Penetrating Muddied Waters: Creationism and Evolution

Darwinism Defended: A Guide to the Evolution Controversies, by Michael Ruse (Reading, Mass.: Addison Wesley Publishing Company, Advanced Book Program/World Science Division, 1982), xvii, 356 pp., $12.50, paper; *Creation and Evolution: Myth or Reality?* by Norman D. Newell (New York: Columbia University Press, 1982), xxii, 199 pp., $25.90; *The Monkey Business: A Scientist Looks at Evolution*, by Niles Eldredge (New York: Pocket Books/Washington Square Press, 1982), 157 pp., $2.95, paper; *Abusing Science: The Case Against Creationism*, by Philip Kitcher (Cambridge, Mass.: MIT Press, 1982), x, 213 pp., $15.

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> *Do you think that a fellow could grasp more of the wickedness of [evolution] if he had an education?*
>
> Buckshot Morgan
> (In Ginger 1958, 109)

THE CONFLICT BETWEEN creationism and evolution in the past few years has probably brought mixed feelings to many Latter-day Saints. Although some excellent scholarship has demonstrated that we have little or nothing in common with the philosophical positions held by modern creationists (Jeffery 1973), their combination of conservative politics, religious devoutness, and concern with the moral condition of our society are appealing to many Mormons.

Most creationists agree on a number of specific beliefs. They insist on a very young age for the earth (generally less than ten thousand years), formation of the fossil record in a single, world-wide flood, unique special creation events for each biblical "kind," separate ancestry for humans and the other primates, and the absolute, literal truth of the Bible as a historical and scientific record. In recent years, efforts to embed these views in public school curricula have been repudiated legally in Louisiana and Arkansas.[1]

Additionally, main-stream scientists have produced a blitz of books aggressively critical of creationism. (In addition to those reviewed here, see Futuyma (1983), Godfrey (1983), La Follette (1983), Montague (1984), Newell (1982), Nelkin (1982), Wilson (1982), and Zetterberg (1983); some are reviewed in Jeffery (1983). Do these legal and scientific counter-attacks represent merely another case of persecution of a religious perspective? Are they an assault by the marshalled forces of the scientific Sanhedrin against a group of right-thinking allies who simply get a bit over-enthusiastic once in a while? The four boks reviewed here have something to offer in answer to these questions.

Michael Ruse is a historian and philosopher of science at the University of Guelph, Ontario. His background and pro-

[1] For reports on the Arkansas trial proceedings see "Judge's ruling hits hard at creationism," *Science* 215 (1982): 381 and 217 (1982): 232–33. For a complete text of Overton's decision, see *Science* 215 (1982): 934–43 or *The American Biology Teacher* 44 (1982): 172–79. The case was more complicated in Louisiana. A trial court struck down the law mandating the teaching of creationism. After various legal maneuverings, this decision was upheld on appeal. The appellate decision can be found in *Aguillard v. Edwards*, 765 F.2d 1251 (5th Circuit, 1985).

lific record seem to justify high hopes for his offering. *Darwinism Defended* purports to be "A Guide to the Evolution Controversies," and therefore it deals with far more than just the challenge from creationism. The first twelve chapters outline the historical development of Darwinism and evolutionary biology into this century. In these discussions, Ruse borrows heavily from earlier works of his own and others, rarely with any improvement over the antecedents.

Most of the discussions are superficial, and some are simply inaccurate — for instance, the slipshod treatment of meiosis and the wholly inadequate discussion of the sources of variation on which natural selection can act. The only source of such variation that Ruse discusses is mutation. While it is true that all variation is due ultimately to mutation, the role of recombination, amazingly, is not mentioned at all. The power of recombination to increase exponentially the possible gene combinations among which natural selection can choose is therefore overlooked, and thus Ruse skims past what was arguably the most important development in the evolutionary history of life on this planet — dioecy, or sex. Many of the other discussions are no more profound.

Ruse also devotes a chapter to the origin of life, or abiogenesis. Although this issue is not, strictly speaking, in the domain of organic evolution, it involves some crucial presuppositions that are assumed in most evolutionary discourse, and its treatment here is not misplaced. In this chapter, he rightly emphasizes the 1953 experiment of Stanley Miller and Harold Urey, which Miller performed as a student at the University of Chicago (Miller 1953). In this experiment he mixed a number of chemicals thought to have been present in the atmosphere of the primitive earth. This mixture was circulated and exposed to an electrical discharge for a week and then assayed for any chemical products. From methane, ammonia, hydrogen and water (Ruse mistakenly implies that hydrogen sulfide also was included), Miller generated several different amino acids, organic compounds fundamental to life. Repeats of the experiment produced a great variety of molecules, thus demonstrating how easily important compounds can be synthesized abiotically.

Unfortunately, Ruse fails to point out that since 1953, experiments of this sort have been repeated at least twenty-six times with a variety of starting mixtures and an impressive array of different energy sources including UV, alpha, beta and gamma radiation, heat at different temperatures, electrical discharges at different strengths, sonication, agitation and more. Molecules synthesized include a great many amino and fatty acids, sugars (including ribose and deoxyribose, essential to nucleic acids), porphyrins (hemoglobin and myoglobin precursors), metabolic energy sources like ATP (adenosine tri-phosphate, which powers most chemical reactions needing energy in the cell), and both simple and complex polymers (Fox and Dose 1977; Calvin 1969). Such a formidable array of results deserves at least passing mention in any discussion of abiogenesis, and Ruse is negligent not to provide one.

His last two chapters deal with creationism. While his preface claims that creationism is "considered in close detail, and an extended refutation is given of every one of the creationist's claims," the first of the two chapters draws almost exclusively on only one creationist source (Morris 1974) to describe these claims while the "extended refutation[s]" are relegated to the concluding chapter of only twenty-six pages. The space devoted to the task is inadequate even to list and describe the relevant claims briefly, much less provide the extended refutations claimed. Here and there Ruse does provide entertaining bits of rhetoric in the "call a spade a bloody shovel" vein, but his style would be better suited to the pages of the *National Enquirer* than to an issue from the Advanced Book Program of a publisher's World Science Division.

Fortunately, the other three books are superior to Ruse. Although Newell's *Creation and Evolution* is somewhat restricted in scope and occasionally flawed (not to mention expensive), it is well constructed and has unique and significant virtues. Curator emeritus at the American Museum of Natural History, Newell has focused on his own strengths in geology and paleontology and in so doing has slighted some biological matters. The discussion of meiosis and probability contains serious misunderstandings, but the take-home message remains accurate—that recombination generates enormous variation as grist for the mill of natural selection. The discussion of intermediate forms in the fossil record is weak, but other authors have handled that subject well, and the good points of the book are quite strong.

Happily, Newell's treatment of a favorite creationist argument is definitive. Creationists argue that evolutionists date the ages of geological strata by specific fossil remains ("index fossils") they contain. The age of these fossils is determined, (so the claim is made) according to their stage of evolutionary progress. Thus, to claim that the fossil record supports an evolutionary interpretation of life on earth is to use the worst sort of circular reasoning — the only reason it does so is that evolution was presupposed in the initial studies! In fact, this is a distortion, and Newell deals with it by presenting a careful history of stratigraphy.

The study of stratigraphy was pioneered by William Smith, "an unsophisticated English civil engineer unacquainted with evolution" (p. 88). Beginning in 1781 as a land surveyor's assistant, Smith followed his work around England. His lively curiosity and precise methodology soon led him to notice "that many of the rock layers, or 'beds,' changed in thickness and character from place to place, but he found that the fossil assemblages maintained their general characteristics and lay in the same relative sequence throughout the region of his study. In spite of gradual changes in rock characteristics from place to place, he could keep track of the sequence and depths of strata by reference to the fossils" (p. 92). Smith was thus able to predict accurately which strata would be encountered by drilling or shafting in certain places. English coal mining companies benefitted, Smith's data base grew, and, as Newell points out, "the international geologic time scale that eventually emerged was a product of stratigraphic studies by practical men who had neither knowledge of, nor interest in, organic evolution" and was "established and widely used by 1840" (p. 93), nearly twenty years before Darwin published *The Origin of Species.*

Indeed, almost all the "practical scientists" who developed the techniques of stratigraphy were creationists who had moved beyond the positions of most "modern" creationists, that fossils are remains from the Noachian Deluge. Cuvier (1768–1832) demonstrated the untenability of this thesis; and from his time forward (until recently), those who believed in special creation were most likely to embrace his notion of a series of special creations interspersed with waves of extinctions, each easily seen in the fossil record.

Newell also discusses the dating methods geologists use in reaching their consensus opinion of a very great age for the earth (approximately 4.5 billion years). More detailed treatment can be found in Brush (1982, 1983); and while Newell's analysis is good, one section, that on varves, is weaker than it need have been.

In many lake-formed strata geologists find paired layers of alternating light and dark bands of finely grained sediment. By observing the same sorts of laminae formed in modern lake beds by seasonal variation in the texture of runoff deposits they conclude that each paired structure — a "varve" — represents an annual deposit. Newell mentions that "long sequences of varves equivalent to several tens of thousands of years have been counted and studied in North America and Europe," but he overlooks a far more impressive example in the Rocky Mountains. The

Green River formation is centered over a wide area in portions of Idaho, Wyoming, Colorado, and Utah. It was laid down during the Eocene Period (beginning roughly 58 million years ago). Varves found in this ancient lake-bed are particularly fine and have been studied in some detail (Bradley 1929). An estimate for the age of the Green River Epoch, based on conservative assumptions of the number of varves it contains, yields a figure of 6.5 million years. Similar analyses of the Wasatch and the Bridger and Uintah formations yield estimates of their durations at 10.7 and 5.7 million years, respectively, for a total Eocene of 22.9 million years! If growth rings in bristlecone pines, corals, or simply the sight of the Grand Canyon coupled with a little humble reflection don't negate creationist claims of a young earth, these Green River varves certainly should.

To give a capsule judgment of Newell's book, it is lucid and informative and its considerable geological strengths make it well worth reading.

With *The Monkey Business*, Niles Eldredge has provided us with the second entry from the American Museum of Natural History, where he is curator of invertebrates. A mass-market paperback, this well-written book is the most entertaining of the four and potentially the most effective.

He opens with a brief history of creationist movements in the United States and the interaction of science and society in our culture. He follows with a brief sketch of the evolutionary history of life on earth and the development of ideas on the subject. This is followed by an exposition of creationist arguments, and a final, summary chapter on creationism, religion and politics. All the discussions are well-framed, succinct and entertaining. The only points of disagreement I found involve minor, specialist nit-picking. But the best discussion deals with taxonomy and systematics (naming species and defining their relationships) and how these disciplines contribute to evolution and are misconstrued by creationists.

The particular focus Eldredge uses in this discussion is the creationist notion of "kinds." By contrast, to a biologist a species is basically a reproductive community. There are a variety of ways to test this criterion, and most of them lead to the strong conclusion that a species is a real unit in nature. No such precision can be gleaned from creationist writings on the subject of "kinds." Eldredge quotes from the least inarticulate creationist treatment, that by Gish (1978):

> It is obvious, for example, that among invertebrates the protozoa, sponges, jellyfish, worms, snails, trilobites, lobsters, and bees are all different kinds. Among the vertebrates, the fishes, amphibians, reptiles, birds and mammals are obviously different basic kinds. . . . Within the mammalian class, duck-billed platypuses, opossums, bats, hedgehogs, rats, rabbits, dogs, cats, lemurs, monkeys, apes and men are easily assignable to different basic kinds. Among the apes, the gibbons, orangutans, chimpanzees, and gorillas would each be included in a different basic kind (pp. 116–17).

Eldredge points out Gish's anthropocentric bias:

> The closer we come to mankind, our own species *Homo sapiens*, the smaller the "basic kinds" Gish and other creationists wish to recognize. The invertebrate groups Gish lists are huge: "worms" include at least five phyla, snails constitute an entire class of molluscs (comparable at least to the vertebrate classes, such as birds and mammals), and trilobites are an arthropod class. Protozoa — one-celled animal-like creatures — include many different phyla. . . . Trilobites are as diverse and prolific as the mammals, and examples of evolutionary change linking up two fundamental subdivisions of the 'Class Trilobita' . . . are as compelling examples of evolution as any I know of. Airily dismissing 350 million years of trilobite evolution as "variation within a basic kind" is actually admitting that evolution, *substantial evolution*, has occurred (pp. 117–18).

Eldredge is also eloquent on the age of the earth and the correlation of index

fossils with the stratigraphic record. He writes,

> Creationists have even maintained that when fossils are found out of the "proper" sequence, they are ignored — a charge which is nothing short of a vicious lie. . . . There is such a complex system of cross-checking of independent ways of assessing age — all pointing to the same results — that I must remind myself that scientists cannot claim to have the ultimate truth. . . . There are far too many independent lines of evidence — *none* of which is based on the assumption of, let alone an underlying commitment to, evolution — that amply confirm what geologists thought must be so 150 years ago: the earth simply cannot be a mere ten thousand years old pp. 98, 104).

There is more, and all of it is accurate and entertaining, but by now it should be clear that this book is well worth $2.95. No individual interested in creationism and evolution should be without it.

Philip Kitcher's *Abusing Science*, however, is the best of the four, though a difficult book to review. A philosopher of science from the University of Vermont, Kitcher handles almost every issue very well, and his mix and balance are superior. He is not quite so patiently scholastic as Newell, nor as engagingly edifying and combative as Eldredge, but Kitcher has combined two different approaches — analyses of substance and of structure — with rare success.

I have observed that, in the clash between creationism and evolution, the intelligent responses to creationism fall into two distinct groups. Some, mostly scientists, address the specific issues that creationists raise and offer data-based, point-by-point refutations. The second group, composed largely of philosophers, emphasizes problems of methodology, logic, and the types of claims susceptible to proof. The difficulty with the first approach is that, although I have yet to see a creationist argument that cannot be well and truly refuted, for every canard that scientists dispose of creationists hasten to prop up several more. As one observer commented, "An advocate more concerned with winning an argument than with seeking the truth can utter more nonsense in five minutes than can be adequately refuted in five hours." Furthermore, no individual can be fully conversant with all the areas of study that creationists have distorted in their fanatical advocacy. On the other hand, although philosophical critiques are ultimately far more devastating to creationist positions than are responses to specific points, the same certainty that makes a creationist impervious to evidential argument gives him the conviction that philosophical issues are even less relevant.

Obviously, attempts to wring concessions of defeat from creationists by debate are time wasted. But if the goal is to educate an uninformed audience and to demonstrate the nature of the issues at stake, then neither of the two approaches can be used exclusively without losing the power of the other. An effective balance is most difficult to find, and it is this balance that Kitcher achieves so well.

In the foreword, Kitcher outlines his strategy: "The Creationist is allowed to choose one battleground after another. . . . In every case, 'scientific' Creationism is defeated. When all the distortions have been removed, all the attempts to flaunt credentials examined, all the misleading questions returned to their contexts, all the fallacies laid bare, we shall see Creation 'science' for what it is — an abuse of science." This Kitcher does, time and again. Repeatedly he focuses on an issue of creationist choice, defines the philosophical parameters, delivers a mortal blow and then illustrates with specifics. He draws on nearly every major creationist work from the past twenty years, revealing the plethora of internal inconsistencies that others have often overlooked.

One of the most effective sections Kitcher develops deals with the "quotation out of context" issue. Creationists are often belabored for taking the writings of mainstream researchers and transplanting them

to new contexts wherein they appear to support, if not creationist causes, at least their anti-evolutionary interpretations. Kitcher gives several detailed examples (after establishing that arguements from authority in science have almost no value) that derail some favorite creationist arguments (e.g., the supposed absence of transitional forms and the allegedly non-humanoid characteristics of australopithecene locomotion). As the oft-misquoted Stephen Jay Gould has written,

> It is infuriating to be quoted again and again by creationists — whether through design or stupidity, I do not know — as admitting that the fossil record includes no transitional forms. Transitional forms are generally lacking at the species level, but are abundant between larger groups. The evolution from reptiles to mammals . . . is well documented. Yet a pamphlet titled 'Harvard Scientists Agree Evolution is a Hoax' states: "The facts of punctuated equilibrium which Goul and Eldredge are forcing Darwinists to swallow fit the picture that Bryan insisted on, and which God has revealed to us in the Bible" (Gould 1981, 34, 37).

In the end though, the section of the book I found most interesting is that describing the nature of science. Most scientists today distinguish science from nonscience according to the criterion of "falsifiability" developed by Karl Popper. Briefly, this holds that science can *prove* nothing; rather, science can only disprove, by demonstrating with counter-examples. If an experiment (real or imaginary) cannot be devised wherein at least one possible outcome must compel the rejection of the tested hypothesis, then the hypothesis was not scientific in the first place. Deriving this principle primarily from the physical sciences, Popper first criticized evolutionary theory from this perspective, but since learned something about the subject and recanted (Popper, 1976, 1978, 1980), something I have yet to hear a creationist admit. Kitcher concedes that Popper's criterion of falsifiability has been very important historically but asserts that the work of philosophers of science (particularly Hempel and Quine) over the past thirty years has demonstrated this "naive falsificationist" view to be inadequate, and he describes an alternative.

Kitcher believes that there are three characteristics of successful science against which theories should be judged. They are *independent testability*, which "is achieved when it is possible to test auxiliary hypotheses independently of the particular cases for which they are introduced. *Unification*, [which] is the result of applying a small family of problem-solving strategies to a broad class of cases, [and] *fecundity* [which] grows out of incompleteness when a theory opens up new and profitable lines of investigation" (p. 48). He concludes that evolution is a scientific theory par excellence, and then quotes from Mayr, "The theory of evolution is quite rightly called the greatest unifying theory in biology," and from Dobzhansky, "Nothing in biology makes sense except in the light of evolution" (p. 54). Kitcher also demonstrates that creationism is "a theory that has no detailed problem solutions to its credit (except those borrowed from its rival), that has no clearly defined problem solving strategies, that encounters anomalies whenever it becomes at all definite, but that typically relapses into vagueness whenever clear-cut refutations threaten. Why should we taken this 'theory' to be worthy of any consideration?" (p. 155). Not surprisingly, he concludes that we should not.

As excellent as Kitcher's book is, however, neither it nor any of the others develop two significant topics: the relationship between evolution and cosmology, and the interaction between evolution and the second law of thermodynamics. By "the relationship between evolution and cosmology" I do not mean the existence of an evolutionary scheme that astronomers and physicists use to explain the present appearance of the universe. Rather, I mean the testimony provided by cosmological studies indicating that natural laws are the same today as they were in the beginning,

"the same yesterday, today and forever" (1 Ne. 10:18; 2 Ne. 27:33, 29:9; Alma 31:17; Morm. 9:9; Moro. 10:19).

Measurements of astronomical distance from stellar parallaxes and cepheid variable stars combine to place us in a very large galaxy. Cepheid variables can, in turn, be observed in nearby galaxies. Correlation of these data with cosmological red-shifts, extend our view and calibration of space to a distance of as much as 20 billion light years, and thus the age of the universe to a similar number of years as a minimum estimate. Any good, modern astronomy text should treat cosmological red shifts and the size/age of the universe. The most lucid treatment for the critical role of cepheid variables remains the absorbing account in Shapley's (1943) classic with an up-to-the minute account in Hanes (1985). Spectral analyses give us excellent reason to suppose that the natural processes we see close at hand are the same as those operating at great distances, and that neither have changed during this length of time. These deductions build a formidable case for the very great age of the earth and the constancy of natural law, while directly repudiating such nonsensical claims as that of Morris who insists that "the evolutionist is committed to the constantly changing nature of law" (Morris 1974, 12).

A second, pivotal argument involves the second law of thermodynamics, a two-edged sword creationists often wield. Simply put, the result of this law is that the state of any closed system will tend towards maximum disorder, or maximum entropy. Creationists are fond of claiming that the second law therefore prohibits the generation of order from disorder, and that life, obviously a highly ordered process, could not have arisen from nonlife without external guidance. This supposedly disproves the possibility of evolution. Scientists inevitably counter by pointing out that the second law applies to *closed* systems, which exchange neither matter nor energy with an external environment. Living things constantly violate this constraint by eating food and being warmed by the sun, and thus are *open* systems, immune to the constraints (such as the second law) that apply to closed systems. All four books make responses similar to this, and they are correct. It is also true that if one were to isolate the solar system, not only would entropy be seen to be increasing, but life on earth would be shown to accelerate this process significantly.

But none of these four authors develop the most interesting application of thermodynamics to open, living systems. In 1977, the Nobel Prize in Chemistry was awarded to Ilya Prigogine of the Free University of Brussels and the University of Texas. He has investigated open systems of a particular sort — those far from thermodynamic equilibrium. These are systems that experience a significant influx of energy from the environment (*e.g.*, living things on a planet bathed in sunlight). In studying them Prigogine developed the concept of "dissipative structures." These structures are complex forms that self-assemble spontaneously, and function to decrease the energy gradients in open systems. Their only requirements are very simple starting materials and energy inputs that are, in thermodynamic terms, high; that is, sufficient to produce a situation "far from equilibrium." Living systems are precisely these sorts of dissipative structures when viewed thermodynamically. Prigogine's work thus leads to an interesting conclusion: not only does the second law not preclude the evolution of life, but rather it seems, in fact, to predict it! These ideas have been developed at several levels accessible to the (determined) layman, (Prigogine, et al., 1972, 1973; Prigogine and Stengers, 1984; Schieve and Allen, 1982) and have been brought to the attention of the appropriate creationists. But like so much that is troublesome to their goals, this work has been ignored by creationists, "whether through design or stupidity I do not know" (Gould 1981, 37).

In summary, of the four books, those by Newell, Eldredge, and Kitcher are worthy to the task (or a sufficient part of

it) and the last two are excellent. Reading any of them leads to one unavoidable conclusion about creationism: it is a parochial dogma without substance, and its contemporary advocates do not share our own love and respect for learning and scholarship, nor our commitment to honesty. They use methods that betray the values we hold dear. Whatever their motives, they are not the guardians of our faith and have no comfort to offer us.

BIBLIOGRAPHY

Bradley, Wilmot H. "The Varves and Climate of the Green River Epoch." U.S. Geological Survey Professional Paper 158-E. *Shorter Contributions to General Geology* (1929): 87–110.

Brush, Stephen G. "Finding the age of the earth: By physics or by faith?" *Journal of Geological Education* 30 (1982): 34–58.

———. "Ghosts from the Nineteenth century: "Creationist Arguments for a Young Earth." Ed., Laurie R. Godfrey. *Scientists Confront Creationism.* New York, 1983, pp. 49–84.

Calvin, Melvin. *Chemical Evolution.* New York: Oxford University Press, 1969.

Fox, Sidney W., and Klaus Dose. *Molecular Evolution and the Origin of Life.* New York: Marcel Dekker, Inc., 1977.

Futuyma, Douglas J. *Science on Trial: The Case for Evolution.* New York: Pantheon Books, 1983.

Ginger, Ray. *Six Days or Forever?* Boston: Beacon Press, 1958.

Gish, Duane E. *Evolution: The Fossils Say No!* (Public School Edition). San Diego: Creation-Life Publishers, 1978.

Godfrey, Laurie, ed. *Scientists Confront Creationism.* New York: W. W. Norton, 1983.

Gould, Stephen Jay. "Evolution as Fact and Theory." *Discover* (May 1981): 34–37.

Hanes, David A. "Cepheids and Cosmic Distance." *Nature* 317 (19 September, 1985): 200.

Jeffery, Duane E. "Seers, Savants and Evolution: The Uncomfortable Interface." DIALOGUE 8 (Fall 1973): 41–75.

———. "Dealing with Creationism." *Evolution* 37 (September, 1983): 1097–1100.

La Follette, Marcel, ed. *Creationism, Science and the Law.* Cambridge: MIT Press, 1983.

Miller, Stanley. "A Production of Amino Acids under Possible Primitive Earth Conditions." *Science* 117 (15 May 1953): 528–29.

Montague, Ashley, ed. *Science and Creationism.* New York: Oxford University Press, 1984.

Morris, Henry M., ed. *Scientific Creationism.* San Diego: Creation-Life Publishers, 1974.

Nelkin, Dorothy. *The Creation Controversy.* New York: W. W. Norton, 1982.

Newell, Norman D. *Creation and Evolution. Myth or Reality?* New York: Columbia University Press, 1982.

Popper, Karl. *Unended Quest.* La Salle, Illinois: Open Court, 1976.

———. "Natural Selection and the Emergence of Mind." *Dialectica* 32 (1978): 339–55.

———. "Evolution." *New Scientist* 87 (21 August 1980): 611.

Prigogine, Ilya, Gregoire Nicolis, and Agnes Babloyantz. "Thermodynamics of Evolution." *Physics Today* 25 (Nov.–Dec. 1972): 23–28; 38–44.

Prigogine, Ilya, Agnessa Lambert-Babloyantz, Marcelle Herschkowitz-Kaufman, Gregoire Nicolis and Rene LeFever. "Can Thermodynamics Explain Biological Order?" *Impact of Science on Society* 23 (1973): 159–79.

Prigogine, Ilya, and Isabelle Stengers. *Order out of Chaos: Man's New Dialogue with Nature.* New York: Bantam, 1984.

Schieve, William C., and Peter M. Allen, eds. *Self-Organization and Dissipative Structures.* Austin: University of Texas Press, 1982.

Shapley, Harlow. *Galaxies.* Philadelphia: The Blakiston Company, 1943.

Wilson, David, ed. *Did the Devil Make Darwin Do It?* Ames: Iowa State University Press, 1983.

Zetterberg, J. Peter, ed. *Evolution vs. Creationism: The Public Education Controversy.* Phoenix: Oryx Press, 1983.