

Pierre Duhem and the History and Philosophy of Science

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Making a fundamental contribution to any discipline is a noteworthy achievement. Thus the early 20th century French chemist Pierre Duhem (1861–1916) is recognized by physical chemists for his work in thermodynamics, hydrodynamics, and elasticity (1).

Probably Duhem is best known for his efforts to establish a rigorous mathematical foundation for the investigations carried out by Gibbs and Helmholtz on chemical potential. It was Duhem who first applied Euler's theorem to the equation developed by Gibbs relating a change in a given thermodynamic property, G , to partial molal thermodynamic quantities

$$dG = \bar{G}_1 dn_1 + \bar{G}_2 dn_2$$

(with temperature, pressure, and number of moles of all other constituents held constant). The result Duhem arrived at, which shows how a variation in composition leads to changes in the chemical potential of each component, is now known as the Gibbs-Duhem equation (2)

$$n_1 d\bar{G}_1 + n_2 d\bar{G}_2 = 0$$

Although Duhem never accepted atomism and expressed reservations about relativity theory, his research in various fields remains relevant. In fact in recent years several scientists have acknowledged their indebtedness to his pioneering investigations (3).

Few scientists are aware, however, that in addition to his scientific work Duhem also carried out studies in both the history of science and the philosophy of science. His historical researches cover several different works, but two in particular deserve attention: the three-volume "Etudes sur Leonard de Vinci" (4) and the ten-volume "Le Système du monde" (5). These works still provide a useful starting point for modern historians of science. Similarly Duhem's exposition of the roots of scientific theory, "La Theorie physique, Son objet et sa structure" (6), occupies an important position among philosophers of science. The issues he raised about the role of theory and his own austere critical position continue to receive attention (7).

Impressive in both scope and depth, Duhem's works in the history and philosophy of science testify to his erudition and his intellect. They also constitute proof of his courage since, in presenting his findings and the conclusions he based on them, Duhem was challenging the notions prevalent in the

academic and intellectual circles of his day. Many of the French elite at that time were hostile to Christianity—specifically the Catholic Church—and to its intellectual patrimony, the scholastic tradition of the middle ages. Duhem was taking a considerable risk in portraying the church as the safeguard of intellectual inquiry and the medievals as the precursors of modern science.

Duhem, though, had qualities of both mind and character to fit him for his task. His parents attended carefully to his formation. After being privately educated in a small school near the family home in Paris, Pierre was sent at age 11 to an excellent lycee, the College Stanislas. Here he demonstrated a proficiency in classical languages (which would prove very useful for his historical studies) and developed an interest in scientific subjects. Upon completion of the courses at the college he gained entrance to the prestigious Ecole Normale Supérieure. At the Ecole the rigor of the work in the sciences and mathematics helped to instill in Duhem a highly critical outlook regarding scientific explanations. In particular he learned to look upon mechanistic and atomistic theories with distrust. Thus it was that he turned to thermodynamics for a dissertation topic, hoping to find in it the satisfaction his mind demanded. Duhem chose to defend a thesis in which he developed and extended Gibbs' concept of chemical potential. However, in using chemical potential as the measure of spontaneity for chemical processes, he was running directly counter to the position of the well-established and influential Marcellin Berthelot, a leader in the French scientific community. On the basis of his own experimental work Berthelot had devised the so-called "principle of maximum work" according to which the enthalpy governs the spontaneity of a reaction (8). Thus, to no one's surprise, the thesis was rejected, and Duhem was required to prepare another topic. However, in a characteristic move, Duhem proceeded to have the original work published. In all probability, this action, along with his forthright manner and his uncompromising adherence to his Catholic faith, prejudiced his chances for a good university appointment. As it turned out Duhem never had the opportunity to teach at one of the major schools in Paris. Instead he received a post at Lille from which he later on went to Bordeaux where he spent most of his career.

The injustice done to him did not prevent Duhem from applying himself in his teaching and research. He worked

without stint—partly, perhaps, to assuage his grief at the death of his young wife in childbirth—and gradually the ideas that he had promoted won general acceptance.

It was in the course of his teaching at Lille that Duhem was first led to historical and philosophical studies of science. By his own account, his attempts to present students with a coherent picture of the foundations of mechanics and thermodynamics forced him to take a searching look at the whole scientific enterprise. His first work on the history of science appeared in 1895. A few years later he published the results of his investigations on the origins of statics and mechanics. These preliminary studies culminated in the "Études" and the "Système du monde." What is striking about these works is that, unlike many previous efforts in the field (as well as some subsequent ones), they were not derived from secondhand accounts of science in earlier ages. Duhem consulted original manuscripts, concentrating especially on the writings of physical theorists at the University of Paris during the 14th, 15th, and 16th centuries. What he found has provided historians with considerable material for both study and controversy. Unfortunately, this work is still unknown to the wider public.

On the basis of his research Duhem contended that the discoveries of the 17th century, most notably those of Galileo, grew out of a tradition that extended back several centuries. The names of major thinkers in natural science—Jean Buridan, Nicolas Oresme, Albert of Saxony, and Domingo de Soto, among others—gained currency mostly through the labors of Duhem as did the argument that the isolated genius cannot be regarded as the sole source of scientific discovery. As Duhem wrote, "Great discoveries are almost always the fruit of a slow and complicated growth occurring over a period of centuries" (4). Further, "Science knows no spontaneous generation. The most unexpected discoveries are never created entire within the intellect that gave them birth" (9). What was even more upsetting to Duhem's opponents was his further claim that only in the matrix of a Christian society was a fully consistent science possible.

Modern science was born on the day when it was possible to proclaim this truth: the same mechanics, the same laws govern both celestial motion and sublunary motion . . . For it to be possible to think such a thing the stars had to be removed from the realm of the divine where antiquity had placed them; a revolution in theology had to be brought about . . .

That revolution was the work of Christian theology (5).

This, essentially, was the burden of Duhem's greatest work, the "Système du monde." In several thousand pages he traced the gradual development of scientific thinking from Plato to Copernicus and showed the debt that each culture owed to its predecessors as ideas were borrowed and assimilated into new systems. However, he maintained that one major discontinuity, the overthrow of pantheistic theologies by Christian theology, had laid the basis for the development of modern science. Only when God and nature were recognized as distinct objects of study was science able to flourish.

Duhem was also bold in his thinking on the philosophy of science. Because his critical outlook resembles Ernst Mach's philosophy, he has often been classified along with Mach as a

positivist. It is true that Duhem saw theory as a method of organizing the facts of experience in an economical fashion and that he believed it to be devoid of explanatory power (6). However, it would have been difficult for someone like Duhem, a great admirer of Pascal's critical but realistic thought (especially his Christian apologetics), to be a thoroughgoing disciple of Mach whose skepticism extended to almost everything (10).

Duhem's description of his own position in the "Aim and Structure of Physical Theory" points up his differences with Mach. Unlike Mach, Duhem granted that the classification of laws approaches a "natural classification"; in theory he believed that one might find something similar to "a transparent reflection of an ontological order" (6). Thus the scientist's representation of reality is not arbitrary by any means. Rather, it leads him toward reality.

The neat way in which each experimental law finds its place in the classification created by the physicist and the brilliant clarity imparted by this group of laws . . . persuade us . . . that such an order does not result from a purely arbitrary grouping imposed on laws by an ingenious organizer . . . Without claiming to explain the reality hiding under the phenomena whose laws we group, we feel that the groupings established by our theory correspond to real affinities among the things themselves (6).

Thus is the way opened for contact between the abstractions of the scientist and the real world around him. Duhem was able to steer a course between idealism and naive realism because, like Pascal, he possessed the insight to recognize the limitations of skepticism. It was just these limitations that Mach overlooked.

One of Duhem's biographers has described him as the greatest intellect of France at the turn of the century. Yet as Duhem himself realized, his intellectual achievements rested upon his ability to temper his keen mind and wide learning by careful reflection upon experience and by a strong religious faith. It was these which enabled him to avoid what he once called "the mad ambitions of dogmatism as well as the despair of Pyrrhonian skepticism" (11).

Duhem's life, as much as his work, deserves careful study by scientists.

Literature Cited

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- (8) But see Veibel, S. In "Dictionary of Scientific Biography"; Gillispie, C. C., Ed.; Scribner's: New York, 1971; Vol 13, 358. (Veibel points out that a Danish chemist, Hans Thomsen, had arrived at the same generalization many years earlier.)
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