Perrin does not hold a prominent position in the historiography of modern physics because his results were basically qualitative. There was no new "rule" to name after him.

Another historical puzzle that has invited misinterpretation is the demise of the caloric theory of heat. Count Rumford's experiments, which, perhaps, should have persuaded physicists and chemists that heat could not be a substance, in fact had no such effect. Caloric kept its supporters until the idea was almost universally replaced in the 1830's by an erroneous, briefly held, "wave theory of heat." The success of the wave theory of light in the 1820's and 1830's suggested a comparable theory for radiant heat. It was an easy step to conclude that all heat transfer except for the bulk motion of convection was accomplished by radiation. Conduction, in particular, could be explained by waves in the aether between neighboring molecules. Because the caloric theory could not easily explain heat radiation, it seemed simpler to account for all heat transfer by vibrations in the aether. The wave theory of heat served as a temporary bridge between the caloric theory and the kinetic theory, spanning a conceptual gap that most scientists had been unable to cross.

Brush also finds that scientific concepts often have extremely vague meanings while they are being developed and that the historian has to be constantly on his guard against mistaken interpretation. For instance, in reference to the wave theory of heat mentioned above, Professor Philip Kelland of Edinburgh stated his continuing support of the caloric theory by saying that recent experiments had demonstrated that the heat is transmitted by vibrations of the parts of the caloric. But according to the old caloric theory, caloric *is* heat. In referring to vibrations in the caloric, Kelland abandoned the substance of the caloric theory. He claimed to be an advocate of the caloric theory and used its terminology, but in fact he adopted the wave theory.

Another example is the so-called ergodic hypothesis, that a mechanical system left to itself will pass through every point of the phase space lying on a certain energy surface. Even with very close reading of the texts, it is difficult to tell whether Ehrenfest, for example, meant ergodic or quasi-ergodic when he discussed the hypothesis, that is, whether he saw the system as passing through every point or only infinitely close to every point. The distinction is crucial, but because it was not regarded as crucial at the time the meaning of the term "ergodic" is blurred.

The word "randomness" presents similar problems. Does a scientist describing a "random" process mean that the process itself is random or merely that it appears random because of our lack of knowledge? Often the scientist himself does not see the difference.

In a final example, Brush shows that the concept of conduction in a gas did not have a clear meaning until the advent of kinetic theory and that even then it was next to impossible to separate the phenomenon of conductive heat transfer from that of radiative heat transfer in a gas. Modern textbooks regard conduction and radiation as very different phenomena and therefore relegate them to different chapters. The history then tends to become divided along the same lines as the textbooks, but it should not be. Historically the phenomena were studied together.

In these and other examples, Brush does a great service to the history of science by emphasizing the confused state of developing concepts in physics. It is all too easy for the historian to see a familiar word like "reversibility" and attach an equally familiar meaning to it without checking to see if the original author was using the word in the same way.

Another innovation in this book is the use of referees' reports to document the reception of a new theory. The first papers on the kinetic theory by John Herapath and John Waterston were rejected by the Royal Society. Waterston's statement of the equipartition theorem was in a paper that Sir John Lubbock called "nothing but nonsense, unfit for reading before the Society." When we consider that at approximately the same time Laplace and his coterie at the French Academy were blocking papers by physicists of the caliber of Fresnel and Fourier, we begin to wonder how much the course of 19th-century science was directed by private animosities and personal prejudices. Even Clerk Maxwell, the most even-handed of critics, was not above making use of a paper by Osborne Reynolds that he had refereed and casting aspersions upon Reynolds's ideas before the author was in a position to defend himself.

I have concentrated on the more controversial and interpretative parts of Brush's book. It also contains a great deal of factual information of value to any historian of 19th-century physics. It is not a book that one is likely to read straight through, but there is much in it for specialist and nonspecialist alike to think about.

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Sidelights on Darwin

The Collected Papers of Charles Darwin. PAUL H. BARRETT, Ed. University of Chicago Press, Chicago, 1977. Vol. 1, xviii, 278 pp., illus. $20. Vol. 2, viii, 326 pp. $20.

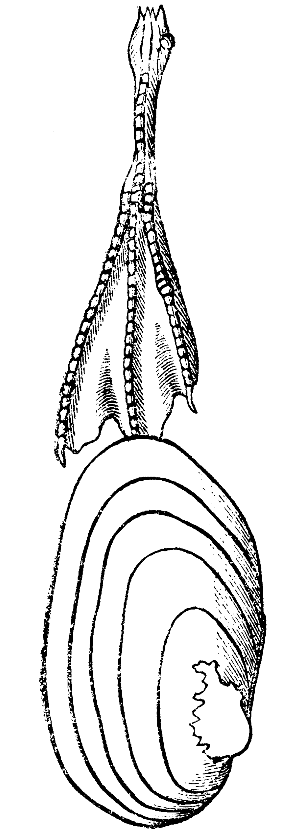
Hitherto it has been necessary to seek out Darwin's minor works in a variety of journals many of which are hard to come by. Barrett has rendered an invaluable service to Darwin scholarship by searching through often obscure sources, such as horticultural journals, and presenting us with many previously unknown or forgotten publications.

However, the fact that Darwin's works are more accessible does not mean that they will be read, much less read with understanding. One must realize that Darwin was as near to being a pantologist as was possible in his day. In the late 1830's he worked out a vast theoretical system. But he did not begin to publish on it until 1858, and it took the rest of his life to present his views in detail. The evolutionary content of the works he published prior to 1858 is cryptic, and even those published later are hard to follow. To appreciate the minor works requires a solid grasp of the major ones, and the general reader would best prepare himself by reading Darwin's books first. Even for a reader who has undergone such preparation a certain amount of exegesis would be helpful. Barrett provides none, and it seems appropriate that I proffer a few suggestions in this review.

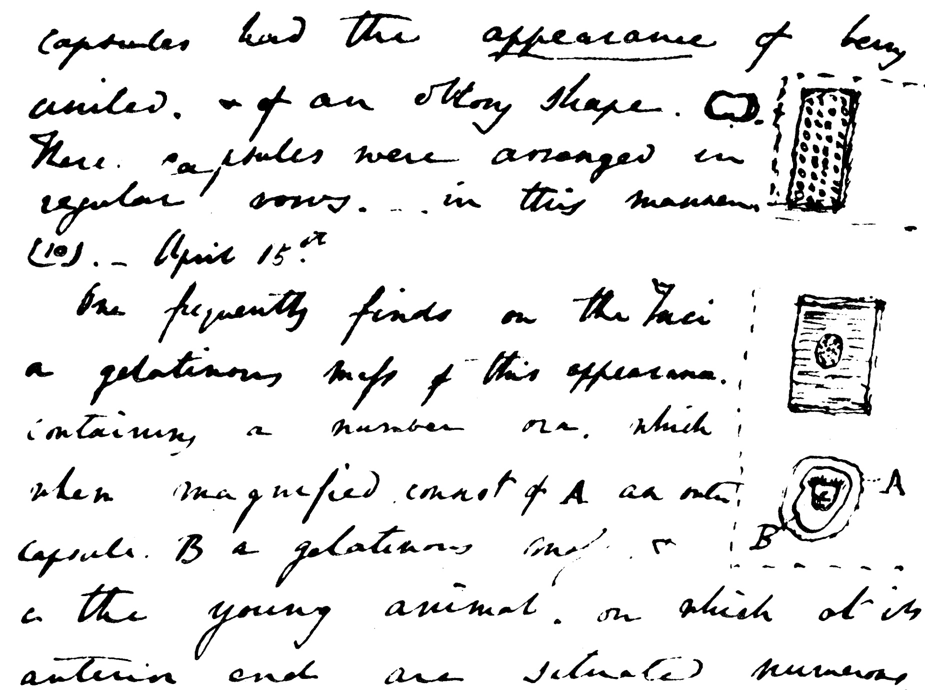
Some of the papers, such as the joint publication with Wallace and the ones on heterostyly and orchids, are preliminary notices of work Darwin later presented in greater detail. The general reader will find them interesting curiosities, but would be better off using the definitive works. Specialists will find them invaluable, for, as with revised editions, point-by-point comparison manifests the evolution of the views expounded. Likewise the paper on the parallel roads of Glen Roy (of which Darwin was "ashamed") and his reply to Galton on pangenesis cast some light on Darwin's errors, but they are hard to assess unless one has an appreciation of what data were available at the time.

Many of the papers are brief communications filling in details of interest and following up on earlier publications. A few reply to criticisms and are of interest for that reason, but one needs to go back and read the critiques themselves before one can evaluate them.

There are, however, many papers of broader interest. The joint paper with



A living specimen of *Unio* "secured in the act of being transported." In a communication to *Nature*, 30 May 1878, Darwin wrote, "It is well known that animals and plants inhabiting freshwater have, as a general rule, a very wide distribution; yet each river system . . . seems completely cut off from every other system of the same country. Still more complete is the separation between the freshwaters of distinct continents or of islands; nevertheless they often possess . . . species in common. In my "Origin of Species" I have suggested various means of transportal; but as few facts on this head are positively known, the case [shown here] seems to me well worth recording." According to Arthur H. Gray, from whom Darwin received the sketch, the bird was a blue-winged teal (*Querquedula discors*) shot near the Artichoke River at West Newbury, Massachusetts, and the mollusk was *Unio complanatus*. [From *The Collected Papers of Charles Darwin*]


capsules had the appearance of being coiled. & of an oblong shape. (9). These capsules were arranged in regular rows. . . in this manner. (10). — April 15th.
One frequently finds on the Fuci a gelatinous mass of this appearance, containing a number ova, which when magnified consist of A an outer capsule. B a gelatinous mass. & C the young animal. on which at its anterior end are situated numerous

A passage from "On the Ova of Flustra, or, Early Notebook, Containing Observations Made by C. D. When He Was at Edinburgh, March 1827," Cambridge University Library Handlist (1960), no. 118. [Reproduced in *The Collected Papers of Charles Darwin* by permission of the Cambridge University Library]

FitzRoy on "the moral state of Tahiti, New Zealand, &c." (1836) and the much later notes on vivisection reveal Darwin's concern with moral issues. This is well borne out by the correspondence. Everyone should read Darwin's "Biographical sketch of an infant." This was published in 1877, but is based on observations made 37 years earlier. It deals with such questions as whether the "moral sense" is innate or learned. Darwin's early notebooks contain much along these lines. Way back in the 1830's he was actively engaged in research on some of the questions that currently occupy sociobiologists, and in 1872 he published an important treatise on the evolution of social behavior. His papers on instinct also are of some current interest and show his views on evolutionary psychology.

Geologists especially will want to study Darwin's papers on that subject. Everybody knows of Darwin's theory about the origins of coral reefs, but his lifelong interest in and extensive contributions to geology tend to be forgotten.

The paper entitled "Geology," first published as a chapter in *A Manual of Scientific Enquiry; Prepared for the Use of Her Majesty's Navy: and Adapted for Travellers in General* (1849), edited by John Herschel, provides advice for the beginner and a candid exposition of how science should be done. The paper was much reprinted, and I note in passing that editions vary.

A number of the papers amount to requests for information. They, together with letters, tell us what questions Darwin was asking and when. More important, they show that he did indeed ask questions. He held that people are good observers because they are good theorists, not the reverse. Unfortunately, he tends to fake it as a "Baconian" in most of his publications.

It is interesting to uncover the hidden meaning behind some of the papers. Anybody who knows the *Origin of Species* will understand the rationale of the papers on the effect of seawater on seeds. Like biogeographers today Darwin was interested in dispersal. The paper on double flowers (1843) can be appreciated only by an expert. It deals with the effects of the environment in producing variants by action upon the reproductive system, a topic to which Darwin returned in his evolutionary books. This paper is of no small interest, for it demonstrates beyond a shadow of a doubt that Darwin was, as he claimed, working on pangenesis way back in the 1840's; the idea was not, as his detractors have sometimes maintained, merely an effort to explain away difficulties in his theory. The papers on chaetognaths and flatworms are of great interest, but only if one realizes that they represent only a minor sample of the great mass of manuscript on invertebrate zoology done during the *Beagle* voyage, which Darwin never found time to publish. This material rests virtually unexamined in the Cambridge archives. Should it ever be exposed to view, it will set yet another myth to rest. Huxley vastly underrated Darwin's ability as a zoologist.

One could go on, but the point has been made. This collection reinforces our emerging reassessment of Darwin. He was a genius of the first rank and a man of immense learning, and he often worked a century or more ahead of his time. What a pleasure it is to bask in the sunlight of his intellect.

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