Book Reviews

The Strategies of Real Science

Method and Appraisal in the Physical Sciences. The Critical Background to Modern Science, 1800–1905. COLIN HOWSON, Ed. Cambridge University Press, New York, 1976. viii, 344 pp. $24.50.

If we ask such questions as "How do scientific theories develop through time?" or "What leads to the replacement of one theory by another?" we find that much of the best-known historical scholarship provides no satisfactory answers. A different weakness haunts much writing within the philosophy of science. Philosophers have offered us many careful and detailed analyses of scientific inference, but there is virtually unanimous agreement that none of the classical philosophical models of science finds any actual exemplifications in science itself. Erstwhile philosophers of science thus often find themselves developing models not of science as it is or has been but of some utopian enterprise which science neither is nor can become.

The essays in this volume aspire to achieving what neither history of science nor philosophy of science usually does: an account of actual science which, by utilizing a blend of historical data and philosophical argument, exhibits both how science has developed and the conditions under which such development can be regarded as rational and progressive. Put simply, the authors seek to apply the methodology of scientific research programs (a philosophical tool originally developed by Imre Lakatos) to a series of classical cases of theoretical confrontation in the sciences. Among the episodes treated are phlogistic and oxygen chemistry, wave and corpuscular optics, atomism and thermodynamics, and early relativity theory. In each case, the author's concern is to give a historically accurate and philosophically relevant explanation of the confrontation between different "paradigms." Some contributions come closer to achieving this goal than others; to that extent the volume is of uneven quality. It is nonetheless a fitting memorial to Imre Lakatos, since virtually all the contributions represent attempts to apply his provocative philosophy of science to some of the classic controversies in the history of science. If the book has any persistent flaw it is the reluctance of most authors to utilize the historical cases they discuss as instruments for moving beyond Lakatos's methodology. There seem to be times when opportunities for cogent criticism are ignored and when the actual cases are too rigidly compartmentalized in order to accommodate them within the framework. But the great strength of this work is that it does manage, rather more successfully than Kuhn's classic *Structure of Scientific Revolutions*, to raise some deep philosophical questions about the manner in which modern science has taken the form it has. It raises them, moreover, within the context of a fine-grained analysis of some of the most exciting episodes in the history of science.

Doubtless the book will encounter much resistance. Historians of science will see it as a sinister subversion of true history, insofar as its authors seek to force the complexities of history into the confines of a rigid philosophical system. Traditional philosophers, on the other hand, will be dismayed by the presumption that the data of history can have any significance for debates about the nature of scientific rationality.

On the whole, the essays vitiate these traditional criticisms. Here is a refreshingly brash approach which says to the philosopher of science that the legitimative and argumentative strategies of real science are far richer and more subtle than most philosophical models have allowed. Equally, it says to the historian that hidden within the seeming minutiae of the past are a set of profound philosophical puzzles about the nature of rationality, puzzles that bring a vitality and relevance to the past that are sorely lacking in most historical scholarship.

LARRY LAUDAN
Department of History and Philosophy of Science, University of Pittsburgh, Pittsburgh, Pennsylvania

Progressionism

Fossils and Progress. Paleontology and the Idea of Progressive Evolution in the Nineteenth Century. PETER J. BOWLER. Science History Publications (Neale Watson), New York, 1976. viii, 192 pp., illus. $9.95.

Popular accounts of geology work by synecdoche in assigning entire periods to single groups. Thus, an age of fishes (though it contained orders of magnitude more brachiopods) yields to an age of reptiles, and finally to an age of mammals (with vastly more beetles). Popular accounts of science follow the same strategy—the 16th century is Copernicus's, the 17th Galileo's, and the 19th Darwin's.

Evolution becomes the great watershed for natural science in the 19th century, and we align its scientists by their stance toward Darwin's insight. Buckland, Cuvier, and Agassiz stand together as antievolutionists (and bad guys); Lyell redeemed himself with a belated conversion; Darwin is a hero, and Chambers is a prophet (for his anonymous defense of evolution in 1844).

This anachronistic typecasting by the issues most relevant to our concerns often distorts the course of debate in its own time. I would be dismissed incredulously by many colleagues if I pulled out a scorecard with Buckland and Lyell on one side and Chambers and Agassiz on the other. Yet this is the proper lineup for an issue that agitated 19th-century paleontology far more than evolution—the continuously vexatious question of progress in the history of life. Does life move from lower to higher during its history (as the absurdly selective account in terms of "ages" implies)? If it does, what is the mechanism of advance? Bowler's splendid little book on progressionism in 19th-century paleontology finally restores a group of fine scientists to their own primary concerns.

Bowler traces ideas of progress from unilinear schemes of successive, disconnected creations to the branching and diverging trees of later evolutionists (though Darwin himself cared little for doctrines of progress and preferred to view evolution as a tale of adaptation to changing local environments). Once evolution triumphed, Spencer's belief in progress as the universal direction of development replaced earlier creationist accounts of organic advance. Earlier rationales proceeded along two very different paths. Some geologists followed the Paleyan tradition of natural theology: animals are exquisitely designed to fulfill their roles on a harmonious earth. The cause of organic progress must be sought in a direction of environmental change; for life must always match its surroundings perfectly. The earth, Buckland argued, cools continually through time. Mammals replace reptiles when colder climates require constant body temperatures for optimal design. Others, like Agassiz, argued that progress must reflect an intrinsic and independent tendency for perfection; since progress records the operation of God's mind in time, it cannot merely reflect something so vulgar as a vector of environmental change. Thus, Lyell and Buckland lined up on the side of climatic determinism, though they differed on the question of progress. For Buckland, climate changed directionally with time, and life progressed to match it. For Lyell, climates remained in dynamic steady state, and the mean complexity of life stayed constant. Agassiz and Chambers, on the other hand, accepted intrinsic progress as a sign of God's plan. For Agassiz, God worked by successive extinctions and creations; for Chambers, he labored by transmutation. Pro- and anti-evolutionism was simply not the issue.

The book, needless to say, is not without its problems. I hate to sound like a carping esthete, but I do wish that the quality of bookmaking matched the quality of content. The pages are cut unevenly in both copies I have seen, and my Xerox machine would have done much better with the plates. Bowler's fine work deserves better. Pride in craft goeth before higher prices, but ten bucks isn't cheap enough to excuse such a shoddy job.

Of course, the content is not immaculate either. With its passive infinitives and numerous discussions of minor debates among scholars, the book reads like a doctoral dissertation (perhaps it is). More seriously, its lack of attention to German sources (except for a few translated into English and French) leads to some parochialism. For example, Bowler claims that the argument of intrinsic advance, introduced by Agassiz and Chambers in the 1840's, represented a "totally new form of progressionism." But the German *Naturphilosophen*, writing for the most part between 1790 and 1810, had founded a whole school of thought upon this premise. In fact, as Bowler mentions in passing, Agassiz had studied with its two leading lights, Oken and Schelling. Admittedly, the *Naturphilosophen* did not emphasize fossils, but neither did anyone else in the days before Smith and Cuvier recognized their stratigraphic importance.

It might have required another book, but I wish that Bowler had not dismissed in a paragraph (admittedly by acknowledging its importance) the social and political influences upon arguments for progress in the 19th century. The absence of this dimension gives his book a character too close to his subject. It almost seems to argue for inevitable progress in scientific views about progress: as more and more fossils are found, scientists approach the evolutionary model of a branching tree. I don't wish to place myself in the camp of extreme relativism. As a professional paleontologist, I will be astounded if branching trees do not embody an empirical truth. Still, I do not see how any account of progressionism can be fully satisfying without an explicit treatment of the political themes that were wedded to its assertion. If progress had not been extracted from biological evidence, an age of aggressive imperialism would surely have invented it. If stately gradualism had not been championed as the primary mode of geological change, then liberals facing a world in revolution would have found it somewhere else in nature. Progress was the hottest subject in Victorian England. Working men at the Hand and Banner public house argued about it in George Eliot's *Daniel Deronda*. Kipling asserted a right of dominion over "lesser breeds without the law." Spencer outsold Darwin by a long shot. This faith did not rest on the evidence of fossils.

STEPHEN JAY GOULD
Museum of Comparative Zoology,
Harvard University,
Cambridge, Massachusetts

Petrology

The Evolution of the Crystalline Rocks. D. K. BAILEY and R. MACDONALD, Eds. Academic Press, New York, 1976. xii, 484 pp., illus. $35.

Although this book is composed of six chapters by six authors, it is too highly unified to be regarded as a collection of papers. The theme is the contribution of experimentally estimated phase equilibria to our understanding of nonsedimentary rocks. The editors' preface suggests that the book is intended as a sequel to N. L. Bowen's epochal and unsurpassed 1928 work, *The Evolution of the Igneous Rocks*. Except in spirit, it is clearly not that; half of it deals with metamorphic rocks, which Bowen did not cover, and many aspects of igneous petrology are not treated. The field has grown too large for adequately detailed treatment in a single volume. One of the most important variables represented in the book's numerous phase diagrams is pressure, which could not be adequately controlled at the same time as temperature until a decade after Bowen's book was published (all of his diagrams are limited to pressures of less than 80 atmospheres).

The book is, nevertheless, highly successful in its own right. Thanks to careful editing, the chapters are thoroughly integrated and cross-referenced, with little duplication of explanatory material. Increasingly sophisticated concepts are introduced throughout the book, so that the reader must study the chapters on metamorphic rock as well as those on igneous rock. In light of the increasing specialization among petrologists, this necessity is an exhilarating challenge that can only improve communication between specialists.

In the first part of the book, D. K. Bailey provides a 99-page summary of experimental techniques and strategy that is adequate for the nonpractitioner and a generally clear explanation of how to interpret phase diagrams. Bailey follows Bowen in avoiding thermodynamic vocabulary and equations, but he will surely offend most readers (from advanced undergraduates on) by claiming that "classical thermodynamic terms and concepts are not common currency among earth scientists." The omission of the definitions of fugacity and free energy and of discussions of entropy and volume changes during reactions would be far more serious if most potential readers were not already aware of them.

Fortunately, the authors of subsequent chapters do introduce thermodynamic arguments. R. C. Newton and W. S. Fyfe compare experimental phase relations with natural mineral assemblages in high-pressure metamorphism. H. J. Greenwood reviews metamorphic reactions at moderate temperatures and pressures, summarizing the roles of water and carbon dioxide. W. Schreyer provides an updated summary of mineral stabilities and metamorphic assemblages at high temperatures and low pressures. W. C. Luth presents previously unpublished results and informative new projections of familiar data concerning granitic rocks. Bailey summarizes our incomplete understanding of alkaline rocks. All of the authors point out the limitations of their data and caution against their misuse. Luth, in particular, emphasizes the astonishing lack of experimentation with granite systems at pressures between 500 bars and 1 atmosphere.

These are highly competent reviews of important topics, and most are current through 1974. The generation of magmas is not mentioned, and very little is said about how primitive magmas may evolve into felsic rocks. Bowen began with basaltic magma and derived other igneous rocks by crystal fractionation at progres-