption of the evolution of the theories of place and a return to wrong ideas (Duhem 1909a: 109–110), on the other hand, our historian declares that by defending the homocentric spheres theory, the Averroists reminded everyone that the Ptolemaic system was not the only one available so that although they were "ruled by tendencies diametrically opposed to

the true scientific spirit [. . .] they paved the way for the Copernican revolution" (Duhem 1911/1996: 181).

In his valorization of errors, Duhem echoed his colleague Paul Tannery (Brenner 2004: 43–45). When considering the pre-Socratic philosophers as being primarily "physiologists," Tannery, author of *Pour l'histoire de la science hellène*, states that

> It does not matter that his science had been nothing more than a tangle of errors or a series of inconsistent hypotheses; error is ignorance's pathway to the truth; the hypothesis, insofar as it can be verified, is the means to acquiring certainty. The history of the origins of science must, above all, concentrate on those errors, scrutinize the hypotheses of the earliest times; it must perceive in what aspects some served progress and others blocked it. (Tannery 1887b/1930: 11–12; Duhem 1905a: 219)

Thus, the mathematician justifies his position stating that error is to truth as hypothesis is to certainty. A history that does not have the objective of summarily listing the set of successes that led to the extant science of today to justify it must, according to Tannery, take into account the errors and aborted successes. An integrated history of the errors and the successes enables a better calculation of what we can expect in the future. Satisfying a vain curiosity is far from being history's only objective. History can be the means to foreseeing the future: "History does not have as its only objective the satisfaction of a vain curiosity; it is the future that must eventually clarify the studies of the past" and, farther on, "[. . .] the real problem that actually imposes itself in that history is defining the circumstances and determining the cause of the past decadence with a view to knowing what precautions to take to avoid a future decadence" (Tannery 1887a: 8, 9; Duhem 1905a: 221, 222). Duhem was to find his colleague's historical research useful in two ways. The historical description of the legacies of the past and the theoretical influences received were important for Duhem the historian, but the history itself, in the way that Tannery framed it, also aroused the interest of Duhem the philosopher, anxious to know what services error had rendered to the truth (Duhem 1905a: 223).

Thus, the study of the past of science has a current value for the scientist as well serving as a guide to avoid his incurring analogous methodological errors. In Duhem's case, that conception is founded on a double presupposition: (a) the naturalization of the history of science, that is to say, the idea that the evolution of "our conception of the external world" takes place just as it does in inanimate nature, subject to laws that can be discerned (Duhem 1898/2002: 235), and (b) the notion that it is possible to elaborate a scientific history of the past, so history is a science (albeit a hypothetical one) capable of elaborating reliable descriptions, forecasts, and retrodictions (Duhem 1915/1991: 41–56). It is knowledge of those laws that, in turn, can orientate the physicist as to his theoretical options. For history to be capable of teaching us something about the present, it must be captured in its own dynamics according to its regularities. In Duhemian history, what remains beyond the individual is more important than the individual as such so that it is actually a history of the evolution of ideas, problems, and (possibly unsuccessful) attempted solutions.

The Historical Conditionings and the Search for Precursors

Even in his earliest epistemological essays, Duhem always took pains to distinguish between the English and French spirits and in that way explain the idiosyncrasies of the theories engendered in the respective nations. He was to further elaborate that distinction in his work *La théorie physique* extending it to the historical narratives. When he took up that theme once more, the new examples addressed the differences in the ways the English and the French treat social and political history. In his view, due to his enormous factual memory, the English historian will readily describe the historical events with no logical connections among them, whereas the narrowness and profundity that characterize the French spirit demand that the discourse on history should adopt a clear and simple approach that unfolds with order and method "just as corollaries are deduced from a theorem" (Duhem 1914/1991: 68). Instead of singling out compartmentalized events, when reconstructing history, the Frenchman seeks for a *rationale*, a vision of the whole.

Actually, especially in the historical reconstructions he wrote up until 1903 but even afterward in smaller essays, Duhem dedicated himself to examining the genesis and affiliation of scientific ideas as if they took place in a geometrical demonstration. Echoing once again Paul Tannery when discoursing on the theories of optics, he would say

> He who loves ancient things because they are old can satisfy his curiosity researching what the Egyptians or the Greeks thought of Mercury or of magnets; the man of science, however, will not find, in the march of their doctrines, continuous evolution or logical catenation. Actually, it is that very evolution and catenation that interests us in the history of physics; effectively, they reveal the laws according to which our knowledge of the external world develops; they establish the genesis of the commonly acknowledged theories and thus allow us to weigh the exact value of theories that currently enjoy our confidence, to assess their chances of lasting. (Duhem 1894: 94)

History provides the material from which calculations can be made to measure the value of current theories. Only with the admission of a history marked by an evolutive continuum, the true interest of the man of science (and not exactly of the historian), does it become possible to evaluate the probability of the success of individual theories. The narrative style of this admirer of Fustel de Coulanges (Duhem 1915/1991: 71), characterized by the chronological causal exhibition that almost always starts from the origins to seek out the historical regularities, is invariably guided by a general idea: the understanding of the facilitating elements and the obstacles that led to the trusted theories of today. The basic belief subjacent to that procedure is the idea that the present is as if it were the natural fruit of the past and its emergence is conditioned by preceding factors that prepare and explain its emergence:

> The development of mechanics is, correctly speaking, an evolution; each stage of that evolution is the natural corollary of the stages that preceded it; it is pregnant with the stages that are to follow. The consideration of that law must be the consolation for the theoretician. (Duhem 1903: 346)

The generational succession of the theories is also their logical succession, thus, the author of *La théorie physique* declares that "To give the history of a physical principle is, at the same time, to make a logical analysis of it" (Duhem 1914/1991: 269). When dimensioning the conditionings involved in scientific practice, Duhem's language comes close to historical determinism, revealing that "the physicist does not choose the hypothesis on which he will base a theory" and that "the physicist is limited to opening his thought through attention and reflection to the idea which is to take seed in him, without him" (Duhem 1914/1991: 256). The theoretician's freedom of choice is no greater than the freedom of a flower to choose the grain of pollen that will fertilize it. In his aspect as a creator, the physicist is first of all a simple passive receiver of autonomous ideas that hover in the air (Martin 1991: 123–126). Determinism only does not have the last word because Duhem eventually makes a distinction between (passively) receiving the hypotheses and (actively) promoting them. It all takes place as if the physicist's freedom is exercised in regard to the possibility of the ideas that germinate in him not taking hold, that is to say, in the decision not to develop them.

There is no room, in the heart of a conception that hyper-valorizes the intellectual environment, for the isolated genius, for super-human creative and a-historical capacity. The traditional concept of genius is reduced to a mere fiction, produced by a superficial narrative that ignores the intermediate stages of theoretical elaboration. It is therefore necessary to acknowledge that the inventor's initiative is always "guided or conditioned, in a manner more or less conscious to him, by an infinity of external and internal circumstances" (Duhem 1914/1991: 254). The Duhemian approach converts what is strange into something intelligible and the unusual into the natural, into something almost forcible (Duhem 1902a: 110). With the support of reflections of his colleague François Mentré, Duhem used precisely that conception to explain how impressive scientific discoveries made simultaneously by different authors with no communication between them could come about (Duhem 1914/1991: 255; 1906: 774; Mentré 1904). In the final analysis, even the greatest scientists are only the depositories of a tradition:

> Science knows no spontaneous generation. The most unexpected discoveries were never created *in toto* by the mind which gave birth to them, but they always issued from a seed first planted in the mind of a genius. The role of the genius was limited to making the small seed within him germinate and grow until the tree in full foliage might offer its flowers and fruits. (Duhem 1905–1906/1991: 114)

Given the nonexistence in science of an intellect capable of producing "a completely new doctrine at one stroke" (Duhem 1905–1906/1991: 439), most discoveries will be the result of an enormity of small efforts and the competition of innumerable hidden tendencies. In the work of Raffaello Caverni, Duhem identified certain ideas regarding the object of the historian that were analogous to his own. For the author of *Storia del metodo sperimentale in Italia*, "the task of the historian is to reveal the hidden causes that produce the supposed prodigies, and having done so, reduce them to the natural order" (Caverni *apud* Duhem 1906–1913/

1984, v. 2: 363). Duhem applied that maxim in his *Études sur Léonard de Vinci*. In the preface to the first volume, he declares that the ideas that sprang up in the Da Vincian spirit are always produced by some external cause: an experience, a report, or a reading (Duhem 1906–1913/1984, v. 1: vi). Leonardo, humanized in that way, would also be an inheritor of the Parisian tradition (Duhem 1906–1913/1984, v. 3: xiii). The initial admiration, in view of the height to which the most colossal genius rose, becomes more pondered. It can then be seen that the nature of his intelligence is not so different from our own and that he too, on the road to his discoveries, took obscure directions, hesitated, and got lost. Such setbacks are almost always obliterated by the inventor himself, who is more inclined to reveal to us the *iter regium* (royal journey) of the trajectory (Duhem 1906–1913/1984, v. 1: iv). In other words, *fide digno* knowledge of scientific activity requires going beyond the context of justification.

The vision of science in its aspect as a collective activity is reinforced in Duhem's preface to Albert Maire's book *L'oeuvre scientifique de Blaise Pascal* (1912). In it, Duhem states: "No scientific discovery is a creation *ex nihilo*; it is essentially a composition, a combination of preexisting elements that organize themselves according to a new plan" (Duhem 1912: iii). Thus, the notion of novelty, as an exclusively subjective creation, melts away insofar as all creation will gradually sprout from rearrangements or combinations of previous materials. That makes it difficult to attribute an invention to a specific author because, unlike the case of artistic creation, which is always personal, "scientific creation is never a spontaneous emission gestated by an isolated and autonomous genius"; "it is collective and, as it were, social" (Duhem 1912: viii). Thus, the intelligent reading of a simple treatise will require burrowing in libraries in search of the precursors that prepared it, of their contemporaries, irrespective of whether the latter were collaborators or contradicters, and also of their successors responsible for demonstrating its latent fecundity and extracting its often unsuspected potentialities. Consequently, the study of the precursors must be accompanied by the study of the successors as the subtitle of *Études sur Léonard de Vinci* – "*Ceux qu'il a lus et ceux qui l'ont lu*" [Those he has read and those who have read him] makes clear. Understanding what, of Da Vinci, posterity stored away and what it developed is also a means to understanding it (Duhem 1906–1913/1984, v. 1: vii). In this kind of history in which innumerable "spirits" converge toward the same discovery and numerous others diverge in the extraction of their results, every eponym must be simply viewed as a "convenient label" (Duhem 1912: i).

Duhem's incessant quest for precursors has received the attention of the critical literature: it is sometimes considered to be an "emergent technique" that artificially makes connections of continuity appear (Agassi 1967/2008: 154), sometimes, as the "clearest possible symptom of unsuitability for epistemological critique" (Canguilhem 1968: 21), and even as being dangerous, insofar as it makes it difficult to know the work of a given author by deeming it to be the precursor of another (Koyré 1961: 18, 79, note 3). Furthermore, there are textual elements that are the basis for affirmations that Duhem's postures lead to a radicalization of the search for the precursors of an idea (Biard 2004: 16) as can be seen in the first page of *Le système du monde*:

> In the genesis of a scientific doctrine, there is no absolute beginning; however far back one goes in the lines of thinking that prepared, suggested, announced that doctrine, one always arrives at opinions which in turn were prepared, suggested and announced. (Duhem 1913–1959, v. 1: 5)

That being so, it follows that the point of departure chosen for the beginning of the description of the evolution of scientific ideas must always be a provisional one and will provide an opportunity for future investigations, which, going ever further into the unfathomable past, will reveal its harbingers. Actually, Duhem is not precise about which criteria he adopts to characterize a given thinker as being the precursor of another. Frequently, it is enough that a hypothesis or argument anticipates another for the connection to be established, despite the contextual divergence. In turn, identification of the anticipation is mediated by the existence of one or more formal or argumentative analogies, and a temporal sequence of analogies will establish a research tradition. (In many cases, the analogies drawn are summary and demand knowledge, imagination, and complacency on the part of the reader. Here are some examples of this kind taken from *Le système du monde*: Duhem 1913–1959, v. 1: 271 (between Damascius and Henri Bergson); 1913–1959, v. 7: 83 (between Albert of Saxony and Richard Dedekind); 1913–1959, v. 7: 134 (between Gregory of Rimini and Georges Cantor); 1913–1959, v. 7: 415 (between John the Canon and Henri Bergson); 1913–1959, v. 10: 347 (between Nicholas of Cusa and Hegel).) One of the most illustrative examples of that is the case of Oresme whom Duhem saw as being a precursor of Copernicus insofar as, in his commentary on Aristotle's *De caelo*, Oresme defended the idea of the Earth's daily rotation. The precursory link is obtained by argumentative analogy, that is to say, based on the similarity of the arguments used by the two in favor of terrestrial rotation. Duhem considered that the confluence of the passages in *Livre du ciel et du monde* and *De revolutionibus orbium coelestium* was so striking that one could read the latter as "a very compact and somewhat obscure summary" (Duhem 1909b: 873) of the theses Oresme presented in his commentary. Fortunately, in the article's final paragraph, we come across a narrower determination, and we are informed that an "inspirer" would be a specific kind of precursor, namely, one who had a direct influence on an author. That criterion presupposes an author's awareness of the source of inspiration. It is a distinction that facilitates the preservation of the thesis that Oresme had been a precursor of Copernicus even though the latter had not been directly inspired by him. That distinction, by no means a singular occurrence, was to be resumed in regard to Copernicus's real inspirer, Aristarchus of Samos: "that astronomer [Aristarchus] had the glory of not only being the precursor, but furthermore, the inspirer of Copernicus, who was aware of the astronomer's attempts and took support from them" (Duhem 1913–1959, v. 1: 418).

A Legalistic History

Even though, in his mature work, Duhem would come to insist that men, in their aspect as agents of history, are free, the legalistic terminology he employed supports

the conception that favors the existence of ineluctable rules against which man might revolt but he would be unable to overcome them. The laws of history have sufficient weight in his view for him to busy himself in declaring that his methodology could be historically confirmed and that it would be possible to foresee future aspects of physics theory. He gives several examples of those historical laws in his various publications, and some of them will be succinctly addressed below.

Ever since his earliest writing, Duhem defended a kind of "sophisticated methodological falsificationism" (Maiocchi 1985: 97–98; Chiappin 1989: 230–240) and attributed to it the character of a historical law:

> When a law is attacked, generally the physicists' first effort consists of circumventing the objections raised by experiment by means of skillful interpretations designed to rescue it. It is only when a new theory shows not only that the then accepted Law was false but also indicates a new law that should replace it that most spirits will renounce the long-respected error. We find a first example of that historical law when studying the vicissitudes of thermochemical theory. (Duhem 1893: 124; also 76–77, and Duhem 1895/2002: 158)

From the strictly epistemological standpoint, when a theory runs up against an experimental confrontation, the physicist's only obligation is that of altering at least one of his hypotheses in order to restore the empirical adequacy of the theory. Given that it is always possible to impute the cause of the contradiction to an auxiliary hypothesis and logic does not offer any guidance in that sense, in principle, any hypothesis can be maintained unscathed. Innumerable factors guide the physicist's choice such as the education he has received, his philosophical preferences, his own self-love, and powerful authorities who can motivate him to "compose skillful interpretations" with the aim of saving hypotheses that are dear to them from the claws of experiment, even when that means contradicting the most glaring experimental evidence. The weight of authority will only stop being determinant when a new theory demonstrates the falsity of the former hypothesis and exhibits its own superior empirical adequacy. There is a deeper reason that explains those "not very logical procedures": "it is necessary to attribute them, above all, to the human spirit's need to group together in some way the phenomena that it observes associated to certain ideas" (Duhem 1893: 176). Abandoning a theory immediately after an empirical contradiction of it would result in "the chaos of empiricism," in the disorganization of our knowledge of the world. That explains and to some extent legitimizes the scientific community's conservative attitude in many historical cases. Decreeing, as it does, that "A theory of physics which is formally contradicted by a well-established fact is a theory it would be absurd to defend" (Duhem 1895/2002: 158), epistemological analysis shows itself to be inadequate for describing the activities of scientists. The study of history under the aegis of a historical law would complement the dictates of epistemology. Only a historical epistemology is capable of describing how science really functions.

If the anterior law makes the Duhemian theory of science richer and more complex, drawing it closer to the post-positivist analyses, then the next example is essential for sustaining the author's very methodology and epistemology. Since the beginning of his publications, Duhem contrasts two views concerning the evolution

of physical theory. On the one hand, it is associated with a "house of cards," which totally collapses at the first occurrence of a failure, so much so that many feel the breath of "the wind of skepticism" (Duhem 1894: 122). On the other hand, he states that the careful historian will be capable of identifying a pattern behind that alternation, namely, "the thread of a tradition, of a slow but uninterrupted progress" (Duhem 1894: 123) obeying a "harmonious concatenation" (Duhem 1894: 125). To each one of those perspectives, the author connects a part of the theory: to the first, he attaches its explicative part, metaphysics, which seeks to define structure and the ontology as essential causes of the experimental laws; to the second, the representative part, he attaches a merely symbolic-mathematical classification of the experimental laws. According to Duhem, that second part conditions theoretical progress insofar as, in view of the precarious empirical adequation presented by the metaphysical explanation attempts, these last find themselves submitted to incessant, drastic reformulations. With that, therefore, the cause of disbelief in regard to the theory is identified. It stems from that historical analysis that "An attentive study of the laws which have governed the evolution of these theories for nearly three centuries would perhaps allow us to catch a glimpse of the rules that must be followed in order to achieve the reform" (Duhem 1895/2002: 191). It is the anti-mechanist reform that he defends in the name of a physics that concedes ample space to the qualities that Duhem refers to.

Constructed in an autonomous manner, directly based on experimental laws and without appealing to metaphysical explanations, physics theory will thus evolve slowly and uninterruptedly. Questioned as to what would guarantee the maintenance of the uninterrupted progress provided that those conditions were satisfied, Duhem's reply was in the form of another question: "Why should this evolution, whose law is manifested to us in this history, stop suddenly?" (Duhem 1905b/1991: 296). We can see in that legalistic conception of history a rationalizing vein that confers a self-regulating quality on theory evolution and guides it in a determined direction, that of achieving a maximally unified theory that is a totalizing and adequate representation of all known experimental laws. The role left to men, the lesser actors on a very broad stage, is to know the rules that pervade the development of history and to optimize scientific progress. (Nowhere did Duhem expressly manifest his views regarding the statute of laws associated to theory evolution. Consequently, we cannot know whether its relations with the idea of a providential governance are conflictual or harmonious. The fact is that, as he did not show any unease at a possible incompatibility, we suppose that the said relationship would be pacific. It is only left for us to determine whether the said laws were considered to be instituted by divine will and action and, if so, whether they were expected to continue to depend on them. Up until now we have not been able to offer an answer to those questions.)

Up until now, everything leads us to believe that being condemned to undefined re-beginnings, metaphysics is reduced to the condition of an eternal battlefield in which any real advance would be impossible. Eternally posed by the human spirt, the philosophical questions receive disputable responses destined to be abandoned without delay. Even so, in the conclusions of *Le mouvement absolu et le mouvement relatif*, Duhem (1909a: 280) envisages the existence of progress in regard to such questions:

> However, when a philosophical theory, once in vogue, is taken up again after centuries of abandonment, the form in which it emerges is not exactly identical to that which it had at the moment when forgetfulness consumed it: it reappears clearer and more precise, rich in content; in short, more perfect.

With attention directed at the solving of problems alien to philosophy, the spirits indirectly foster the progress of a kind of knowledge that will help them in the future to solve the ancient philosophical problems. Thus, when they decide to apply themselves a second time to the same problems, that will do so with more profound knowledge; their tools will be better; new facts will be discovered; old prejudices will be cast aside; unsuspected points of view will be suggested. Not even the times when there was lack if any interest in philosophical issues have been in vain. That "general law that presides over the development of philosophy" in consonance with Duhem (1909a: 281) will manifest itself particularly when we think of the theories of movement that had already emerged in ancient Greece. The Greeks' initial concern was revived by the fourteenth century medieval scholars and discussed a third time by the modern ones when it achieved an extraordinary degree of precision. In the long intervals in which the discussion died down, new evidence arose, stemming from areas like dynamics and astronomy, new arguments were elaborated, and when it was resumed in modern times, the decision favoring the existence of absolute movements imposed itself more convincingly. To sum up, philosophical responses may oscillate, but they are perfectible.

Wishing to go beyond producing a simple empirical report of the discoveries and pursue the quest for more general evolutive laws that make it possible to find the reasons for them, Duhem treats history as a scientific discipline. Thus, the past can be explained and the future prognosticated even when going against the currently predominant opinion. Hence, the Bordeaux professor dared to prophesize the downfall of the neo-atomist school, supported on the model of the electron and the coming victory of its Energetics (Duhem 1917: 157). The sustainability of that prediction stemmed from the correct methodological conception: the object of physics theory is to classify and put in order the experimental laws and not to explain them as the atomists wish to do. Nevertheless, if the fecundity of the cosmological schools of which neo-atomism is a species is destined to be exhausted, what explains its undeniable past success would be another of those "laws that preside over the development of science" (Duhem 1892/1996: 18). According to Duhem, just like a child whose moment of greatest learning in infancy coincides with the height of its ingenuousness, in mathematical physics, a more accelerated development can be expected at its beginning, which will coincide with the period when its promoters are least well prepared to judge the value of their hypotheses. However, just as it is not the child's ingenuousness that causes its learning, so also the mechanical nature of the theories is not the cause of their success. Thus, we have the concomitance of ingenuousness and learning in the child and that of the mechanical nature and theoretical fecundity in physics. Far from being negated, the initial progress of mechanical theories is actually explained. While the history of science seems to contradict Duhem's methodology, his philosophy of history, on which the former comes to depend, takes on the task of eliminating the apparent contradiction.

Duhemian (Dis) continuism in Question

We have seen that the Duhemian philosophy of history induces a continuist interpretation of the evolution of theories, antagonistic to the existence of ruptures and revolutions. That aspect is constantly registered in Duhem's use of metaphors (a potency that is actualized, the seed that germinates, the tree that bears fruit), and its context is linked to topics such as the notions of a "Providence" that initiates and regulates the evolution of theories; the assimilation of this to a logical demonstration; the teleological conception of theory development; the existence of historical laws; and the passivity of the physicist in his choice of hypotheses. To a considerable extent, the passages that sustain that interpretation are to be found in prefaces and conclusions of historiographic and philosophic works, and their language is universalizing. In contrast, especially in the body of his eminently historiographic works, when he is meticulously analyzing and comparing theories, Duhem never failed to acknowledge conceptual ruptures between theories, explaining the existence of greater or lesser revolutions in various areas of physics. The one he particularly appreciates is the revolution that gave rise to modern science, the "new physics" that would come to replace the Aristotelian physics. Thus, when he rejects the predominant vision that situates the founding revolution of modern science in the seventeenth century, he is not excluding the existence of revolutions in toto but merely pushing back the beginning of that revolution to the fourteenth century. The seventeenth century represents the culmination of a lasting process. Prior to and after his discovery of medieval science, Duhem acknowledges the existence of various singular individual revolutionary occurrences (the syntagm "scientific revolution" is absent from his works). Buridan's revolution in dynamics was one "of the most profound" but not the only one. Among others that he acknowledged, we can mention Lavoisier's revolution with his anti-phlogiston theory (Duhem 1895/2002: 135; 1902b/2002: 28; 1911/1996: 217; 1916a: 185); Proust's, with his law of definite proportions (1902b/2002: 41) in chemistry; the revolutions of Copernicus (Duhem 1905–1906/1991: 258, 261, 317–318, 324, 349, 445; 1911/1996: 181; 1909a: 182; 1906–1913/1984, v. 2: 90, 269; v. 3: 374–375; 1913–1959, v. 1: 210, 241, 467; v. 3: 162; v. 9: 418; v. 10: 367) and Kepler in astronomy (Duhem 1911/1996: 195); Maxwell's revolution with his electrodynamics (Duhem 1902a: 5, 55; 1919: 118); Black's revolution with his discovery of latent heat; and Regnault's, with the introduction of new experimental methods in the studies of the heat engine in thermodynamics (Duhem 1895/2002: 132; 1899: 392, respectively). In all those cases, the criterion used was that of subversion (*bouleversement*) of the principles of the most disseminated and accepted theories in each area. They were genuine conceptual ruptures with the introduction of new methods and concepts that were incompatible with the former ones. If we disregard the explicit appearance of the term "revolution" and concentrate on the changes made to those principles that had eventually and mistakenly been accepted as definitive, then we would also have a revolution in electrodynamics with Lorentz's physics of the electron (Duhem 1915/1991: 103) and another in optics with the discovery of diffraction that clashed with the extant fundamental principle of that science:

> The history of physics shows us that very often the human mind has been led to overthrow such principles completely, though they have been regarded by common consent for centuries as inviolable axioms, and to rebuild its physical theories on new hypotheses. (Duhem 1914/1991: 212)

For a thousand years, insists our author, it was believed that light travelled in straight lines in a homogeneous medium. Immediately after Grimaldi discovered diffraction, physicists tried to attribute those observations of the "curving" of light to some kind of error until they audaciously decided to reject the theory of the rectilinear propagation of light and construct an optics based on "entirely new foundations." Thus, drastic alterations can equally well lead to enormous progress. It is important to note that those conceptual ruptures, described above as revolutionary, take place in the representative part of the theories and not in their explanatory or metaphysical part.

Examples like those described above show that even the principles of the most successful theories are subject to the control of experiment. Duhem's historical fallibilism associated with his epistemological holism prevents any hypothesis, however well verified it might have been in the past, from being transformed into a convention subtracted from the control of experiment. In the light of its struggle with the experience of framing exceptions, physics incessantly submits itself to constant adjustments:

> Physics does not progress as does geometry, which adds new final and indisputable propositions to the final and indisputable propositions it already possessed; physics makes progress because experiment constantly causes new disagreements to break out between laws and facts, and because physicists constantly touch up and modify laws in order that they may more faithfully represent facts. (Duhem 1914/1991: 177)

Given that physical theory rests on provisional hypotheses that have nothing analogous to the axioms of geometry, whose certainty is immediate (Duhem 1907: 199), the veritably cumulative development is restricted to mathematics, the "sciences of reasoning" that can do without experimental confrontation (Duhem 1915/1991: 5–20). Exclusively in their case, new conquests do not pose any risks to those already conquered. In its modest way, physics limits itself to desiring a pacific and regular "continuous progress," like that of mathematics (Duhem 1914/1991: 10). Not even the fact that physics became mathematicized could alter its nature so that its laws will maintain their provisional nature because they are irremediably approximate (Duhem 1914/1991: 171).

Conclusion

In synthesis, between the two levels of discourse addressed in this chapter, that of the philosophy of history, which would seem to definitively overlook any possibility of abrupt revolutions, and the epistemological one, predominant in the historiographic works, which admits the existence of occasional, restricted, and particular

revolutions, Duhem does not see any kind of incompatibility. Our philosopher-historian plays with both those discursive levels, suggesting that there is no contradiction between a series of partial developments and, in the long term, the acknowledgment of a great revolution (Duhem 1913–1959, v. 7: 3–4) or even, in the short term, of a localized conceptual rupture. From the historical point of view, we will never have a great event without a cause; from the epistemological standpoint, concepts and theories are capable of revolutionizing an area of science. For that reason, we think that caution must be exercised before classifying the Duhemian position in one or other of the opposing "continuists versus discontinuists" poles given that whichever option is taken, without the observations put forward here, would possibly attribute to our author an anachronic contraposition that was not his own.

Cross-References

- ▶ Historical Epistemology: A German Connection
- ▶ The French Style in the Philosophy of the Sciences
- ▶ The Historiography of Scientific Revolutions: A Philosophical Reflection

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