Reviews

The Cosmic Blueprint: New Discoveries in Nature's Ability to Order the Universe. By PAUL DAVIES. New York: Simon and Schuster, 1988. 224 pages. $17.95.

Paul Davies's *Cosmic Blueprint* falls into three distinct parts. The first part, which contains an exposition of recent developments in chaos theory, shows how the behavior of certain elementary devices, accessible in everyday life, eludes causal explanation even in principle. The second part is a survey of complex systems, studied by the various special sciences, whose behavior has also eluded causal explanation. Davies repeatedly suggests that the behavior of these more interesting complex systems may ultimately be as inexplicable on a causal basis as the behavior of the elementary devices discussed in the first part. (This reiterated suggestion falls considerably short of demonstration.) Finally, in both his introductory and concluding chapters, Davies floats a *very* speculative (and vague) suggestion as to how the behavior of such complex systems might be understood (or at least interpreted) so as to affect our attitude toward the (allegedly) transcendent source of creation (i.e., God). I shall consider these three components of Davies's book in turn.

Davies, to this reviewer, is the most readable, illuminating, and generally enjoyable expositor of physics for laymen since George Gamow. Much of what I believe I know about contemporary physics may be traced to what I have read in Davies's numerous popular expositions. I confess, moreover, that I did not understand the significance of a number of recent developments in chaos theory until I had read Davies's exposition in this book. I consider his three chapters on this topic (3–5) worth the price of the book in and of themselves. Chaos theory, it turns out, is philosophically important because it reveals a heretofore unsuspected way in which the cosmos can be continuously creative.

The Newtonian world of Laplace was like that of the Book of Ecclesiastes in that it countenanced "no new thing under the sun." Once the state of an isolated system was specified (assuming the laws of its dynamics were known), all future and past states of that system would also be given (by implication at least). No new information could be generated by the dynamic evolution of such a system.

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Twentieth-century physics has, of course, shown Laplace's conceit to be inapplicable to the real world. Prior to chaos theory, there were at least three known sources of "new creation" within the cosmos. First, there was the emergence of the cosmos from the singularity of the "big bang," a kind of "new creation" first clearly articulated by Abbé Georges Lemaître. (I shall bracket, for the moment, Stephen Hawking's recent denial that the cosmos originated from a singularity. Even Hawking's postulated beginningless and endless cosmos is *contingent* with respect to the form of its laws and the values of its basic constants. Such ineliminable contingency is sufficient to provide a content for this first sort of "creation." See Hawking, *A Brief History of Time* [New York: 1988], Bantam, 141.) Second, there is the continuous generation of negative entropy from cosmic expansion itself, which, unlike the expansion of gas in a refrigeration unit, creates *new space* into which matter can move to generate new structures of order. This source of "new creation" has been emphasized by David Layzer. (See Layzer, *Cosmogenesis* [New York: Oxford Univ. Press, 1990], 162–64, 302.) Third, there is the widely discussed consequence of quantum mechanics in which the determinant outcome of an act of measurement is literally a "new thing under the sun," which could not have been predicted even by a Laplacean deity. (For a discussion of how this sort of "creation" arises in quantum mechanics, see Davies, *Cosmic Blueprint,* 168–69.) Chaos theory now provides a fourth way in which "new creation" can occur, even within a world governed by completely deterministic, Newtonian-type causal laws.

Davies introduces us to the basic ideas of chaos theory by reference to the very simple algorithm of "clock doubling." If we double a quantity such as length along a line, we get a simple linear progression, represented by the formula $y = 2x$. But if we apply the concept of doubling to the angle swept by a hand on the face of a clock, and if we add the requirement of *dropping* any amount greater than twelve hours (so that six hours plus eight hours equals two hours rather than fourteen hours), the procedure will generate a very complex function that cannot be represented by any simple algebraic formula. The future states of a system, expanded in accordance with such a clock-doubling rule, will become unpredictable (and hence inexplicable) *in principle* as the number of doublings becomes large. (See Davies, *Cosmic Blueprint,* 23–30.)

Having introduced us to the concept of clock doubling, Davies then introduces us to a device called a *driven conical pendulum,* which swings on a rigid arm that is hung from a ball-and-socket joint, which allows the bob to swing in loops and circles as well as back and forth

in a plane. A pendulum is "driven" by an external power that continuously "pumps" it (the way a girl "pumps" herself on a swing), so that it need never stop due to friction. When the experimenter applies certain combinations of driving and dampening forces to such a pendulum, it will sometimes assume stable patterns of trajectories. The shapes of these stable trajectories are just as unpredictable, however, as the future states of a system governed by the doubling algorithm. (See Davies, *Cosmic Blueprint,* 44–50.) These stable dynamic patterns are ontological emergents that are, quite literally, new things under the sun.

Once I had read Davies's description of a driven conical pendulum, I realized (with a start) that I have seen such devices in curio and gift shops—small devices, usually about six to nine inches tall, in which a pendulum is driven by an electromagnet in its base. They are apparently intended as conversation pieces or objects of contemplation, like a lava lamp. I had no idea, prior to reading Davies's book, that they are continuously creating ontologically novel structures.

The second part of Davies's book is an extended argument from analogy. Since we *know* that the ordered products of complexity are causally inexplicable in such elementary systems as the driven conical pendulum, it is reasonable to suppose that the patterns that arise from complexity in the more interesting cases of morphogenesis, biological evolution, and mind-body interaction are also causally inexplicable.

Is this not simply a counsel of intellectual despair? It would appear so, except for Davies's further postulation of a "cosmic blueprint" in his introductory and concluding chapters. I read his idea of a cosmic blueprint as similar to David Bohm's "implicate order" in quantum mechanics. Davies discusses Bohm's ideas at some length (77, 156–57, 176), but he never links Bohm's idea of the implicate order to his own idea of the cosmic blueprint. Davies, who credits his idea to Aristotle, understands Aristotle's concept of the "essence" of a living substance, such as an acorn, to be a kind of interior blueprint that governs the acorn's development into an oak tree by (noncausal) holistic and teleological means (6–7, 96–97, 100, 202). Just as an essence may guide the morphogenesis of an acorn in noncausal ways, there may also be an essence for the cosmos as a whole that is guiding it toward ever more complex structures of order. Davies even identifies this idea of a cosmic blueprint with the traditional Christian understanding that both the cosmos and history are unfolding in accordance with God's providential plan (6–7).

Davies answers the question of his last chapter, "Is There a

Cosmic Blueprint?'' as follows: ''The very fact that the universe *is* creative, and that the laws have permitted complex structures to emerge and develop to the point of consciousness—in other words that the universe has organized its own self-awareness—is for me powerful evidence that there is 'something going on' behind it all'' (203).

This sounds, at first, like the traditional argument from design; but it is really quite different. Davies does *not* argue from analogy to conditions that *can* be understood causally—as William Paley argued with his famous analogy between the making of a watch and the making of the cosmos. Instead, Davies argues for the existence of the cosmic blueprint from our *ignorance* of the causes why order emerged from complexity. This might sound like an argument for what Ernan McMullin called ''the God of the gaps''—that is, a God invoked to explain what is *not* understood, so that the domain of God's providence shrinks as our knowledge expands. (See McMullin, ''Natural Science and Belief in a Creator,'' *Physics and Theology,* ed. by R.J. Russell, W.R. Stoeger, and G.V. Coyne, Vatican City Observatory [1988], p. 67.) Davies's inference to the cosmic blueprint, however, is unlike McMullin's inference to the God of the gaps, for Davies is arguing that the emerging cosmic order *has no undiscovered causal explanation,* which is the point of his analogy between the emergence of orderly structures and trajectories in both the cosmos and the driven pendulum. The pendulum's patterns have no causal explanation—for the same reason that future states of the clock-doubling algorithm cannot be calculated by an algebraic equation.

Chaos theory differs from ordinary causal theories in that it admits of no causal ''gaps'' to be filled by our growing knowledge of the whys and wherefores for the behavior of complex systems. We might call Davies's inference to the cosmic blueprint an argument from *miracles* rather than from design. (We can cite the miracles of morphogenesis, of the visible structures of the galaxies against their isotropic background radiation, of the evolution of biological complexity beyond its requirement for reproductive success, of the collapse of the wave function in quantum mechanics, and of consciousness arising from chaotic brain functions.) Whether such a speculative surmise is sufficient reason for accepting Davies's cosmic blueprint is for his readers to decide for themselves.

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Philosophy of Biology Today. By MICHAEL RUSE. Albany: State University of New York, 1988. 155 pages. $29.50; $9.95 (paper).

But Is It Science? The Philosophical Question in the Creation/Evolution Controversy. Edited by MICHAEL RUSE. Buffalo, NY: Prometheus Books, 1988. 406 pages. $24.95.

The Darwinian Paradigm: Essays on Its History, Philosophy and Religious Implications. By MICHAEL RUSE. London and New York: Routledge, 1989. 299 pages. $25.00.

The three volumes under review show Michael Ruse at his best as he brings together disparate arguments and authors, summarizing and evaluating diverse topics. *Philosophy of Biology Today* contains succinct summaries of the issues that have exercised biologists and philosophers of biology over the past two decades, from evolutionary theory and population genetics through molecular biology and systematics to teleology and human biology. The text serves not only to sketch the salient issues but also to orient the reader to the relevant literature. Roughly a third of the book consists in bibliography. For anyone interested in delving into a particular set of issues in the philosophy of biology, Ruse's book is the most convenient point of entry. Ruse has done us all a great service by producing this research tool.

But Is It Science? includes twenty-seven selections on the creationism/evolution controversy, seven by Ruse himself. The creationism controversy is especially frustrating to philosophers because, ostensibly, it is about one set of issues when actually it turns on quite a different set of considerations, and the source of this equivocation can be found in the compromise between the powers of church and state sketched by the Founding Fathers in the Constitution of the United States. Hypocrisy may be a necessary social lubricant, but it is designed to drive philosophers to distraction. The separation of church and state (or the *Establishment Clause,* as it is sometimes termed) works only to the extent that no one forces the issue. In 1981 the General Assembly of the State of Arkansas did just that by requiring balanced treatment of so-called creation-science and evolution-science in the public schools of that state. Given the Establishment Clause, those religious groups that wanted to force their brand of Christianity into public schools had to pretend that it counts as science. Both scientists and religious leaders felt threatened.

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Scientists do not want to teach Bible stories in their biology classes, while adherents of other religions do not want the beliefs of Protestant Fundamentalists incorporated in school curricula.

In describing his experience as a witness in the Arkansas trial, Ruse makes it clear that trials are not spontaneous inquiries into truth but carefully staged theater. Each side knows what the other is going to say, even before the proceedings begin, because of all the rehearsals that precede trials. Ruse and the other expert witnesses were selected and coached by a team of bright, ambitious lawyers from the American Civil Liberties Union and the New York law firm of Skadden, Arps, Slate, Meacher, and Flom, as well as local attorneys. These lawyers made it abundantly clear that a court of law is not a graduate seminar. The endlessly sophisticated deconstruction appropriate in classrooms had to be suppressed, at all costs. The object was to convince the judge that the boundary between science and all forms of nonscience, including religion, is sharp and that evolutionary biology falls unequivocally on the science side of the fence, while creationism, as "low rent" as it may be, falls just as surely on the side of religion. Nothing else would do.

In the light of open court, the arguments that supposedly led a majority of Arkansas legislators (not to mention President Reagan) to conclude that creationism deserved equal treatment with evolutionary biology looked embarrassingly bad. Judge Overton ruled the Arkansas law unconstitutional. The "good guys" may have won, for a change, but if Ruse thought that creationists could play rough, he must have been surprised when his fellow philosophers responded to his testimony. Both Larry Laudan and Philip Quinn evaluated Ruse's testimony and Judge Overton's ruling from the perspective of cogent argumentation and found them seriously deficient. Although Laudan concluded that Judge Overton's "verdict itself is probably to be commended, it was reached for all the wrong reasons and by a chain of argument that is hopelessly suspect" (p. 351). Quinn was even harsher in his denunciation of both Overton and Ruse: he had no objection to philosophers serving as expert witnesses, but he thought that Ruse set a peculiarly bad precedent.

Laudan argues that the activities and beliefs customarily regarded as scientific are too heterogeneous to be captured by any definition in terms of necessary and sufficient conditions. In fact, the "problem" of demarcating science from pseudoscience or, more generally, nonscience is only a pseudoproblem. However, if one insists on applying such demarcation principles as falsifiability, the appropriate conclusion is that many tenets of creationism are not only falsifiable but false. Although the immediate effects of Overton's ruling may

well be commendable, Laudan fears that in the long run its consequences may come back to haunt us.

Needless to say, Ruse felt called upon to defend himself. In the first place, he thinks that traditional criteria *can* distinguish between science and nonscience reasonably well. The fault lies with the unrealistically high standards that philosophers set for such criteria, standards that are so high that no analysis of any concept has yet to generate much in the way of consensus among philosophers—"disagreement is almost our defining characteristic" (p. 391). On reasonable standards, some of the basic tenets of creationism are unfalsifiable; others are not only falsifiable but clearly false. Although philosophers can argue over the in-principle falsifiability of naturalism, Ruse thinks that something more basic is at issue. Some of the tenets of creationism, such as the Flood, are falsifiable in the sense that, although evidence applies to them, Ruse complains that creationists will not "relinquish belief in the Flood, whatever the evidence. In this sense, their doctrines are unfalsifiable" (360).

Laudan and Quinn could not be more searing in their response to Ruse's substitution of people for propositions. According to Laudan, "the *ad hominem* charge of dogmatism against Creationism egregiously confuses doctrines with the proponents of those doctrines. Since no law mandates that creationists should be invited into the classroom, it is quite irrelevant whether they themselves are close-minded" (353). Quinn agrees that the "soundness of creation-science can and must be separated from all questions about the dogmatism of creationists" (366).

I find the preceding dispute frustrating. Of course, many of the tenets of creation science are false. Of course, falsifiability is not good enough to distinguish science from pseudoscience, let alone nonscience, but I think that the real issue is people and not propositions. Scientists are hardly undogmatic. In the face of recalcitrant data, they do not capitulate on the spot. Just as Darwin characterized himself as a "master wriggler," anyone familiar with the creationist dispute can discern a significant difference in how creationists and genuine scientists treat data. Perhaps this is not a philosophically significant difference, and perhaps it should not be mentioned in any discussion among philosophers about the status of creationism, but it is more important in understanding science than any principle of demarcation. That Ruse and I should disagree with Laudan and Quinn about the nature of philosophy should come as no surprise, since there is even less consensus about its nature than there is about the nature of science.

Ruse seems to grant that treating creationism as abysmally bad

science, rather than as religion, would be intellectually preferable. "Unfortunately, the U.S. Constitution does not bar the teaching of weak science. What it bars . . . is the teaching of religion" (357). Hence, those who challenged the Arkansas law had to show that at least some of the tenets of creationism count as religious. At bottom, I think that the fault lies not with Overton, Ruse, or expert witnesses but with our legal system. Courts of law are not the place to decide whether creationism is science, bad science, pseudoscience, or religion—anymore than a judge should rule whether free verse is poetry—but, given current laws, this is exactly what judges must do on many diverse subjects, from sanity to pornography.

Sooner or later in the creationism dispute, someone needs to protest a system that allows state legislators to enact laws requiring teachers in public schools to teach anything that these legislators see fit—just so long as these laws do not touch on religion. If they choose, they can outlaw the teaching of non-euclidean geometry or mandate the teaching of free-market economics. It says something about politicians that they have sufficient good sense not to exercise this power very often. It also says something about religious leaders, that so few have been willing to stand up to the sleazy elements in their profession. Courage, moral or otherwise, hardly seems a striking characteristic of theologians and the clergy.

Although most of Quinn's discussion concerns the cogency of arguments, he acknowledges that the methodological problems so dear to philosophers of science are "only of secondary importance in the debate about so-called 'creation-science.' Methodological positions bear on the debate only to the extent that they can be made to serve as weapons in a political struggle, and methodologists should be interested in taking part in the debate only insofar as they wish to play a role in the policy-making arena" (395). As Quinn notes, sound arguments may not be very effective, and effective arguments may not always be sound. Under such conditions, possibly philosophers should stay out of such legal and political disputes. Although Quinn treats Ruse harshly, he reluctantly concludes that "it is morally permissible for us to use the bad effective arguments, provided we continue to have qualms of conscience about getting our hands soiled" (399). Apparently, Ruse's sin is that he does not feel guilty enough.

The Darwinian Paradigm, a collection of Ruse's essays, covers Darwin, sociobiology, and other issues in contemporary biology. At his best when dealing with Darwin, Ruse knows the Darwin literature thoroughly, and has considerable sympathy for the man and feel for the period. Ruse is also much more sympathetic to sociobiological

research than are most of his fellow philosophers. He argues that *Homo sapiens* is as much a species as any other, and truths about species in general must also apply to us. Yes, we are unique, but all species are unique. Yes, we are a social species, but so are a few others. It is also true that here on Earth we are the only species that understands very much about the world in which we live, but Ruse does not think that this difference entirely frees us from our biological heritage.

His main concern, however, is ethics. After asking whether rape is wrong on Andromeda, Ruse investigates which of our characteristics are likely to recur in moral creatures, no matter where these creatures might evolve. What are the empirical prerequisites for creatures being moral? First and foremost is sociality; morality is as inherently social as language, and for exactly the same reasons. But a high level of understanding is also required, and Ruse argues that sociality is just as necessary for any creature's being able to know enough to make moral decisions. A creature in isolation might come to know a bit about its environment, but if that knowledge always died with it, the levels of understanding necessary for moral decisions could never develop.

Ruse follows this line of reasoning even further, down to the basic processes of biological evolution. He argues that once living creatures appear, the processes of biological evolution will take over. Many of the characteristics that living creatures exhibit are largely a function of the accidents of their evolution, but some result from the basic features of the evolutionary process. Natural selection will surely play the same major role in evolution no matter where life arises. The prevalence of multicellularity and sexual reproduction are another matter; both appeared quite late on Earth and are far from universal even now. But there seems to be something about multicellularity that encourages sexuality; it is also a prerequisite for extensive knowledge acquisition. Single cells cannot discern, store, or process much information about their environments. Sociality also poses problems. Although sociality has evolved more than once on Earth, it evolved only recently and only in a few species.

Hence, extraterrestrials need not be moral; but if they are, they will be multicellular, social organisms who (that) are capable of extensive knowledge acquisition. Because Ruse is a realist when it comes to knowledge acquisition, he concludes that knowledge of the empirical world that any extraterrestrials develop will resemble our own. Basic regularities are there for anyone to discover. Routes to understanding the nature of the empirical world may differ markedly, but the results will eventually converge. Extraterrestrials

will no doubt devise different notations for their mathematical systems, but these systems will be equivalent to ours: 2 + 2 will equal 4, regardless. But will those extraterrestrials, who, have what it takes to be moral, have the same morals as we do?

Ruse concedes that there are likely to be considerable apparent differences between us and extraterrestrials. After all, there is considerable variation here on Earth on such things as circumcision, suttee, and alcohol consumption. Ruse also argues for important similarities at deeper levels of morality; for example, it is very likely that extraterrestrials will develop principles very much like the "greatest happiness principle" and the "categorical imperative." No matter that these principles are applied only selectively by people, and on certain issues lead to different prescriptions. Extraterrestrials are no more obligated to hold consistent sets of moral principles or to apply them more consistently than we are. Ruse finds the biological basis for the greatest happiness principle in kin selection and for the categorical imperative in reciprocal altruism.

But how about rape? The "biological requirements" for rape in human beings are different sexes and the tendency to be selective in mating, especially on the part of females. Female selectivity, in turn, follows from the fact that, in humans, women have done and continue to do most of the child rearing. If human males could spread their semen to the winds the way that some plants do and if children could fend for themselves at birth, as in many species, the issue of rape would never arise. A woman's becoming pregnant would be as much a matter of chance as catching a cold. Ruse cannot say with certainty that extraterrestrials will reproduce sexually, but if they do there will be two sexes. (The possibility of three or more sexes evolving is negligible.) If there *are* two sexes, there is good reason to expect that one will produce small motile gametes, the other large sessile gametes. Hence, by definition, one will be male and the other female. To reproduce, males and females must mate; but here Ruse's argument falters. He can find nothing in biological evolution to suggest that the conditions that make rape morally wrong for humans would also exist for extraterrestrials. Creatures that lack the prerequisites for rape may well have developed this concept for other species, but they are likely to find extension of this moral concept to themselves as strange as we find extending it to maple trees, slime molds, and pedunculated isopods.

I have strong reservations about using science-fiction examples in philosophy, because they introduce endless confusion and make philosophical discussions look silly to the uninitiated. However, Ruse's extraterrestrials are merely a device to illustrate what can

and cannot be inferred about living creatures on the basis of evolutionary theory. As Ruse would be the first to admit, some of the connections that he discusses are speculative, but as tentative as his conclusions are, they present morality in a different light—so different that some readers might conclude that conventional systems of morality can find little support in evolutionary biology, and in fact conflict with it, which is the topic that Ruse addresses in his concluding essay.

In "Evolutionary Theory and Christian Ethics," he argues that certain Christian morals are incompatible with biological evolution. If we attempt to practice them, we will have to overcome our biological heritage. He begins with the Catholic church's teaching on sexual behavior as exemplified in the 1968 encyclical *Humanae Vitae,* in which Paul VI argues that both birth control and homosexuality are immoral because they are not natural. If by "natural" the pope meant what scientists say, he is simply mistaken. Procreation is not the *only* function of sexual intercourse. For a species such as ours, which requires so much parental investment in raising children, pair-bonding plays a vital role as well. At an even more basic level, the primary biological function of sexual intercourse is to increase genetic heterogeneity. And as far as homosexuality is concerned, it is far from biologically unnatural. Selective nonreproduction can be evolutionarily quite adaptive. For example, from the perspective of kin selection, homosexuals can increase their genetic inclusive fitness by helping to raise their close relatives.

Of course, all the preceding depends on the pope's using the term *natural* to refer to what scientists tell us about nature. Actually, it is as much a technical term in Catholic theology as *altruism* in biology, and has more to do with Aristotle than anything in present-day science.

More generally, if morality is viewed as an evolutionary adaptation, the claim that we must love our neighbor as ourselves conflicts with modern evolutionary thought. According to contemporary theory, the frequency with which parents seriously deprive their offspring to benefit very distantly related children, on the other side of the globe, will be almost nonexistent. Rare exceptions notwithstanding, people behave according to the theoretical prescriptions of evolutionary biologists rather than the religious prescriptions of theologians. Ruse concludes that "when it comes to ultimate foundations, the evolutionist and the Christian part company. For the evolutionist, morality . . . rests in the contingencies of human nature. In an important sense, therefore there are no ultimate foundations, just a biological illusion of objectivity" (271).

One possible conclusion to Ruse's argument is that he has merely shown that biological evolution cannot provide an adequate foundation for morality. But how about the other foundations, provided by philosophers and theologians? They agree that some such foundation must exist, but they disagree vehemently over what these foundations are; and more people have died over such disagreements than over any other cause, save major plagues and natural disasters.

Evolutionary morality makes me feel uneasy, but I feel safer placing myself at its mercy than in the hands of those who profess Christian brotherly love—and that goes for "true Christians" as long as they remain paralyzed while their fellow "false Christians" continue their evil ways. The arguments that Christianity per se is not responsible for anything that Christians may or may not have done are about as convincing as those that exonerate Exxon for anything that members of this corporation may or may not have done. Ruse puts his message more reassuringly than I have explained it, but no one can say that Ruse lacks the courage of his convictions, whether testifying at the Arkansas trial or lecturing at seminaries.

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Science and Providence: God's Interaction with the World. By JOHN POLKINGHORNE. Boston: New Science Library-Shambhala, 1989. 114 pages. $10.95.

In this unique book an eminent physicist dares to write on key problems that arise when modern science confronts theology on the most controversial issues. Dr. Polkinghorne is not defending some watered-down theology, such as process theology or some version of panpsychism. He has expertise in Christian theology, especially in its Anglican version, and gives documentary evidence for all of his statements, often with a biblical reference. Complementarily, he gives references to the scientific and philosophical literature. We therefore have assurance that his text is a work of scholarship.

The book concentrates on God and the universe, with special reference to "self-conscious" persons: "Many detailed problems remain about the nature and location of God's activity but its general

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conceivability has been enhanced by recent developments in science. Neither God nor man is perceived as caught in the grip of relentless causal rigidity'' (p. 13.8). God's relationship to the world of his creation is recognized as both transcendental and immanent. Modern physical scientists, such as Einstein and Schrödinger, in stressing the transcendental God missed the essential message of Christianity, which concerns the immanent, loving God who is, especially, the creator of each of us, with our unique, ineffable selfhood—our *soul,* in Christian parlance.

In discussing our mental and our material pole, Polkinghorne ''suggest[s] that this complementarity enables us as psychosomatic unities to participate at our mental pole in a noetic world,'' and then ''that humans are mind/matter amphibians participating in both material and mental worlds.'' As a radical dualist, I completely agree. Later, however, Dr. Polkinghorne ''seeks to avoid an incomprehensible Cartesian dualism.''

Despite much reference in the book to the mind-body problem, it must now be recognized that the brain mediates in all reciprocal actions between body and mind; so we should talk about the mind-brain problem in philosophy and religion. The brain-body problem is exclusively neuroscientific. Once we concentrate on the mind-brain problem, the way is open to a radical dualism, and it is now possible to formulate scientific and philosophical hypotheses about the operation of ultramicrosites of the cerebral cortex where quantum physics is applicable. Yet Dr. Polkinghorne is dubious: ''I am not saying that there are never circumstances in which quantum effects are amplified to have macroscopic consequences, only that they are unlikely by themselves to provide a sufficient basis for human or divine freedom.''

The main part of the book is theological in its successive chapters on providence, miracle, evil, prayer, time, the Incarnation, and sacrament. I admire Dr. Polkinghorne's ability to write scientifically on these themes, which are largely theological.

He writes on miracles as they are usually defined: ''He (God) is the Creator and Sustainer of the whole physical world. Those very laws of nature, said to be violated by a miracle, are themselves the expression of his Creatorly will. One does not doubt, in one sense, his capacity to countermand them. Such action of itself cannot be beyond the power of an omnipotent God.'' ''A theologically acceptable account of miracles will have to incorporate them within a total, and totally consistent, understanding of God's activity, and not see them as singular exceptions.'' Thus *miracle* is restricted to material happenings. (I have always thought of miracles as happening also in

the mental world, for example, in a sudden conversion. The best-attested, most momentous miracle happened to Paul of Tarsus on the way to Damascus. I have also used *miracle* for the coming-to-be of each unique, conscious self or soul. As I have argued, this uniqueness that each of us experiences is not explicable materialistically [e.g., genetically].)

I especially commend chapter 5 on evil, where Dr. Polkinghorne displays great wisdom, feeling, and understanding in discussing human persons. However, there is inadequate reference to the evolutionary origin of *Homo sapiens,* from apelike ancestors that lacked self-consciousness and so cannot be accused of evil acts. It is theologically perplexing how, in hominid evolution, there came to be creatures (Neanderthalians) who practiced ceremonial burials with ochre-covered bodies and with weapons, tools, and ornaments for an afterlife. Much earlier, there had probably developed a society with a family structure and social cohesion, along with those "positive" virtues that would also be called evil practices (such as aggression, theft, torture, and killing) because they are performed by self-conscious beings. So evil came into the world, in hominid evolution, as the dark side of the developed freedom of the will that gives us opportunities for all the virtues. We must recognize that hominid evolution was God's greatest gift, the divine guidance of creative evolution, leading eventually to the loving creation of the soul at the center of each human being. Dr. Polkinghorne's discussion of evil accords with our evolutionary origin.

The chapter on prayer is purely theological. (My own belief is that petition for favors is a low level of prayer; surely prayer should be the opening of our minds [our souls] in love to God in gratitude and thanksgiving.)

There is much wisdom in the chapter on time, where Dr. Polkinghorne can speak authoritatively as a physicist and as a theologian. He states, quoting from Isaiah: "The True God is at once the high and lofty one who inhabits eternity" and, at the same time, the one who dwells "with him who is of a contrite and humble spirit." "These fundamental intuitions are part of the dialectic of divine eternity and divine temporality."

The chapter on hope is dominated by the anthropic principle and the fate of the cosmos in thousands of millions of years. However, that is beyond all imagining. The Christian belief is that our spiritual self, or soul, survives the death of the body. It has transcended the bondage to physics and physiology and so has passed to the cosmos and awaits fulfillment in some future existence in God's providence. It is appropriate to quote Arthur Peacocke in speaking of

biological evolution: "The Creator is an improvisor of unsurpassed ingenuity."

The last sentence of this memorable book must be cited: "The world in fact discerned by modern science has an openness in its becoming which is consonant, not only with its being a world of which we are actually inhabitants, but also a world which is the creation of the true and living God, continually at work within its process."

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Universe: An Evolutionary Approach to Astronomy. By ERIC CHAISSON. Englewood Cliffs, N.J.: Prentice-Hall, 1988. 544 pages. $50.60.

The scientific paradigm of evolution has proven to be a robust and powerful framework for understanding nature at a fundamental level. Though more often known for its biological ramifications, astronomers use *evolution* as a convenient shorthand to describe the temporal unfolding of inorganic structure in the universe. For example, we speak of the formation and decay of a star as its "birth" and "death." The stages in between represent a sequence of physical transformations governed by gravity and nuclear energy acting on matter.

Rather than as a single, unique process, the details of biological evolution are increasingly seen as part of a continuum of events: organic chemistry is inextricably embedded within the larger dynamics of inorganic matter. In this grand pageant of causally ordered events, the appearance of DNA on Earth can be traced, through an unbroken chain of physical interconnections, to conditions that attended the "birth" of the universe itself.

Maturation of the scientific understanding of how matter and energy transform continuously has led to an exciting, holistic worldview, referred to as *cosmic evolution,* that is beginning to find its way into the classroom. Beyond its potent philosophical implications, it is invaluable as a pedagogical tool in organizing seemingly unrelated topics in astronomy into a tight unity of thinking. Rather than unrelated phenomena, students perceive that some astronomical phenomena are crucial precedents for others. Supernovas create,

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and violently disgorge, carbon, nitrogen, oxygen, and many more elements, which can become the building blocks of DNA and organic life.

Based largely on his popular undergraduate course at Harvard between 1975 and 1982, Dr. Chaisson's *Universe: An Evolutionary Approach to Astronomy* is a fast-paced and concise account of the physical basis, and evidence, for cosmic evolution. The author reaffirms the scientific view that biological evolution is an overwhelming empirical fact of our existence. Organic life represents the penultimate evolutionary stage in inorganic matter, acted upon by natural forces in the universe. In a sense, matter evolves into living creatures almost as inexorably as stars evolve from interstellar dust clouds, provided the physical conditions are suitable. The verity of the evolutionary paradigm is placed on the same footing as the fact that Earth revolves around the sun. Clearly, this book is intended for instructors who are comfortable with this no-nonsense assertion—for instructors who are not apologists for such an assertion despite inevitable criticism by religious Fundamentalists.

Striving to paint with broad strokes the central themes and highlights of cosmic evolution, Dr. Chaisson succeeds admirably, offering the nonscientist much to think about in clear and concise prose. The volume of information in any one chapter, though overwhelming, is skillfully presented so that the reader periodically "comes up for air." There is a tendency for major points to get lost among interesting anecdotal details; however, the preambles in each chapter are well crafted and summarize all important issues.

This is one of the first books of its kind, to my knowledge, and no "first edition" is without its shortcomings. Most of the major deficiencies in *Universe* cannot be traced to omissions or inaccuracies by the author, but to editing lapses during manuscript preparation and the galley stages. In addition to an unusually large number of typographical errors (e.g., star names such as Alpha Centauri should *not* be hyphenated), very little care was taken in rendering many (500+) figures. Illustration problems begin with the frontispiece of the textbook, which was printed upside down (at least in the reviewer's copy). Beyond this, many of the black-and-white photographs are almost unreadable, especially when line drawings are superimposed on photographs of galaxies and nebulae. Also, the selection and reproduction of color prints were not carefully supervised, with an eye toward basic artistry.

Of course, because no two authors will include precisely the same material in a textbook, a reviewer will therefore inject a certain amount of personal bias into his or her evaluation, based on a pre-

conceived notion of what a textbook of a given title should "reasonably" contain. This said, I must acknowledge that various lapses of timeliness and technical accuracy made *Universe* somewhat uncomfortable to read.

For example, little or no mention is made of the discovery of bipolar outflows or protoplanetary disks associated with very young stars. Both of these discoveries, made since 1982 but prior to 1987, are crucial to the argument that solar systems are a common, if not unavoidable, phenomenon in the Milky Way galaxy. Apparently, astronomers are beginning to detect the material out of which planets may form around young nearby stars, suggesting that one day, perhaps with the recently launched Hubble space telescope, we may detect individual, Earth-like planets revolving around other stars.

Nor is mention made of the powerful technique of dating speciation by DNA differences and genetic clocks. This procedure appears to reproduce the "tree of life" taxonomic classification independently and is able to determine the times when various species became distinct. The discovery of "Mitochondrial Eve" by this technique certainly deserves a few paragraphs.

The author describes dinosaurs as "Great Failures" in his chapter on Darwinian evolution, even though they lasted several hundred million years (a feat we humans may not be able to match). The manner of their sudden demise sixty-five million years ago leads naturally to a discussion of the Cretaceous Impact Theory, which has received much attention over the last ten years. The three brief paragraphs that describe this new scenario for the dinosaurs' extinction does not seem quite sufficient in view of its role in bringing celestial and biological events together with dramatic finality.

In spite of the many new advances in physics and cosmology, there is little mention of the exciting developments in this research, so that the textbook appears to be at least fifteen years out of date in this area, which has revolutionized the way astronomers view the universe. The author's review of nuclear physics portrays quarks as a matter of "popular consensus" rather than as the experimental reality that they actually represent. Physicists have demonstrated the existence of five quarks, and are ready to confirm a sixth. The nature of the cosmological constant is dismissed as arbitrary and ad hoc, even though it appears as a natural property of space-time in nearly all unification theories that have been developed since 1975. The author's admonition, that "to speculate about times before the origin of the universe is simply not science," would probably be viewed as a parochialism by such luminaries as Stephen Hawking and Stephen Weinberg. In today's dynamic intellectual age, it is probably safer

to adopt the maxim that "what scientists 'do' is what science 'is.' "

One of my pet peeves is the common misinterpretation, by many astronomers, that the cosmological redshift is a Doppler shift, caused by the apparently enormous velocities of distant quasars. Again, this interpretation is false and misleading. The correct, mathematical interpretation, obtained directly from Einstein's theory of general relativity, has always been (at least for cosmologists) that the redshift represents a gravitational "stretching of space = time" between transmission and reception points as light makes its journey from the quasar to the observer. This has nothing to do with relative velocities between the observer and the distant quasar. Thus the author's quantitative discussion of the energetics of quasars is also, at times, misleading.

Apart from these difficulties, as a textbook for the nonscientist and the first of its kind on this wide topic I think that *Universe* goes a long way toward presenting astronomy as a complex human endeavor and the universe as a rich canvas, filled with exciting, inspiring phenomena and interconnections, and capable of rational understanding. It is unfortunate that the author's dynamism and enthusiasm have been diminished by poor execution and editing. Since these details can be easily remedied, I trust that the second edition will be given more careful attention.

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