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Physics in Perspective

Pierre Duhem, Entropy, and Christian Faith

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The French physicist and polymath Pierre Duhem was strongly devoted to Catholicism but insisted that science and religion were wholly independent. In an article of 1905 he reflected at length on the relationship between physics and Christian faith, using as an example the cosmological significance of the laws of thermodynamics. He held that it was unjustified to draw cosmological consequences from thermodynamics or any other science, and even more unjustified to draw consequences of a religious nature. I place Duhem's thoughts on "the physics of a believer" in their proper contexts by relating them to the late-nineteenth-century discussion concerning the meaning and domain of the law of entropy increase. I also consider Duhem's position with respect to Catholic science and culture in the anticlerical Third Republic.

Key words: Pierre Duhem; Ernst Mach; Georges Lemaître; Catholicism; neo-Thomism; religion; cosmology; thermodynamics; entropy; heat death.

Life and Work of a Classical Physicist

Pierre Maurice Marie Duhem (1861–1916, figure 1) was a scientist and scholar of unusual breadth whose contributions ranged from the history of medieval natural philosophy to mathematical physics. He began his academic career in the 1880s with works in chemical thermodynamics and continued over the years to develop this branch of science, intermediary between physics and chemistry, into still more general formulations. Together with Wilhelm Ostwald (1853–1932), Jacobus Henricus van't Hoff (1852–1911), Svante Arrhenius (1859–1927), and Walther Nernst (1864–1941), Duhem counts as one of the pioneers of physical chemistry. In spite of his important contributions to thermodynamics, electromagnetism, hydrodynamics, and the theory of elasticity, however, he never obtained a university chair in Paris, the absolute center of French intellectual life. Partly as a result of his disagreements with the scientific and political establishment, and not least with the powerful chemist and politician Marcelin Berthelot (1827–1907), Duhem had to spend his professional life in the provinces, serving as lecturer and professor at the universities in Lille, Rennes, and Bordeaux where he became full professor in 1894. He engaged actively in physics teaching and established himself as an innovative teacher of physics.[1] Apart from his scientific and intellectual work, and the controversies in which he was occasionally involved, Duhem's life was uneventful. He married in 1890, but his wife died two years later, leaving him with their

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Fig. 1. Pierre Maurice Marie Duhem (1861–1916). *Credit*: ©Académie des Sciences de l'Institut de France.

daughter, Hélène (who published a biography of her father in 1936). Duhem died of a heart attack in 1916, at the age of fifty-five.[2]

Duhem was politically conservative, strongly anti-Republican, and an orthodox Catholic. His conservatism extended to the realm of science, at least in the sense that he resisted the new trends in physics that appeared in the 1890s, beginning with the discoveries of X rays, radioactivity, and the electron. Having the mind of a classical physicist in the French mathematical tradition, and subscribing to the ideals of positivism (of a kind), he denied the existence of atoms and subatomic particles as real entities. When quantum theory and the theory of relativity arrived on the scene in the first decade of the twentieth century, he chose to ignore these new theories. He spelled out his antiatomism in several works, first in 1892 in the Catholic journal *Revue des questions scientifique* and ten years later more elaborately in *Le mixte et la combinaison chimique*.[3] As late as 1913 – the year that saw the atomic model of Niels Bohr

(1885–1962) – Duhem defended his nonatomistic and nonelectronic view of physics and chemistry:

> The school of the neo-atomists, the doctrines of which center on the concept of the electron, have again taken up with supreme confidence the method we refuse to follow. This school thinks its hypotheses at last attain the inner structure of matter, that they allow us to see the elements, as if some extraordinary ultra-microscope were to enlarge them until they became perceptible to us. We do not share this confidence. We are not able to recognize in these hypotheses a clairvoyant vision of what there is beyond sensible things; we regard them only as *models*.[4]

In 1915 Duhem gave a series of four lectures on "German science" at Bordeaux that severely criticized *la science allemande* and its roots in what he saw as the deplorable mindset of the German race.[5] In this work of chauvinistic propaganda he described German physicists as good mathematicians who unfortunately were unable to think intuitively and therefore produced abstract theories with no connection to the real world: "The German, then, quite skillful in the use of the deductive method, but weakly endowed with intuitive knowledge, will multiply the occasions on which the former may be applied, and restrict as much as possible the circumstances which call for the latter."[6] Duhem had nothing to say about quantum theory, but he mentioned the theory of relativity (meaning the special theory) as a typical example of abstract and sterile German theorizing. Rejecting the principle of relativity as contrary to common sense, he wrote that it "is so plainly a creation of the mathematical mind that one does not know how to articulate it correctly in ordinary language and without recourse to algebraic formulas."[7] But it, and its abandonment of the classical concepts of space, time, and motion, "does not excite the distrust of German physicists," among whom he mentioned Albert Einstein (1879–1955), Hermann Minkowski (1864–1909), and Max von Laue (1879–1960).

Today Duhem is probably best known as a philosopher of science, a reputation primarily based upon his classic book, *The Aim and Structure of Physical Theory*, first published in 1906.[8] Given Duhem's lack of appreciation of Einsteinian relativity, it is ironic that his book influenced Einstein's way of thinking to a considerable degree. It appeared in German in 1908 as *Ziel und Struktur der physikalischen Theorie*, translated by Einstein's close friend Friedrich Adler (1879–1960) and with a sympathetic foreword by the famous Austrian physicist and philosopher Ernst Mach (1838–1916). Einstein read Duhem's book, probably in 1909, and it exerted a long and lasting influence on his epistemological views. What particularly impressed Einstein was the theoretical holism and the underdetermination of theory choice (often called the "Duhem-Quine thesis") that were central theses in Duhem's philosophy of physics. In a letter of 1918, Einstein referred approvingly to "the clear book by Duhem."[9]

Duhem's legacy is not restricted to either his scientific contributions or his work in philosophy of science. He is recognized as one of the pioneers of the modern history of science and a founding figure of the scholarly study of medieval natural philosophy. By a careful study of the notebooks of Leonardo da Vinci (1452–1519), Duhem was led to recognize important schools of mathematics and natural philosophy in the late thirteenth century and the following two centuries, and he was the first to investigate in detail the works of scholastic philosophers such as Jean Buridan (*ca*. 1300), Albert of Saxony (*ca*. 1200–1280), and Nicole Oresme (*ca*. 1320–1382). Duhem's pathbreaking work in the history of science resulted in numerous publications, culminating in his three-volume *Études sur Léonard de Vinci* (1906–1913) and his ten-volume *Système du monde* (1913–1959) of which half were published posthumously. When the chair in history of science at the Collège de France had to be filled in 1904, he was asked to put himself forward as a candidate but refused to have his name placed on the list of candidates; if he was to go to Paris, it would be as a physicist. He always insisted that he was a physicist, not a philosopher or historian of the physical sciences. (The chair was filled by Grégoire Wyrouboff (1843–1913), a crystallographer of modest distinction in the history of science.[10])

Like Mach, Duhem used the history of science in support of his philosophical ideas, for example, in arguing that metaphysics and hidden causes were detrimental to scientific progress. He defended a continuity thesis, that progress was (and is) obtained by the accumulation of empirical knowledge and the gradual refinement of concepts. According to his understanding of the history of science, the works of the Christian thinkers in the Middle Ages constituted a break with orthodox Aristotelianism and thereby paved the way for the later change in natural philosophy that came with Galileo Galilei (1564–1642) and his generation. Although Duhem's radical continuity thesis no longer enjoys support among historians of science, in a more moderate version it continues to inspire medievalist historians.

Thermodynamics as the Basic Science

Before accounting for Duhem's view of the cosmological aspects of thermodynamics, I must emphasize that he was one of the period's great experts of this science, second perhaps only to Max Planck (1858–1947) and J. Willard Gibbs (1839–1903). But in contrast to these physicists, the antiatomist Duhem never accepted the statistical-mechanical view of thermodynamics initiated by James Clerk Maxwell (1831–1879) and Ludwig Boltzmann (1844–1906). As Louis de Broglie (1892–1987) later commented: "inspired by a genuine horror of all mechanical or pictorial models, … he never became interested in the interpretation of the abstract concepts of classical thermodynamics, though it was so instructive and fruitful, which statistical mechanics furnished in his own lifetime."[11]

Inspired by the thermodynamical works of Gibbs and Hermann von Helmholtz (1821–1894), Duhem developed the theory of chemical potentials (such as the free-energy functions) in his first book, *Le potentiel thermodynamique et ses applications à la mécanique chimique et à la théorie des phénomènes électriques* of 1886. His general method, based upon Gibbs's work, was to base thermodynamics on the condition that at equilibrium the potential must be a minimum. Among other things, he considered systems in which phase changes or chemical reactions take place and wrote the change in chemical energy as $n_1\mu_1 + n_2\mu_2 + \ldots + n_k\mu_k$, where the n's refer to the amounts of the components and the μ's are chemical potentials. According to what is known as the Gibbs-Duhem equation, $n_1 d\mu_1 + n_2 d\mu_2 + \ldots + n_k d\mu_k = 0$ for a process taking place at constant temperature and pressure.[12]

Duhem also launched an attack on Berthelot´s thermochemistry, which was based upon the assumption that the quantity of heat evolved in a chemical reaction was a measure of chemical affinity. According to Berthelot's "principle of maximum work," first stated in 1864, all chemical reactions are accompanied by heat production, and the process that actually occurs out of all possible ones is the one in which the most heat is produced. However, as Duhem argued, this principle was based only upon the law of energy conservation and failed to take into account the entropy changes given by the second law of thermodynamics. What Berthelot had stated as a fundamental principle of science was, according to Duhem, nothing but a "ridiculous tautology."[13] Berthelot was not the only chemist who failed to understand the nature and role of entropy; as late as 1894 he characterized this concept, by then nearly thirty years old, as "an obscure notion and an unknown quantity."[14] Duhem emphatically disagreed. He gave full accounts of the generalized chemical thermodynamics in two monographs published about the turn of the century, in his two-volume *Traité de mécanique chimiques* (1897–1899) and in his *Thermodynamique et chimie* (1902).

Duhem's vision of a generalized thermodynamics (or energetics, as he called it) was a sort of nonmechanical, phenomenological theory of everything with distinct Aristotelian features. It was, he said, "not a branch of physics, but the trunk from which several subjects branched off. … These laws govern all the changes that it is possible to produce in the inorganic world."[15] He deliberately contrasted the new thermodynamics with the old paradigm of rational mechanics:

> Thirty years ago, rational Mechanics still seemed the queen of science of which all other physical doctrines must be an expression. It was required that Thermodynamics reduce all its laws to mere theorems of Mechanics. Today, rational Mechanics is no more than the application to a particular problem of *locomotion* of this general Thermodynamics, of this *Energetics* whose principles encompass all the transformations of the inorganic world or, according to the peripatetic description, all *physical movements*.[16]

Entropy, Heat Death, and Catholic Thought

Shortly after the formulation of the second law of thermodynamics, independently by William Thomson (1824–1907) and Rudolf Clausius (1822–1888) in the early 1850s, it was applied to the universe at large, first by Helmholtz in an address delivered in Königsberg in 1854.[17] The essence of the second law, as understood at that time, was that the energy in a closed system will spontaneously and irreversibly be "degraded," be transformed into a lower-temperature form of heat unable to produce mechanical work. As Helmholtz pointed out, the consequence would be a state of equilibrium scarcely distinguishable from death: "Then all possibility of a further change would be at an end, and the complete cessation of all natural processes must set in. … In short, the universe from that time onward would be condemned to a state of eternal rest." This scenario of the so-called heat death (*Wärmetod*) immediately became the subject of much discussion among both scientists and nonscientists. Thomson formulated the prediction in terms of dissipation of energy and Clausius framed it in terms of entropy, a concept he introduced in 1865. "*The entropy of the universe tends towards a maximum*," he emphasized in a paper of 1868.[19] When the state of maximum entropy had been attained, the universe would be dead, never to wake up.

The second law of thermodynamics not only predicted a heat death in the far future, it also seemed to imply that the world is of finite age and thus had a beginning in time, since if the universe had existed an eternity ago, the entropy would already have reached its maximum value, which was clearly not the case. This entropic argument for a beginning of the universe was introduced in the late 1860s and adopted as a reasonable hypothesis by leading physicists such as Thomson, Maxwell, and Peter Guthrie Tait (1831–1901) who were impressed by its apparent agreement with the Christian message of a created world. A substantial part of the debate in the late nineteenth century was concerned with the apologetic use of thermodynamics and the significance of the second law in the ideological and cultural battle that raged through much of Europe at the time. By and large, those in favour of political conservatism, idealism, and Christian values looked with sympathy to the cosmological claims of thermodynamics, whereas socialists, materialists, and atheists denied these claims, in part because they suspected them to be Christian religion masquerading as science.[20] The standard argument of the latter group was that the second law was valid only for a finite collection of bodies and not for the supposedly infinite universe, in which case their favored worldview of an eternal and cyclical universe did not conflict with the laws of physics.

The heat death could be avoided even without presupposing an infinite material universe, namely, by arguing that the inference was methodologically invalid. That was the position of Mach, who opposed extrapolations of the laws of nature to the entire universe. His opposition to the heat death was undoubtedly related to his hostility toward Christian faith.[21] In 1871, while professor of physics at Prague, Mach gave a lecture on the history of the principle of energy conservation in which he criticized the concept of the heat death and its corollary, the origin of the universe, by arguing that they were scientifically meaningless. It is "completely illusory," he wrote, to apply the second law to the entire universe. This was not because of any problem with Clausius's law in particular but because no meaningful statements could be attached to the universe. Mach argued that, for the statement to be meaningful, we must consider the object separate from another part of the universe, which acts a clock. But this is impossible for the universe itself, since there is nothing left that can serve as a clock. "*The world* is like a machine in which the motion of certain parts is determined by the motion of other parts, only *nothing* is determined about the motion of the machine as a whole. … For the universe there is no [measure of] time."[22]

During the second half of the nineteenth century the Catholic church was seriously disturbed by what came to be known as the "modernist crisis," a confrontation between traditional church dogmas and modern ideas coming from the humanities and natural sciences. In Bismarck's new, unified Germany the confrontation culminated in a campaign to keep Catholics out of public life and culture, an important element in what is known as the *Kulturkampf*. In France, the situation was marked not only by the successful trend of Comtean positivism but also by the Third Republic's sustained anti-Catholicism and anticlericalism. In 1880 Jesuits and other unauthorized congregations were disbanded by law, and this measure was followed by a general offensive against faith and church. This campaign reached its climax shortly after the turn of the century when Catholic schools were closed and thousands of monks and nuns expelled. Finally, in 1905 the Republic broke totally with the church and ceased to recognize any form of religion. Priests and Catholic thinkers responded in a variety of ways, one being more active participation in scientific, social, and philosophical debates. Part of the Catholic intellectual counteroffensive was directed against the attempts to use science as a weapon against religion.[23]

The Catholic counteroffensive agreed with, and to a large extent was inspired by the more modernist and reconciliatory strategy of Leo XIII (1810–1904), pontiff from 1879 to 1904. The Pope actively encouraged scholars to engage in the world of science and to demonstrate that Catholic thought and modern science were not irreconcilable. In his widely read *History of the Conflict between Religion and Science*, the chemist John William Draper (1811–1882) had concluded that "Roman Christianity and Science are … absolutely incompatible; they cannot exist together; one must yield to the other; mankind must make a choice – it cannot have both."[24] The new generation of Catholic scholars was eager to refute Draper's diatribe and to show that science was not a born enemy of faith; on the contrary, if supplied with the right metaphysical foundation in the form of neoscholasticism, science would be a valuable ally of faith.

Neoscholasticism or neo-Thomism, a revised version of the philosophical system of Thomas Aquinas (1225–1274), became the foundation of the new Catholic philosophy, natural philosophy included. Although many Catholic scientists fell for the temptation to use science apologetically, this was not the aim of neoscholasticism. The Belgian Cardinal Desiré Joseph Mercier (1851–1926, figure 2), a leading neo-Thomist and the organizer of the *Institut Supérieur de Philosophie* associated with the Catholic University in Louvain, emphasized that the purpose of the new institute was "to form, in greater numbers, men who will devote themselves to science *for itself*, without any aim that is professional or directly apologetic."[25] Among the professors at the Louvain institute was Désiré Nys (1859–1927), who in his youth had studied chemistry under Ostwald in Leipzig and in Louvain taught courses on cosmology and chemistry. In one of the volumes of his *Cours de philosophie*, Nys examined in detail the claim that the second law of thermodynamics implied a beginning and an end of the world. He concluded that the law could not be assigned absolute certainty, and for this and other reasons he dismissed its apologetic use and retreated to the safe haven of faith. "Did the world have a beginning? Only faith permits us to respond to this question with complete certainty."[26] According to Nys, human reason was unable to provide a definite proof against the possibility of an eternal world.

Nys's view was in complete agreement with neoscholastic philosophy as expounded in the authoritative *Manual of Modern Scholastic Philosophy*, written by Cardinal Mercier and several of the professors at the Louvain institute. According to Mercier, cosmology comprised three parts, namely, (i) the origin of the inorganic world, meaning its first efficient cause; (ii) its intrinsic constitution or ultimate constitutive causes; and (iii) its destiny or final cause.[27] Cosmology in the neoscholastic philosophical tradition thus constituted a much broader subject than the current meaning of the term with its emphasis on physics and astronomy. It was "natural philosophy" rather than

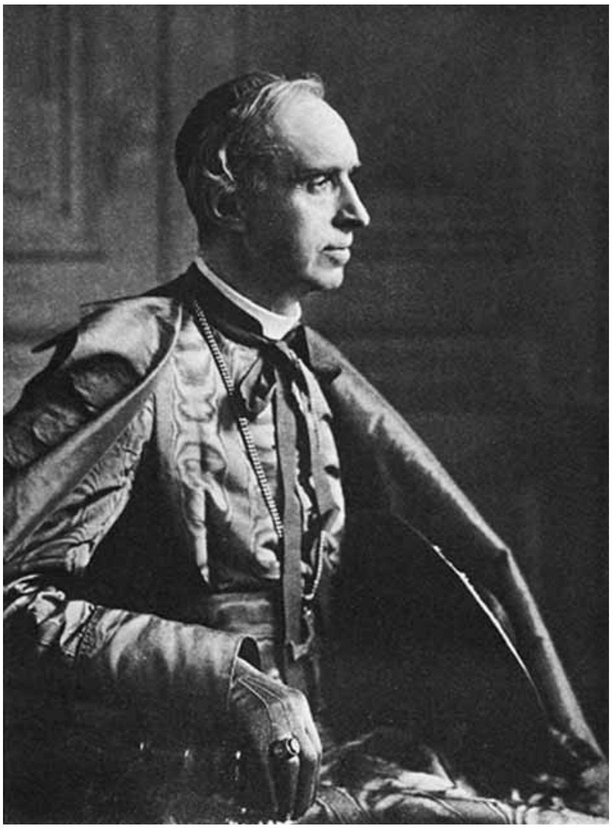

Fig. 2. Cardinal Desiré Joseph Mercier (1851–1926). *Source*: Mercier, *Manual of Modern Scholastic Philosophy*. Vol. I (ref. 27), frontispiece.

"the science of the universe." Mercier and his coauthors were careful not to accept the thermodynamic argument of the origin of the world as a proof of God's existence:

> But even if science could demonstrate that the actual state of this world as we find it had a commencement; … if the law of entropy could establish as a fact that the forces of the world have had an origin in far-off ages, reason alone could never be sure that this state was not endlessly preceded by some other state of which science is entirely ignorant.… In any case it is imprudent … to identify the question of the existence of God with that of the commencement of the world.[28]

The cautious attitude of leading Catholic philosophers and theologians was not followed by all Catholics. In fact, the period from about 1880 to 1910 saw a flood of publications in which Jesuits and other writers of Catholic faith argued from the second law of thermodynamics that the world must have had an origin in time and eventually must come to a standstill. Several of these writers concluded that thermodynamics had vindicated a divinely created world and thus proved the existence of God.

Physics of a Believer

As a devout and outspoken Catholic scientist, Duhem could not avoid being drawn into the discussion concerning the relationship among science, philosophy, and theology. While a professor in Bordeaux, he reflected forcefully on this topic in an important article of 1905 entitled "Physics of a believer" in the *Annales de philosophie Chrétienne*, a Catholic journal founded in the 1830s. His article received much wider attention when it was included as an appendix in the second edition of his *Aim and Structure of Physical Theory*.[29]

Duhem's article was a lengthy response to a detailed and critical essay by the young philosopher Abel Rey (1873–1940), who had concluded that "Duhem's scientific philosophy is that of a believer" (note that Rey referred to Duhem's philosophy of science, not his science).[30] Although Duhem was indeed a believer, a sincere and fervent Catholic, he was eager to point out that his works in physics and chemistry should be considered on their own merits, independent of his religion. They were not examples of "Catholic science," nor even colored by his Catholic faith. It followed from his positivistic, antimetaphysical methodology of science that there could be no influence of religion on science, nor of science on religion (whereas he accepted an influence of science on metaphysics). He rejected the idea that arguments from physics, or science in general, could serve as valid objections against religion, and conversely, that such arguments could support the cause of religion:

> Whatever I have said of the method by which physics proceeds, or of the nature and scope that we must attribute to the theories it constructs, does not in any way prejudice either the metaphysical doctrines or the religious beliefs of anyone who accepts my words. The believer and the nonbeliever may both work in common accord for the progress of physical science such as I have tried to define it.…
>
> *In itself and by its essence, any principle of theoretical physics has no part to play in metaphysical or theological discussions*.[31]

In short, Duhem was an ardent advocate of the independence thesis, the view that science and religion deal with different realms of reality and therefore can be neither in conflict nor in harmony.[32] Although he firmly believed that the order of nature was ultimately the work of the Creator, he denied any direct connections between science and religion based upon natural theology. According to his friend, the Abbé Bernies (d. 1929), Duhem held the view 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."[33]

To illustrate his view on the relationship among science, philosophy, and theology, Duhem referred to the case of thermodynamics, his favorite branch of physics. He first commented on the cosmological significance of the laws of thermodynamics in a textbook of 1897 in which he expressed his disapproval of Clausius's formulations of the two laws, which he found to be foreign to physics. According to Duhem, Clausius had illegitimately applied the laws of thermodynamics to the universe,* "which he assimi-

* Duhem's reference to Clausius's view of the universe is puzzling, as Clausius never mentioned this or any other cosmological model.

lates to a system of bodies of limited extension and isolated in an absolutely void space."[34] He repeated his criticism in a later textbook in which he argued that energy and entropy cannot be uniquely defined for the universe as a whole, irrespective of whether it is spatially infinite or finite. He therefore concluded that there was no logical justification for Clausius's cosmological formulation. More generally: "All the philosophical consequences that one believes to be able to derive from an extension of the principle of energy conservation and the principle of entropy increase to the universe prove to be an idea that is completely erroneous with respect to the nature and range of thermodynamics and, in general, the science of physics."[35] This methodologically founded criticism agreed with that of Mach and other scientists of a positivist orientation.

In his article of 1905, Duhem referred to the entropic argument for creation and decay, knowing well that this was a controversial subject. He was aware that the laws of thermodynamics had been used to strengthen the cause of religion, but he considered this to be based upon a misunderstanding of both physics and Christian religion. Concerning Clausius's cosmological version of the second law, he wrote:

> From this theorem many a philosopher maintained the conclusion of the impossibility of a world in which physical and chemical changes would go on being produced forever; it pleased them to think that these changes had had a beginning and would have an end; creation in time, if not of matter, at least of its aptitude for change, and the establishment in a more or less remote future of a state of absolute rest and universal death were for these thinkers inevitable consequences of the principles of thermodynamics.[36]

Duhem, however, did not accept these conclusions, which were "marred in more than one place by fallacies." It followed from his conception of physics that the cosmological use of the law of entropy increase was invalid, and also that the law could have no religious implications. For one thing, the entropic argument "implicitly assumes the assimilation of the universe to a finite collection of bodies isolated in a space absolutely void of matter," he wrote, repeating what he had said in 1897. He saw no reason to accept this assumption. Moreover, he argued that the entropy law merely says that the entropy of the universe increases endlessly, not that it has any lower or upper limit:

> It is true that the entropy of the universe has to increase endlessly, but it does not impose any lower or upper limit on this entropy; nothing then would stop this magnitude from varying from $-\infty$ to $+\infty$ while the time itself varied from $-\infty$ to $+\infty$; then the allegedly demonstrated impossibilities regarding an eternal life for the universe would vanish.[37]

Duhem's assertion that the second law does not imply that a system will end in a state of maximum entropy, even if an infinity of time is available, was not original. A similar argument had been made by Arthur Joachim von Oettingen (1836–1920), a physicist from the University of Dorpat (now Tartu in Estonia), who in 1876 concluded that Clausius's version of the second law was wrong.[38] The idea of an asymptotic increase of entropy was sometimes put forward as an argument against the heat death, but as pointed out by the Catholic philosopher and theologian Constantin

Gutberlet (1837–1928), it did not allow life processes to go on eternally.[39] If the universe was in a state of very high entropy, if not in the maximal state, it would still be dead for all practical purposes.

Duhem's aim was certainly not to argue against a universe of finite age, but to warn that physical theory does not justify such long-term predictions. In this epistemological respect he was an agnostic (of course, he was not an agnostic in the religious sense). "It is absurd," he declared, "to question this theory [thermodynamics] for information concerning events which might have happened in an extremely remote past, and absurd to demand of it predictions of events a very long way off." It would be a gross misconception of the scope and nature of science to believe that one could claim for it "the proof of a dogma affirmed by our faith." In agreement with his general philosophy of science, Duhem pointed out that it would be perfectly possible to construct a new thermodynamics that was in agreement with experimental data and gave the same predictions as the old thermodynamics for ten thousand years; and yet, the new theory could be constructed in such a way that it "might tell us that the entropy of the universe after increasing for a period of 100 million years will decrease over a new period of 100 million years in order to increase again in an eternal cycle."[40] He definitely did not subscribe to such a strange worldview, but wanted to bring home the point that science is incapable of making trustworthy predictions about either the beginning or the end of the world, or its perpetual activity.

Concerning the more general relationship between cosmology and physics, Duhem claimed that the two fields are so different that physical theory cannot be applied meaningfully to cosmology. He did not deny that knowledge of physics can be useful, and even indispensable for the cosmologist, but he argued nonetheless that "physical theory can never demonstrate or contradict an assertion of cosmology, for the propositions constituting one of these doctrines can never bear on the same terms which the propositions forming the other do, and between two propositions not bearing on the same terms there can be neither agreement nor contradiction."[41] The only connection of cosmology to theoretical physics was by means of analogy. Duhem's denial of the possibility of physical cosmology may appear surprising, but one should be aware that he spoke of "cosmology" mostly in a philosophical, neoscholastic sense of the word. The cosmology of Aristotelian physics was, he said, "unmistakably analogous" to generalized thermodynamics.

The Catholic Context

The *fin de siècle* ideology in France was colored in part by a growing revolt against positivism, scientism and the agnostic-materialistic ideas that the scientific worldview was accused of fostering. In early 1895 the French literary critic and orthodox Catholic Ferdinand Brunetière (1849–1906), inspired by a visit to the Vatican, published an article in which he attacked positivistic science and argued that it had failed to answer, or even address the greater questions of matter and life. In the heated debate that followed, some critics of science proclaimed "the bankruptcy of science" (Brunetière himself did not use this phrase, but spoke only of the failure of science).[42] Nor was it only in France that science was charged with being morally bankrupt. The Irish writer and Victorian feminist Frances Power Cobbe (1822–1904) wrote in 1888 that a man bred to science "will view his mother's tears not as expressions of her sorrow, but as solutions of muriates and carbonates of soda, and of phosphates of lime; and he will reflect that they were caused not by his selfishness, but [by] cerebral pressure on her lachrymal glands."[43]

Contrary to what preachers of the scientific gospel claimed, positivistic science was widely held to be inferior to religion because it provided no insight into the supreme mysteries of the universe, or into the mysteries of the meaning of love, life, and death. In this intellectual climate, French Catholics eyed an opportunity to come back on the scene, not only as critics of scientistic tendencies but also as interpreters of and contributors to science. Jesuit scholars engaged in the history of science to demonstrate that a substantial part of the progress of science was due to the work of scientists of Catholic faith.[44]

Duhem was very much his own man. His ideas, whether scientific, political, or religious, conflicted sharply with those held by the cultural and scientific elite of France. Although he was a fervent supporter of Catholicism, he was far from representative of Catholic scientists, most of whom had no problems with arguing apologetically, that is, to the effect that science supported Christian theology. For example, in 1905 the Catholic geologist Albert de Lapparent (1839–1908) gave a series of lectures that was published as *Science et apologétique* and whose message was that that recent developments of science were fully congruent with Christian faith. Contrary to Duhem, Lapparent believed that the idea of a beginning and an end of the universe could be given scientific support: "The [Christian] idea of origin and end applied to the entire creation seems to find a remarkable confirmation in the fundamental law of this energetics in which all the sciences of matter tend more and more to meet."[45]

While Duhem emphatically declined to use science apologetically, he saw his research in the history of medieval science in a different light. The study of the history of science would show, he wrote, that "during those very ages when men cared above all for the kingdom of God and of its justice, God accorded to them as a bonus the most profound and fertile thoughts concerning matters down here."[46] In the second volume of his book, *The Origins of Statics* of 1906, he wrote about the many attempts in the Middle Ages to establish a science of statics that demonstrated the existence of a divine architect:

> How could all these efforts combine with such precision and bring to completion a plan which was not known to the individual laborer, unless this plan existed previously in the mind of an architect, and if this architect did not have the power to direct and coordinate the labor of all the masons? 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 divine 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.[47]

Although natural theology had no place in Duhem's conception of science, it went hand in hand with the history of science. This may seem rather surprising, if not inconsistent. After all, today's science is tomorrow's history of science.

According to Duhem, the controversy between Catholic thought and modern science was essentially a misunderstanding based upon a failure to appreciate the separate domains of the two fields. He had nothing but disdain for the many words wasted on the subject:

> It has been fashionable for some time to oppose the great theories of physics to the fundamental doctrines on which spiritualistic philosophy and the Catholic faith rest; these doctrines are really expected to be seen crumbling under the ramming blows of scientific systems. Of course, these struggles of science against faith impassion those who are very poorly acquainted with the teachings of science and who are not at all acquainted with the dogmas of faith; but at times they preoccupy and disturb men whose intelligence and conscience are far above those of village scholars and café physicists.[48]

Duhem's views were controversial, both within the state university system and within the Catholic church. As an indiscreet Catholic, his career was deeply affected by the hostility of anticlerical governments toward Catholicism.[49] As an independent mind, his insistence on a sharp separation between science and faith made him a target of some Catholics who suspected him of philosophical scepticism and "fideism," the heretical belief that faith rests upon faith and nothing else. Not only was his view concerning science and religion problematical, so was his philosophy of science, primarily because it was radically antimetaphysical and seemed to undermine natural theology.[50] Among Duhem's later critics was the influential neo-Thomist philosopher Jacques Maritain (1882–1973), who objected to Duhem's philosophy of physics and especially its independence of any metaphysical framework, Thomism included.

Bernard Brunhes (1867–1910), Professor of Physics and Director of the Observatory at Puy-de-Dôme, had a high regard for Duhem and his philosophy of physics. In 1908 he published an excellent and comprehensive review of the second law of thermodynamics entitled *La dégradation de l'énergie*, but he chose not to include its wider cosmological and religious aspects. The Catholic Brunhes was not foreign to these aspects, but, like Duhem, he wanted to keep them separate from scientific aspects.[51] Like many other Catholic scientists, Brunhes kept a low profile in matters of religion, aware that controversial statements concerning science and Christian faith might annoy the Republican establishment and harm his career. Although this was not Duhem's style, he agreed that thermodynamics had no religious implications.

Conclusion: Duhem and Lemaître

Duhem's refusal to accept, or even take seriously the metaphysical and religious consequences of thermodynamics, such as the beginning of the universe in a state of low entropy, was not particularly unusual for a Catholic scientist. As mentioned, leading Catholic philosophers and theologians shared the view that physics cannot prove the finiteness of the age of the world and even less its divine creation. Yet Duhem's reasons for dismissing cosmological thermodynamics were different, as they were rooted in his general philosophy of physics. According to his philosophy, theories of physics are mathematical representations rather than explanations. As such, they are neither true nor false but merely convenient statements that more or less completely and exactly cover groups of phenomena; a finite number of phenomena or data may be represented by many different theories. By their very nature, then, theories of physics are noncosmological and therefore also irrelevant to religious faith.

Of course, Duhem is not the only Catholic scientist who has subscribed to the independence thesis. So did the Belgian priest and pioneer of modern cosmology Georges Lemaître (1894–1966). Although he did not share Duhem's view that physics is of no direct cosmological relevance, he did agree that science and religion are different and autonomous ways of knowing. Speaking of the big-bang model of the universe at the eleventh Solvay conference in 1958, Lemaître said: "As far as I can see, such a theory remains entirely outside any metaphysical or religious question. It leaves the materialist free to deny any transcendental Being. He may keep, for the bottom of space-time, the same attitude of mind that he has been able to adopt for events occurring in nonsingular places in space-time."[52] This was a view entirely in agreement with what Duhem had written in "Physics of a believer." Lemaître, however, did not dismiss the entropic creation argument for philosophical or other reasons. In fact, the law of increase of entropy played a significant role in the thinking that led him to propose the big-bang model of the universe in 1931.[53]

As mentioned, at the time of Duhem the heat death was a controversial and much discussed issue. Does the second law of thermodynamics apply to the universe at large? Does it lead to a dead universe in the far future? One year after Duhem's death, Einstein revolutionized cosmology by basing it upon the field equations of general relativity, and since then cosmology has developed into an advanced science of which Duhem and his contemporaries could scarcely dream. Contrary to what one might believe, the rapid progress in physical cosmology has not led to a clarification of the thorny question of cosmic entropy. On the contrary, this entire question rather has become more complicated and muddled. Few modern cosmologists believe that the second law is valid for the universe in any straightforward way. It is far from clear how to apply thermodynamics to a universe governed by classical general relativity, or if the notion of the entropy of the universe is at all well-defined. "I see no reason to expect that there will be a meaningful notion of the 'total entropy of the universe'," says Robert M. Wald, a leading expert on cosmology and thermodynamics. Nevertheless, he believes that "in (quantum) general relativity some notion of entropy will exist and the basic form of the laws of thermodynamics will survive."[54]

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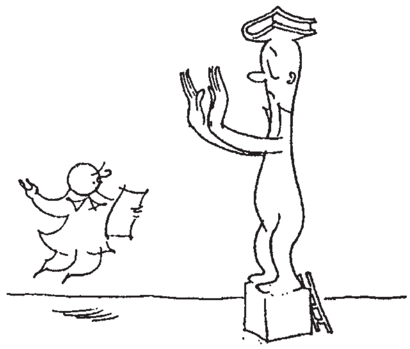

EXPERTS

Experts have
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telling one
just how nothing
can be done.

Piet Hein