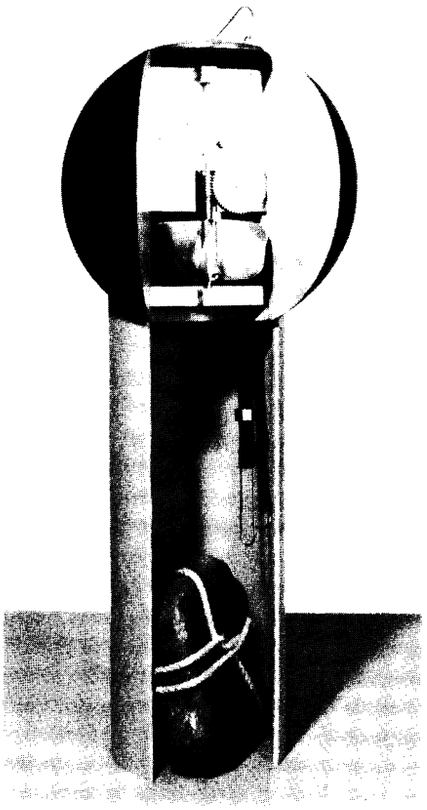

Replica of a sounder introduced by Robert Hooke in 1691. The mechanism in this sounder, one of several designed by Hooke, "resembled a land surveyor's waywiser. . . . A vane was turned by water flow, and the number of its revolutions were counted on a register during the descent. On its ascent, a lid automatically dropped over the mechanism so that it became inoperative. . . . The value of Hooke's work [on oceanographic instruments] lies less in its originality, which he himself disclaimed, than in the detailed descriptions which became widely known through the medium of the *Philosophical Transactions*." [From *No Sea Too Deep*; Crown Copyright, Science Museum, London]

tinued to be of concern throughout the 19th century, even the electrical resistance thermometer being far from satisfactory. Devices for biological sampling are also discussed, as are the first attempts to develop a deep-sea current meter.

This reviewer was a little disappointed that the book does not go beyond the end of the 19th century; the pace then picked up. Nevertheless, it gives a fascinating account of the formidable problems facing oceanographic instrument makers (then and, indeed, now) and the ingenious solutions they devised. It will be read with interest and pleasure by anyone who loves the sea.

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Responses to Creationism

Abusing Science. The Case Against Creationism. PHILIP KITCHER. MIT Press, Cambridge, Mass., 1982. x, 214 pp. $15.

Creation and Evolution. Myth or Reality? NORMAN D. NEWELL. Columbia University Press, New York, 1982. xxxii, 204 pp., illus. $19.95. Convergence.

Science on Trial. The Case for Evolution. DOUGLAS J. FUTUYMA. Pantheon, New York, 1983. xiv, 254 pp., illus. Cloth, $16.50; paper, $6.95.

Scientists Confront Creationism. LAURIE R. GODFREY, Ed. Norton, New York, 1983. xxviii, 324 pp., illus. $19.50.

The Monkey Business. A Scientist Looks at Creationism. NILES ELDREDGE. Washington Square Press (Pocket Books), New York, 1982. 158 pp. Paper, $2.95.

Christianity and the Age of the Earth. DAVIS A. YOUNG. Zondervan, Grand Rapids, Mich., 1982. 188 pp., illus. Paper, $19.95.

The concept of organic evolution has always generated opposition from those who perceive it as an attack on their religious convictions. Scientists have normally avoided confrontation on the issue because they have not been involved in any attack and have felt that the argument was falsely based and unproductive. Recently, however, by forcing a presumably intellectual and theological issue into the political arena, the creationists have at last generated direct responses from several quarters. Federal courts have rejected on constitutional grounds the first two state laws mandating the teaching of creationism in public schools. Scientific societies have held symposia on the issue. And now some of the most respected scholars engaged in the study of evolution have examined the arguments of the more vocal creationists and responded in detail.

The six books under review are a bonanza of good, vigorous scholarship. Proponents of creationism have not been ignored or suppressed by the scientific community as the supporters of von Däniken and Velikovsky claim was the fate of their heroes. Although philosophers of science may be nonplussed with the way one argument or another is constructed in the individual books, no one can quibble with the way each book presents the general differences between evolutionary science and creationist arguments. The concept of evolution is shown to be part of a body of successful scientific study built up from many lines of inquiry and regularly modified as reliable new evidence accumulates. The creationist viewpoint is exposed as a position built on assertions derived from only one of many possible interpretations of one religious document. The five books that deal directly with evolution evaluate the creationist objections to evolution and convincingly reject them as having no legitimate place in the scientific arena, either as alternatives to evolution or as acceptable classroom fare.

Lay persons sometimes view science as a body of demonstrated truths, but this is a misimpression. Philosophers of science tell us that certain proof is virtually impossible. As Kitcher says (p. 32), "Complete certainty is best seen as an ideal toward which we strive and that is rarely, if ever, attained." Therefore, I agree with Futuyma that the ideas of Dorothy Nelkin (discussed on pp. 21–22 of *Science on Trial*) expose the central difference between evolutionary science and creationism: namely, whether we require evidence for beliefs or whether we accept beliefs without evidence. Beliefs, not proofs, are the issue. Both tenets of religion and widely accepted scientific theories are beliefs. However, scientific beliefs require evidence of some sort before they can claim to be convincing, whereas religious beliefs are frequently held without substantiating evidence. Indeed, that is one of the qualities that justifies the term faith. In science we must maintain that distinction, or we will have no reason beyond their direct emotional appeal for choosing among the multitude of ideas.

All the books point out that scientific theories, including our current views of evolution, are not sacred writ but are based on observations we regard as evidence. Scientific theories unite the various observations we make in a coherent fashion and are the most useful explanations we know for natural phenomena. They are open to correction, improvement, or modification by new, more effective ideas that unite a wider spectrum of observations or resolve previously observed conflicts. All the books reveal that creationists do not accept any of these approaches in forming their ideas. Their beliefs are based on a priori

assertions and explain nothing about life on earth or its history. Creationist beliefs about life and the earth are not open to modification despite the accumulation of evidence from observations of nature. Creationists believe that their views are correct without any supporting evidence and that other ideas are false even though supporting evidence for them exists. All the books expose the difference between the sciences of biology and geology and creationist views as the difference between reasoning from evidence and the setting up of a suite of beliefs without evidence.

The books all reach the same general conclusions, but each does it in its own way. Kitcher is philosophical, Newell and Futuyma emphasize the evidence for evolution, Godfrey has provided a series of papers by specialists on specific topics, Eldredge exposes the political nature of the controversy. The book by Young is not directly involved with evolution but is written by a geologist who is also an admitted creationist who does not believe in evolution. It illustrates both the argument that ideas supported by evidence (the age of the earth in this case) are compelling in science and the power of a priori belief in influencing what evidence one is willing to accept.

In *Abusing Science* Philip Kitcher, a philosopher of science, deals with the style of argument of the creationists and the fundamental differences between scientists and creationists in the use of ideas. He discusses creationist misunderstanding of evolutionary biology, errors by creationists, with regard both to facts and their meaning, and the systematic efforts of creationists to exploit the tolerance of our social system. The sterility of the creationists' approach is made abundantly clear, as is their invalid methodology. Instead of trying to exclude creationist ideas from the realm of science by tricks of definition, Kitcher develops criteria for recognizing successful science and demonstrates convincingly that evolution is a fruitful and successful subject in science and creationism is not successful science. This is a most helpful way to look at the issue, providing an alternative to the old science-nonscience debate with its many philosophical pitfalls. The last chapter of Kitcher's book (coauthored with Pamela Kitcher) argues that evolution does not attack or threaten religion, nor does knowledge of evolution dictate offensive moral or ethical judgments.

Norman Newell is one of the world's most distinguished paleontologists. His book, *Creation and Evolution: Myth or Reality?* is a clearly written study of the development of thinking in evolutionary science. The book is not technically intricate but it is highly authoritative. A general reader should be able to assimilate the concepts easily. On first reading I felt the book was conservative and did not emphasize exciting new ideas. Then I realized Newell had done a very good thing. He gives us the thread of ideas that were used in building up our understanding of evolution and the backbone of convincing evidence that was the actual inspiration for the development of the science. Newell is reasonable and thoughtful at all times. His study is carefully constructed to guide the reader through the systems of data compilation and comparison that lead to the understanding of evolution. As a paleontologist, Newell effectively integrates information from the fossil record with ideas from biology.

Science on Trial is an intellectually most stimulating book. Douglas Futuyma is the editor of *Evolution*, the journal of the Society for the Study of Evolution. He has constructed a case for evolution that is very tightly reasoned. The book is well written, tough-minded, and packed with up-to-date information. Futuyma confronts the arguments of the creationists with both evidence and logical analysis of the highest order. He explains how evolution makes sense out of taxonomy, how the fossil record is the preserved record of the course of evolution, and how the processes of chemical genetics, population genetics, and speciation are linked together in modern evolutionary theory. The book is intense and serious. It comes to grips with political and emotional issues as well as the scientific situation. The heart of Futuyma's argument is the impressive point that belief in science requires evidence and that it is dangerous to accept beliefs without evidence. I also like his careful, rigorous distinctions, such as that between order and plan, that point up the errors in creationist criticisms of evolution.

Scientists Confront Creationism, edited by Laurie Godfrey, is a collection of papers by major authorities on individual topics ranging from the history of anti-evolutionism in America to the age of the earth to biological and paleontological aspects of evolution to the issue of equal time for creationists. The subjects are all critical issues in the creationist controversy. As with any collection, the quality of the papers varies. They are least effective when an author drifts toward the "old fashioned" reaction of smugly dismissing creationists. For example, George Abell's paper on the age of the earth and the universe is less satisfying than Stephen Brush's discussion and careful refutation of creationist arguments for a young earth. The most interesting papers deal with issues in which creationists have built up arguments on incorrect or poorly done science. Examples of such papers are Russell Doolittle's discussion of probability with its refutation of Hubert Yockey's paper on the improbability of spontaneous biogenesis, John Patterson's discussion of creationist errors on thermodynamics and his presentation of Prigogine's ideas on non-equilibrium thermodynamics and self-generating dissipative structures, and Steven Schaferman's discussion of the logical fallacies in creationist views on stratigraphy and fossils, including rejection of the flaws in J. E. O'Rourke's 1976 paper on pragmatism versus materialism in stratigraphy. The papers on recent aspects of interpretation of paleontology in evolutionary study by David Raup, Godfrey, and C. Loring Brace are also unusually interesting.

I first encountered *The Monkey Business* by Niles Eldredge as a paperback at an airport bookstand. It is a "quick read," written in a clear, rather breezy style with a refreshing, candid, rough-and-tumble approach that becomes a real exposé of creationist tactics and obtuseness. Eldredge is a curator of paleontology at the American Museum of Natural History and one of the original proponents of the punctuated equilibrium view of the pattern of speciation in evolutionary theory. He writes with authority as well as flair. He feels that the creationism controversy should not have had to develop. As he says (p. 149), "It hasn't been an intellectual problem for at least a century." Eldredge is passionate in his desire to preserve the integrity of science education. While he keeps his compassion and humor he is also thoroughly disgusted with the whole issue as forced upon us by the creationists. He displays what I would second as a justifiable anger with the irresponsible misrepresentation of science that is habitually demonstrated by creationists. In Eldredge's pithy words (p. 112), "To disparage the work of geologists over the past two hundred years, to try instead to foist on the naive the charade that there is no tremendous rock record and that the people who have strived so arduously to understand it are merely fools, is as cavalier an act as I have been sorry to witness." Eldredge makes strong reading. He won't please his opposition but he is right.

The last book to be considered is Davis Young's *Christianity and the Age of*

the Earth. This book is not about evolution but is a religious work. The first part of the book documents the way in which the ideas of religious people have changed as knowledge of natural phenomena through observation has increased with time. The second part reviews the geological evidence for the age of the earth. The third part deals with Young's philosophical and "apologetic" considerations. Young argues that blindness to compelling observational data is a handicap to advancing religious good, yet at the same time he is reluctant to accept all types of observational data. As a professional geologist Young believes the evidence obtained from geology for the great age of the earth is convincing. He is concerned that conservative creationists are defeating themselves and their credibility with their continued advocacy of a young earth. Young states (p. 149), "The totality of evidence just does not point to the earth being only a few thousand years old, no matter how ardently creationists might wish that it did. No amount of juggling can change the overwhelming weight of evidence." And on p. 163 Young says, "May I plead with my brethren in Christ who are involved in the young-Earth movement to abandon the misleading writing they provide the Christian public. I urge them to study geology more thoroughly. Geology cannot be learned from a few elementary textbooks. There is far more to it than that." Young also acknowledges that religious concepts need interpretation. He even says (p. 163), "I also urge creationists to be less dogmatic about Scriptural texts over which there has been substantial diversity of interpretation within the historic Christian church."

But in Young's book we also meet the creationist-evolution dichotomy in its clearest form. Young is an admitted creationist (p. 10) as well as a professional geologist. Although he is willing to accept the evidence of the science he happens to practice and even advocates that scripture needs interpretation when it seems to conflict with the compelling evidence of geology, he is not willing to accept the evidence for evolution from biology and paleontology that Futuyma, Newell, Eldredge, and others regard as equally compelling. Because of his personal choice of scriptural interpretation he reaches the conclusion (p. 66) that "Without question a materialist evolutionary philosophy is hostile to Christianity and ought to be opposed by Christians. Likewise the doctrine of the evolution of man is unscriptural and should be opposed." On one hand Young admits that some observational data are compelling and religious interpretations should not attempt to deform or deny them and on the other hand he adopts the view that equivalent observational data must be opposed and denied because of religious interpretation. For judging the age of the earth Young requires evidence for his beliefs, for judging evolution he does not. Here is the issue in a nutshell.

I am afraid this is where the situation stands. Although evolution does not attack religion it does pose the problem of what to do when convincing scientific conclusions come into conflict with the beliefs people hold without evidence. The creationists are no more ready to deal with evolution than the Catholic church was prepared to deal with Copernican (heliocentric) astronomy in the time of Galileo.

Although they will probably not change very many minds among those who already have a conviction on the subject, these books should be of great utility in educating students in the sciences and in presenting the case for science, as separate from religion, to the uncommitted public. We should applaud the good efforts of all the authors of these generally excellent books. The choice of a book to read should be based on the flavor, style, or approach you are most attracted to—but every scientist should read at least one of these timely books. The political importance of the issue requires that we all be responsibly and reliably informed.

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Sex Ratios and Reversals

The Theory of Sex Allocation. ERIC L. CHARNOV. Princeton University Press, Princeton, N.J., 1982. x, 358 pp., illus. Cloth, $40; paper, $12.95.

As is well known, there are various ways to procreate. Certain shrimp, fish, and mollusks reproduce as males early in life but later reverse to the female sex. Other fish do the opposite, whereas most never change gender. Still others are male and female at the same time; so are many snails, earthworms, flukes, and tapeworms, to cite a few examples. Sex ratios of offspring are also diverse: some reptiles and invertebrates can produce almost anything from all male to all female progeny, depending on ecological circumstances, even temperature. Among plants, the forms of sexuality are even more varied.

Can all this variation be accommodated by a single theory? In this monograph Eric Charnov successfully demonstrates that it can. He provides a coherent evolutionary approach to an array of seemingly disparate problems of sex allocation: the allocation of time and energy by plants and animals to male versus female reproductive function. The book is based on "selection thinking" and asks "why" on a subject where "how" has been the traditional question. This focus on natural selection, the penetrating analysis of the problems, the balanced blend of theory and data, and the lucid, simple style make the book a delight to read.

It is organized in three main sections: on sex ratio in dioecious organisms (with the sexes separate and unchanged throughout life), on sex reversal, and on simultaneous hermaphroditism. Some of the problems treated are: What sex ratio among progeny is favored by selection? Should a sequential hermaphrodite be male or female first, and when is the best time to switch? In which proportions should a simultaneous hermaphrodite partition resources for male and female function? When will a mixture of sexual types be stable? And what are the ecological and social conditions favoring a certain sex ratio or sexual system? The unifying aspect of these questions is that answering them usually involves calculation of a population equilibrium (evolutionarily stable strategy) based on the genetic contributions through male and female function.

The theory is expounded in mathematical models. Charnov shows admirable skill in developing the simplest possible model that captures the essentials of a situation. Surprisingly, almost all the different problems can be treated by one main theoretical device: the "Shaw-Mohler equation." The resulting rule in words is that selection favors a mutant gene that entails a proportional gain in fitness through one sex function that