Historical Studies in the Physical Sciences

9

Historical Studies in the Physical Sciences

RUSSELL McCORMMACH
and
LEWIS PYENSON,
Editors
ROY STEVEN TURNER,
Assistant Editor

Ninth Annual Volume

THE JOHNS HOPKINS UNIVERSITY PRESS
Baltimore and London

Manufactured in the United States of America

The Johns Hopkins University Press, Baltimore, Maryland 21218
The Johns Hopkins Press Ltd., London

Library of Congress Catalog Card Number 77-75220
ISBN 0-8018-2045-6

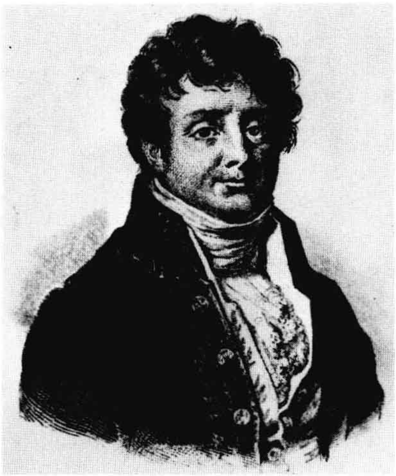
Historical Studies
in the
Physical Sciences
9

Notice to Contributors

Historical Studies in the Physical Sciences, an annual publication issued by The Johns Hopkins University Press, is devoted to articles on the history of the physical sciences from the eighteenth century to the present. The modern period has been selected since it holds especially challenging and timely problems, problems that so far have been little explored. An effort is made to bring together articles that expose new directions and methods of research in the history of the modern physical sciences. Consideration is given to the professional communities of physical scientists, to the internal developments and interrelationships of the physical sciences, to the relations of the physical to the biological and social sciences, and to the institutional settings and the cultural and social contexts of the physical sciences. Historiographic articles, essay reviews, and survey articles on the current state of scholarship are welcome in addition to the more customary types of articles.

All manuscripts should be accompanied by an additional carbon or photocopy. Manuscripts should be typewritten and double-spaced on 8½" × 11" bond paper; wide margins should be allowed. No limit has been set on the length of manuscripts. Articles may include illustrations; these may be either glossy prints or directly reproducible line drawings. Articles may be submitted in foreign languages; if accepted, they will be published in English translation. Footnotes are to be double-spaced, numbered sequentially, and collected at the end of the manuscript. For detailed instructions on documentation form and other stylistic matters, contributors are referred to the *MLA Style Sheet,* 2nd edition (note that the 2nd edition has introduced a number of important changes). All correspondence concerning editorial matters should be addressed to Russell McCormmach, Department of History of Science, Johns Hopkins University, Baltimore, Md. 21218.

Fifty free reprints accompany each article.



Clockwise from the upper left: Joseph Fourier, Michael Faraday, William Thomson, André-Marie Ampère. (Courtesy of the Edgar Fahs Smith Memorial Collection, University of Pennsylvania, and *Oeuvres de Fourier*, 2, ed. Gaston Darboux [Paris, 1890]).

Historical Studies in the Physical Sciences 9

Contents

The Transmission of Physics from France to Britain: 1800–1840

By Maurice Crosland and Crosbie Smith*

1. INTRODUCTION

Although historians have generally agreed that physics had emerged as a subject in its own right by the mid-nineteenth century, they have differed in their assessment of how this came about. Some have stressed methodology, others institutional criteria, and the importance of the energy concept has also been recognized.[1] Yet, there has been no adequate interpretation of the diverse influences on different people working within physical science in Britain during the first half of the nineteenth century. It is, therefore, the aim of our paper to examine the premise that a subject known as *la physique* in France was of crucial relevance to the emergence of physics in Britain and to investigate the implications of this transmission for British natural philosophy in the period 1800–1840.

We shall attempt to study the French-British transmission more closely than has been done up to now. The influence from France has often been seen as a purely mathematical one, and undoubtedly the adoption by British mathematicians of continental analytical methods and notation was of great importance in permitting the solution of complex physical problems.[2] Nonetheless, we cannot accept that mathematics provides a complete answer to the historical question of what was transmitted and how it influenced British science. Other possible dimensions of the question demand consideration. There is the general problem of how *la physique* affected existing British traditions. Were they replaced, modified, or added to? And if so, to

*Unit for the History, Philosophy, and Social Relations of Science, Physics Laboratory, University of Kent, Canterbury, England.

[1]See, for example, R. H. Silliman, "Fresnel and the Emergence of Physics as a Discipline," *Historical Studies in the Physical Sciences, 4* (1974), 137–162, and D. S. L. Cardwell, *From Watt to Clausius: The Rise of Thermodynamics in the Early Industrial Age* (London, 1971), pp. 291–293. The establishment of the first chair and laboratory for experimental physics in Britain is described in J. G. Crowther, *The Cavendish Laboratory: 1874–1974* (London, 1974), especially pp. 23–79.

[2]W. R. R. Ball, *A History of the Study of Mathematics at Cambridge* (Cambridge, 1889), pp. 117–137; J. M. Dubbey, "The Introduction of the Differential Notation to Great Britain," *Annals of Science, 19* (1963), 37–48; J. Herivel, "The Influence of Fourier on British Mathematics," *Centaurus, 17* (1973), 40–57.

what extent? *La physique* could have simply reinforced existing views, or it could have completely changed—conceptually, institutionally, and mathematically—the British systems. Furthermore, did the transmission relate to *la physique* as a whole, or to specific theories or individual branches of it, or to a combination of these possibilities? The aim of our paper is to suggest answers to these questions, and to do so we will have to enquire into the meaning of *la physique* in the early part of the period and to ask in what way it differed, if at all, from natural philosophy in Britain.

Before beginning the enquiry, however, a brief look at what is involved in transmission is necessary. Transmission may take place at two levels. At the first and simple level, someone sees a treatise or printed memoir, for example, and becomes aware of the physical existence of the work. At the second and more complex level, he responds to the work in the light of his own views. Either he may treat the work passively and lay it aside permanently, or he may sooner or later react and be led to realize one or more of several possibilities. He may reject the work wholly and decisively as contradicting his own views and as providing an unacceptable alternative to them. Or he may accept the work either in its entirety or critically and only partially. In the latter situation, he may review, popularize, teach, if necessary translate, debate, or develop the work to the extent that it integrates with, adds to, modifies, or replaces his views. After total or partial acceptance, the original work may be further transmitted either as it was or as it was reshaped, criticized, and developed. The process of transmission is a dynamic one of continual change and debate, involving frequent interaction among men of science through verbal exchanges or letters or through treatises, texts, or papers. In what follows, we will show that all of these aspects of transmission were present in varying degrees.

In his classic analysis of early nineteenth-century European thought, J. T. Merz drew attention to the rigid demarcations between sciences in the continental schools and the absence of such separations in Britain. He pointed out that the links between the sciences in France especially were few and ill-defined, whereas in Britain there was, by virtue of the fluidity of the boundaries of particular subjects and the use of the general term "natural philosophy," the suggestion of some uniting bond between all natural studies.[3] Such a general claim must be given consideration if we want to appreciate fully the nature of the transmission of physics from France to Britain in our period.

[3]J. T. Merz, *A History of European Thought in the Nineteenth Century*, 2 (Edinburgh and London, 1903), 98.

Although British natural philosophers were very loyal to their native Newtonian heritage, they did not all necessarily have the same views. Newtonianism was diverse in its tenets and allowed a wide range of interpretations. For instance, emphasis on experiment and observation and emphasis on mathematical, often geometrical, principles reflected eighteenth century images of Newton's *Opticks* and of his *Principia*, respectively. Desaguliers could stress experiment and a Cambridge mathematician could stress the *Principia*, and yet both were considered natural philosophers.

Of course, the range and diversity of Newtonianism does not permit a simple classification into experimental and mathematical methodologies. Particularly in Scotland, Newtonianism—perhaps interpreted through early Common Sense philosophy—had its own style of demarcating knowledge. John Robison, the professor of natural philosophy at Edinburgh from 1774 to 1805, recognized at least four meanings in the term "natural philosophy."[4] The two most general meanings referred to the study of all nature, both material and immaterial, and of all material nature. In these two senses, the term "physics" was also employed. The third meaning was the study of the laws and causes of the material world as distinct from description and classification, which were termed "natural history." Finally, in its most restricted sense, natural philosophy meant the study of sensible motions, often called "mechanical philosophy," as distinguished from the study of the phenomena of insensible motions, called "chemistry." Robison did not favor the extension of mechanical philosophy to the province of insensible motions, and he wrote of the "lever diagrams" in Joseph Black's chemical lectures: "Dr. Black first employed this diagram, but he gave it up, because it suggested a notion not chemical, but mechanical. Levers can have no place here. . . ."[5] Black himself regarded with suspicion "the attempts of ingenious men to explain the chemical operations by attractions and repulsions."[6] The conceptual divisions between natural, or more precisely mechanical, philosophy and chemistry were also recognized

[4]For a discussion of Robison's demarcations of knowledge, see Crosbie Smith, "'Mechanical Philosophy' and the Emergence of Physics in Britain: 1800–1850," *Annals of Science*, 33 (1976), 3–29, especially 6–11. The concepts of motion and force and the laws of dynamics were central to Robison's mechanical philosophy and provided him with both a demarcation of his subject from chemistry and natural history and a unity among the branches of natural *qua* mechanical philosophy.

[5]J. Robison, ed., *Lectures on the Elements of Chemistry by the Late Joseph Black* (Edinburgh, 1803), *1*, 545. For a detailed discussion of "lever diagrams" see Maurice Crosland, "The Use of Diagrams as Chemical 'Equations' in the Lecture Notes of William Cullen and Joseph Black," *Annals of Science*, *15* (1959), 75–90.

[6]Robison, *op. cit.* (note 5), *1*, 282.

by the Scots Robison, John Playfair,[7] Robison's successor, and Thomas Thomson, later editor of the influential journal *Annals of Philosophy*. Thomson wrote:

> Substances may either be examined in a state of rest, or as acting upon each other and producing changes on each other. The knowledge derived from the first of these views, is called *Natural History;* that which we obtain by the second, is distinguished by the name of Science. But bodies cannot act upon each other without producing motion, and the motions produced by such actions are of two kinds; either so great as to be visible to our senses, and capable of being measured by the space passed over; or so small as not to be distinguishable by our senses, except by the effects produced. The phenomena connected with the first of these kinds of motions constitute what is called *Natural Philosophy* or *Mechanical Philosophy* in this country, and on the Continent, *Physics.* The phenomena connected with the imperceptible motions belong to the science called *Chemistry.*[8]

Thomas Thomson's divisions of natural knowledge into natural history, mechanical philosophy, and chemistry reflected the divisions of the table of contents of the third through eighteenth volume of the abridged version of the *Philosophical Transactions* published in 1809.[9] From the third volume, the contents of each volume were classified under the general headings of mathematics, mechanical philosophy (including dynamics, statics, astronomy, hydrostatics, hydraulics, pneumatics, acoustics, optics, and magnetism), natural history, and chemical philosophy. These demarcations of knowledge were therefore widespread in Britain, receiving particular emphasis in Scotland, at the beginning of the nineteenth century.

In his comment on the continental use of the term "physics," Thomson probably had in mind a French work such as R. J. Haüy's *Traité élémentaire de physique* of 1803, which was translated into English in 1807, the term *physique* being rendered as "natural philosophy."[10] Haüy recognized three divisions in natural knowledge: "physics," chemistry, and natural history. "Physics" considered bodies in their

[7]Smith, *op. cit.* (note 4), pp. 11–14.

[8]Thomas Thomson, *History of the Royal Society from its Institution to the End of the Eighteenth Century* (London, 1812), p. 311. As we shall see, *Annals of Philosophy* was probably the British journal which contributed most to transmission in the period 1813–1825.

[9]*Philosophical Transactions of the Royal Society of London* (London, 1809).

[10]R. J. Haüy, *Traité élémentaire de physique* (Paris, 1803). This work was translated as *An Elementary Treatise on Natural Philosophy* by Olinthus Gregory (London, 1807).

general and permanent properties or bodies undergoing changes that were so slight and transitory "that the causes which produced them need only disappear, in order that the bodies may return to their former state." "Physics" also treated of the laws of action of bodies at "more or less considerable" distances. Chemistry, on the other hand, treated of phenomena which depended "upon an intimate action, which the moleculae of bodies exercise on each other, at distances nearly infinitely small, and in virtue of which these moleculae separate to reunite in a different order, and produce new combinations or new properties."[11]

Like many of his French predecessors[12] and unlike his British contemporaries, Haüy also distinguished between *physique générale* and *physique particulière.* Under *physique générale* he discussed what were for him the general properties of bodies: divisibility, gravitation, affinity, and caloric; under *physique particulière* he subsumed the phenomena relating to water, air, electricity, magnetism, and light.[13] At first sight one sees little that unites all these subjects other than that they refer to general and particular properties of material bodies and that the division is in agreement with Newton's methodology. However, a closer examination of Haüy's *Traité* reveals that he was committed to the Newtonian program of understanding phenomena in terms of attractive and repulsive forces, and he remarked on his debt to Laplace: "we conceive ourselves bound to express our acknowledgement here, that we have gained much from the discourses of the celebrated Laplace. It is known, that in the midst of his sublime investigations relative to physical astronomy, he has discovered the secret of acquiring, in different branches of knowledge, a superiority rarely attained even by those who cultivate only one."[14]

What had emerged as physics in France in the early nineteenth century was occasioned by three main developments. First, in the eighteenth century institutional recognition of demonstration and experiment in the study of nature (and particularly in the new study of electricity) had grown out of a general acceptance of Newtonian concepts and out of the popular success of *physique expérimentale.*[15] The

[11]Haüy, *An Elementary Treatise on Natural Philosophy* (note 10), *1,* i–ii.

[12]For example, Étienne Barruel, *Journal de l'École Polytechnique, 2* (1799), 128–142. See also Silliman, *op. cit.* (note 1), p. 141. Silliman refers to Denis Diderot in this connection.

[13]Haüy, *op. cit.* (note 11), *1,* vii–xvii.

[14]*Ibid.*, *1,* xviii.

[15]See Jean Torlais, "La physique expérimentale," in R. Taton, ed., *Enseignement et diffusion des sciences en France au XVIIIe siècle* (Paris, 1964), pp. 619–645. On Coulomb see C. Stewart Gillmor, *Coulomb and the Evolution of Physics and Engineering in Eighteenth-Century France* (Princeton, 1971).

development was marked by the establishment of a chair of *physique expérimentale* at the Collège de Navarre in 1753. The incumbent was the abbé Nollet, whose *Leçons de physique expérimentale* was influential through its many editions. Collections of physical apparatus or *cabinets de physique* became fashionable. Less dilettante were the interests of some who combined practical interests with mathematical training, notably Coulomb and Borda. In the Académie Royale des Sciences *la physique* was recognized as a subject in 1785 as a result of pressure from Lavoisier who argued that studies in this field had been discouraged by the failure of that institution to devote a section to it. Thus before the Revolution different branches of science had received some measure of institutional recognition in the Academy.[16]

Second, French mathematics had reached a high level during the second half of the eighteenth century, an achievement due at least in part to the support given to mathematics by institutions such as the military academies, of which Coulomb and Borda were graduates, and the Académie des Sciences in Paris, of which they became members. With money from the royal treasury the Academy could tempt a distinguished mathematician like Lagrange to move from Berlin to Paris, and its sections of *Géometrie* and *Mécanique* gave recognition to other outstanding mathematicians including D'Alembert and Laplace. After the Revolution new teaching institutions such as the École Polytechnique concentrated mathematical talent.[17]

The third element contributing to the emergence of physics in France was the reductionist program of Laplace's mathematical physics which reshaped the diffuse conceptions of eighteenth-century French physics, whether general or particular, mathematical or experimental. Laplace's achievements and research program came to dominate early nineteenth-century French physical science.[18] By aiming to reduce all

[16]See Roger Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666–1803* (Berkeley, 1971). On Lavoisier's proposals for reform of the Academy see *Oeuvres de Lavoisier, 4* (Paris, 1868), 559. For a recent assessment of the relation of chemistry to physics in the work of Lavoisier see Henry Guerlac, "Chemistry as a Branch of Physics: Laplace's Collaboration with Lavoisier," *Historical Studies in the Physical Sciences, 7* (1976), 193–276.

[17]A. Fourcy, *Histoire de l'École Polytechnique* (Paris, 1828), p. 73; Maurice Crosland, "The Development of a Professional Career in Science in France," in M. P. Crosland, ed., *The Emergence of Science in Western Europe* (London, 1975), pp. 139–159. At the École Polytechnique *la physique* was assigned to two teachers, Hassenfratz and Barruel, who represented more the experimental and practical aspects of *la physique*. Neither were they of the same calibre as Fourcroy, Berthollet, and Guyton assigned to chemistry or Lagrange and Prony who taught analysis and mechanics.

[18]See Robert Fox, "The Rise and Fall of Laplacian Physics," *Historical Studies in the Physical Sciences, 4* (1974), 89–136. Laplace's major works were *Traité de mécanique céleste* (Paris, 1799–1825) and *Exposition du système du monde* (Paris, 1796).

phenomena of nature to the action of attractive and repulsive forces between the particles of both ponderable and imponderable matter, Laplace gave a new quantitative coherence and unity to physics. Because he enjoyed the favor of the Napoleonic régime, because he had influence at the École Polytechnique, at the Bureau des Longitudes, at the Society of Arcueil, and at the Institute, and because he had a large income, Laplace controlled much of French science. His followers and co-workers soon included Haüy, Poisson, Gay-Lussac, Biot, and Malus who were to become distinguished for a variety of physical researches.[19] Through Laplace, therefore, physics in France was given a comprehensive research program which existed in a centralized system dominated by the political and academic power of the author of the *Mécanique céleste.*

For a time Laplace's physics brought together experimental, theoretical, and mathematical dimensions of the subject. Experiments were used to test theories based on the conceptual framework of attractive and repulsive forces and expressed in the mathematical language of analysis. Speaking of capillarity, Laplace said: "After these phenomena had been reduced to a mathematical theory, it was necessary in order to compare the latter exactly with nature to carry out a series of very precise experiments on this subject. The need for such experiments makes itself felt to the extent that *la physique* as it develops becomes more related to analysis. Then by the comparison of experiment with theory one could raise the latter to the highest degree of certainty of which the physical sciences are capable."[20] In other words, Laplace avoided the extremes of qualitative experimentation on the one hand and of Lagrange's abstract analytical mathematization on the other.

Despite Laplace's unified approach, however, Biot, one of Laplace's most ardent disciples, described the state of European physics in 1816 as one of general disunity. In a key work he aimed to remedy this situation mainly through the realization of the Laplacian program:

> Everyone who has had occasion to make extensive researches has seen with regret the scattered state of the materials of this fine science, and the uncertainty under which it still labours. One result is admitted in one country, and another in another. Here one numerical value is constantly employed, while in another

[19]Maurice Crosland, *The Society of Arcueil. A View of French Science at the Time of Napoleon I* (London, 1967).
[20]P. S. Laplace, *Exposition du système du monde,* 4th ed. (Paris, 1813), p. 349.

> place it is regarded as doubtful or inaccurate. Even the general principles are far from being universally adopted. . . . *What it wants is union.* It is the junction of the parts that makes a single body of it; it is a fixing of the data and the principles which gives the same direction to all efforts. This is what I have attempted to do. The task was difficult: the public will judge of the success.[21]

An examination of Biot's *Traité de physique* reveals the extent to which he saw himself following Newton's methodology of experiment and mathematics. Biot rejected a purely experimental approach to physics and advocated the connecting of phenomena by analytical or algebraic formulas which would allow the reduction of the phenomena to some simple law.[22] This experimental and mathematical methodology provided a unified approach to physics, but it did not guarantee the conceptual unity of the branches of physics. Biot's *Traité* also shows his devotion to the Laplacian reductionist program: he discusses electricity from the point of view of Coulomb and Poisson, light from the point of view of the Newtonian particulate theory, and heat from the point of view of the caloric theory.[23] The concepts of attractive and repulsive forces are never far beneath the surface in Biot's discussions. For the French physicists of the Laplacian school, as exemplified by Biot, therefore, *la physique* was given unity by both Newtonian methodology and the program of reduction to Newtonian central forces.

When the domination of Laplacian physics in France came to be challenged, the tradition of the École Polytechnique encouraged the mathematical treatment of new concepts. The work of Fourier on heat, of Ampère on electromagnetism, and of Fresnel on light were further triumphs for mathematical physics and had, as we shall demonstrate, a tremendous impact on British natural philosophy, introducing to it not only mathematical sophistication, but also new concepts.

British physics in the early nineteenth century did not have the conceptual and institutional coherence given to French physics by the Laplacian program. It is true that in Scotland natural philosophy was separated conceptually from chemistry and natural history, but it lacked advanced mathematical analysis. At the same time there

[21]J. B. Biot, *Traité de physique expérimentale et mathématique* (Paris, 1816), *1*, ii–vii. The translation of this passage from Biot's dedication to Berthollet was made for *Annals of Philosophy, 10* (1817), 459. Our italics.

[22]For an account of Laplace's methodology, see Roger Hahn, *Laplace as a Newtonian Scientist* (Los Angeles, 1967), pp. 7–8.

[23]For a survey of the range of Biot's *Traité,* see *Annals of Philosophy, 11* (1818), 58–63.