TAKING CREATION SERIOUSLY

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There is rarely anything new on the Creation-Evolution front. Creationists keep reciting the same arguments: there are no transitional fossils, evolution is a godless religion, the Second Law of thermodynamics precludes increasing complexity, and so on. We evolutionists come back with stereotyped arguments of our own: here are intermediates in horse evolution, creation is intrinsically religious and not scientific, the Second Law applies only to closed systems—and we all go back to the same old dreary shouting match. SKEPTIC might do an issue rehashing the usual arguments once every decade or so, but only because creationists refuse to go away.

The problem is, it is partly our fault the debate is stagnant. We talk past creationists, not addressing their real concerns. Our standard anti-creationist arguments are often superficial, sometimes even wrong. Not as wildly wrong as the usual creationist arsenal, of course—that level of badness is hard to reach—but wrong nonetheless. As critics, we do not take special creation seriously, treating it as a disease of brains overheated by religious fundamentalism. But while creation is a mistake, it still deserves some respect. If nothing else, it is a mistake which can tell us a lot about science, religion, and our culture.

To illustrate how we misunderstand creationists, I want to examine two common objections to creationism. First, our habit of ruling creation out of court by declaring it an intrinsically unscientific hypothesis. This is because it calls on supernatural forces, or is unfalsifiable, or some such reason. This is all wrong. There is no sharp line dividing science from non-science, nor are tests like falsifiability even a roughly useful way to understand how creationists are mistaken. Creation is a legitimate hypothesis, but one more similar to explanations in human history than to the impersonal theories of natural science. When need to appreciate this, and see how creation is a false historical explanation.

My second example is the classic creationist attempt to play physics

against biology: the Second Law. We are good at pointing out the clumsy way creationists use thermodynamics, but we rarely go beyond the surface to see what in the Second Law is so attractive to them. Creationists are neither perverse nor completely ignorant: they depart from the Second Law to express a commonsense theory of how functional complexity requires an external Designer. As long as we do not address these commonsense beliefs, bringing up open systems only scores debating points.

Finally, with these examples in place, I will suggest creationism is best seen as a populist attempt to reclaim science for a deeply religious culture. We like to think we stand for openness while creationists are fixated on the Authority of their scriptures. But science is an elite institution, and defenders of science naturally take to an authoritarian style of argument. In contrast, creationists make populist, commonsense appeals, envisioning a pragmatic sort of science which fits our everyday religious culture. We evolutionists, then, are in an unenviable political position. Elitists in a democratic culture, we also have to struggle to keep a rickety anti-creation coalition together, using bad arguments to paper over evolution's disturbing implications for liberal as well as conservative religion.

In other words, while skewering creationist absurdities, we might want to pay some attention to the beam in our own eye as well.

Out of Bounds?

Creationism in this day and age seems like believing in a flat earth. No doubt our world could have been flat, but if we take science seriously at all, we know it is round. Flat-earthers are exotic creatures now, and when we come across them, we quickly discover they do not do science; instead, they churn out excuses to protect their beliefs. Creationists do much the same. The forms of life we see could have appeared abruptly, out of nowhere, but we have found that evolution is a much better way to explain them. And creationists obviously do not *practice* science—they cook up apologetics to protect fundamentalist religion from modern science.

So far, so good. Few critics of creationism would quarrel with the observation that creation-science is not quite the real thing. But when we say creationism is not science, we often mean more than that creationists do not practice science, or that special creation is a failed theory like a flat earth. These are not sins enough, apparently. We will not be satisfied unless cre-

ation is an illegitimate hypothesis, not admissible to the bar of science even to be dismissed as a dismal failure. Creation is unfalsifiable, we say—not something science can get a handle on. Worse, creationists have all these gods and demons running around. Supernatural explanations just cannot be allowed in science.

This is not anti-creationist overkill. It is the conventional wisdom. For example, Michael Shermer lists "twenty-five creationist arguments, twenty five evolutionist answers"; a compilation of standard responses. The supernatural is taboo: "as soon as the creation of even one species is attributed to supernatural intervention, natural laws and inferences about the workings of nature become void. In each case, science becomes meaningless." No wonder creationism causes panic among the friends of science. Fortunately, the threat of creation is also its undoing, since "once you assume supernatural intervention, science goes out of the window—so there can be no scientific evidence in support of creationism because natural laws no longer hold and scientific methodology has no meaning in the world of creationists." Creation is a religious idea, and Shermer says religion is "neither testable nor open to rejection or confirmation."[1] The creationist mistake is not mere bad practice or their tapestry of ludicrous arguments, but their belief that science could even consider special creation, let alone confirm it.

This conventional wisdom even enters court decisions. As Judge W.R. Overton put it in his decision against teaching creation-science in Arkansas,

> the essential characteristics of science are:
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> **(1)** It is guided by natural law;
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> **(2)** It has to be explanatory with reference to natural law;
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> **(3)** It is testable against the empirical world;
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> **(4)** Its conclusions are tentative, i.e. are not necessarily the final word; and
>
> **(5)** It is falsifiable. (Ruse and other science witnesses)
>
> Creation science ... fails to meet these essential characteristics.[2]

It would be lovely if we could find some Deep Principles separating scientific and non-scientific fact claims, especially if these principles excluded creation. We could ban creation from the classroom, go home, and live happily ever after. Creationists are not amused, of course. They suspect this

exclusion-by-definition is a bit underhanded; they may even muse darkly about conspiracies by an anti-Christian Establishment. Conspiracies aside, though, the creationists are right. The conventional wisdom does not describe science very well; neither does it exclude special creation. One of its prime attractions, however, is that it makes a good stick to beat creationists with.

Let us start with falsifiability, Karl Popper's key to separating genuine scientific claims from those only masquerading as science. Since science is supposed to explain the world, its theories must have some real content we can put to the test. These theories might then fail. In contrast, pseudosciences produce excuses to fit every possible test.[3] Science *discriminates* between different possibilities; an explanation which cannot fail is no explanation at all.

This sounds very reasonable, indeed obvious. Just so. Precisely because falsifiability is such a broad and obvious requirement, it is very difficult to get it to do useful work.[4] A theory which cannot discriminate does not tell us anything about the world. But whatever the faults of creationists, content-free verbal fog is not among them. Outside of existentialist theology and postmodern moaning about the impossibility of knowledge, such comprehensive vacuity is hard to find. A creationist who says the world was created in six days, six thousand years ago, is not shying away from definite claims. Many of her co-religionists will criticize her for being overly specific.

Creationist writings are full of recklessly definite claims. They say beneficial mutations do not happen, or happen too rarely for life to diversify even in geological time spans. Biologists think this claim is false, not unfalsifiable. Creationists declare functional order cannot self-organize without an intelligent designer. Physicists point out this is wrong; they do not treat it as a claim science cannot even consider. Creationists make legitimate fact claims, and by doing science we find these claims are most likely false.

But what about creationist excuses? Anyone debating creationists will soon get exasperated by their ingenuity in avoiding defeat. Bring them an observed example of speciation, and they say it must be merely variation within a kind. In this case, the ever-vague "kind" is more like a genus than a species. If radiometric dating comes up with rocks millions of years old, radioactive decay rates must have been screwed up during some past cataclysm. It seems the definite claims are side shows. Creationists occasionally give up peripheral claims, but their central belief in special creation remains invulnerable.

But this is beside the point. Some creationists might be bloody-minded in their commitment to creation, but this is a fact about *creationists,* not *creation.* Someone insisting the moon is made of green cheese in the face of all evidence is a fool, but her style of belief has nothing to do with the moon. "The moon is made of green cheese" is a straightforward claim, which happens to be false. It does not have "only a world-class idiot can believe in me" stamped on it—though that happens to be true.

More seriously, giving up peripheral claims while holding fast to an overall theory happens in science as well. Our most ambitious theories are so broad as to be, strictly speaking, unfalsifiable. Say we want to calculate some planetary orbits, so we equip ourselves with classical celestial mechanics. But our observations, while close, do not fit our predictions. Do we now scrap our dynamical laws, the heart of classical theory? Or do we start fiddling with our boundary conditions? A perturbation in an observed orbit, for example, might be due not to a flaw in Newton's laws, but to the gravity of an unseen planet. This is exactly how astronomers began to suspect the existence of the outer planets.[5]

Though boundary conditions give us a lot of wiggle room, this does not make our theories invulnerable. We now think a tiny anomaly in Mercury's motion is evidence for general relativity. But this is not because classical mechanics completely fails for Mercury. Postulating a new planet even closer to the Sun did not work, but there are always more exotic alternatives. Perhaps there is a distribution of invisible matter in the solar system, which behaves in just such a way as to account for Mercury's perihelion. This is, of course, a breathtakingly gratuitous assumption which would grate on the nerves of any self-respecting physicist. But strictly speaking, a set of boundary conditions is available to make Newton's laws fit exactly what we see.

We amended Newton when we had a better theory. Without relativity, any bizarre condition necessary to save classical mechanics would just be an ugly fact of life. Many cosmologists today argue that most matter in our universe must be some unknown, exotic dark matter. Some attractive theories require dark matter to remain consistent with *all* we see. But this is fine. Every theory has arbitrary boundary conditions, adjustable parameters, anomalous cases, and so on. These only become *excuses* when we have a rival theory. For classical mechanics, Mercury's perihelion was a small but unexpected nuisance to be swept under the carpet. For general relativity, it was precisely what to expect. Compared to relativity, the possible classical

explanations became blatant excuses.

Historically, something like this happened as evolution took over in biology. Creation used to make sense of life. We used to explain the structure of living things by asking what God created them *for*. A bird is meant to fly, so its wings must be well-designed for that purpose. Nature must be a harmonious web of purposes, so the bird must exist in a delicate balance with its environment. Furthermore, the designs of life show a certain unity. We can classify creatures in neat hierarchical groups; we see no abominations like mammals with feathers or eight legs. Unity of design and harmony of life is just what to expect from a single Designer with a definite overall Purpose.

Not everything fit smoothly in a creation-framework. Parasites, for example, strained the picture of benign harmony, even if imperfections could be expected in a fallen world. In time, more uncomfortable facts accumulated: evidence for an old earth, extinct species, and so forth. Yet special creation did not die because it was directly falsified by evidence. It died the death of a thousand excuses. Evolutionary ideas began to explain why we should expect the particular imperfections we saw, while also accounting for the strengths of creation. Well-adapted, neatly classifiable life forms became signs of common evolutionary descent. While modified creationist scenarios could remain consistent with the evidence, compared to evolution they became a tangled mess of excuses.

So we might think of creation giving way to evolution as a scientific revolution. Creation was once a handy framework for scientists. But with evolution on the scene, special creation started to look false. A broad framework-theory like creation does not collapse because some mythical "pure data" clashes with the deductive consequences of the theory. Nevertheless, we can say creation is false, like we say Aristotelian physics is false. With Newtonian physics in place, it made no more sense to talk about objects moving in order to achieve their idiosyncratic natural purposes. Similarly, we found we could do biology much better without Divine Purpose.

Emphasizing falsification obscures how creation was once a reasonable idea, and why we now think we can do better. Still, there may be other reasons to rule creation out of bounds. Another way of looking at history is to say the transition from creation to evolution was not a change within science but a step in defining science. Scientists did not find creation was false—they realized it was not science. Perhaps science allows only naturalistic explanations, so a mature science cannot even entertain ideas like creation.

The trouble is, we are interested in what actually happened in the past. Creation is at least a possibility, it seems, whether "scientific" or not. If we define it out of science, it looks like we have rigged science to exclude certain ideas. Sophisticated creationists like Phillip Johnson already charge modern science with being a prisoner of naturalistic presuppositions.[6] Presumably a different science, built on Christian assumptions, would affirm a creationist story of our past. Both creation and evolution become ways of working out deep metaphysical commitments. Creationists can now accuse evolution of being no less an act of faith than creation.

If science is worthwhile, it is because we think it is a good way to get reliable knowledge about our world. We do, of course, start from common-sense assumptions. We certainly carry our metaphysical baggage with us. However, these need not be permanent commitments. In learning more about the world, we often rearrange our conceptual furniture quite radically. Biology started out with creation, but ended up converging on evolution. We would like to think this represents an advance in our knowledge, not a leap from one faith to another. So we cannot avoid comparing creation and evolution as explanations, however tempting it is to define science narrowly.

In fact, our sciences can and do address supernatural claims. Consider spirit-possessions, haunted houses, or prophecies of future events. These may be disreputable ideas, but they could have been true. We can imagine a world in which ghosts haunt houses—where ectoplasmic relics of dead persons float down crumbling stairwells and psychically influence solid objects. When we investigate a haunted house, there is no logical guarantee we will only find eerie sounds caused by air currents. We could stumble upon ectoplasm instead.

Going further, we could have a research program devoted to validating supernatural claims. Our religious and folk beliefs involve similar claims about a fundamentally *personal* reality irreducible to a material world. This personal reality underlies our everyday existence. We, a peculiar union of mind and body, reside in between. However, personality and purpose is the more fundamental reality, creating and causing the material. This deeper reality occasionally breaks through in events of "mind-over-matter." Saints levitate, psychics bend spoons. We can investigate claims of supernatural realms, and we can do this with a working hypothesis that there *is* magic in our world. We can, in other words, do parapsychology.

Psychical research is not, of course, terribly respectable. However, it is more difficult to call parapsychology a pseudoscience than creationism.

Parapsychologists, by and large, practice science. They conduct sophisticated experiments, try to construct theories, and then report and criticize these in scientific journals. They may not convince skeptics, but they still make claims within science. If our Uri Gellers had been clearly more than skillful conjurors, or if the laboratory evidence for psi turned out to be better than marginal effects which do not stand out from among possible mistakes, we would have good reason to suspect a supernatural, mind-first reality underlying a material surface. Our world is different. Parapsychologists have produced no signs of psi, and so they resort to excuses—like skeptics giving off bad vibes—to keep their working hypothesis alive. The quest for psychic power is a failed research program, not an inherently unscientific enterprise.

So some traditionally supernatural claims can be scientifically investigated, even rejected for scientific reasons. Still, if psi existed, it would be a rather regular form of magic. Psychic powers may be capricious, but they are also supposed to be statistically repeatable. Creation-miracles seem to be a different species. A Biblical creationist might explain geology by a global Flood, but the cause of the Flood is ultimately the will of God, in the context of a particular historical situation. Though using quasi-natural processes like a gigantic Flood, God intervened from outside of nature. This was a unique creative act. If real, spoon-bending could fit in a regular supernature, if not nature. But with the grander creation-miracles, we encounter a divine will above all regularity. If science depends on regular, lawful order, what are we to make of a power beyond all law? The concerns Michael Shermer expressed surface: if we allow even one completely arbitrary miracle, where do we stop? We might be able to fashion mind-over-matter into a scientific hypothesis, but creation goes too far.

Creation, however, can survive this objection. First of all, unique and arbitrary events are not out of bounds for science. Modern physics inflicts a lot of randomness on us. Quantum mechanics is notoriously a realm of uncaused, random happenings, but even gravity can give us intrinsic randomness on a cosmic scale.[7] The Big Bang, for example, is an effectively unique and uncaused event, much like a pesky quantum fluctuation. Yet our sciences manage to deal with such events. Physics describes its accidents in an impersonal, naturalistic way. If there was a global Flood, it might make better sense from a personal, supernatural perspective; in any case, we could at least discover that it happened.

More importantly, creationists *do not* propose completely arbitrary divine interventions. "God" is not a code word for randomness—quite the

opposite. Creationists explain their miracles by their God's purposes and moral character. This God is a personal agent: we can begin to understand God's actions in much the same way we tell stories about human actors in history. A historian narrating Caesar's conquest of Gaul relies on physical and documentary evidence to establish the reality of the events, but she also uses personal explanations like Caesar's political ambitions to bring everything together. Creationists can treat their Flood hypothesis similarly, producing a historical narrative about individual events—events which are not just instances of impersonal natural laws.[8] They can seek signs of a global cataclysm, and try to make sense of it all in terms of their God's intentions.

Flood-geologists attempt to do this. They argue that the rock layers we see were laid down rapidly, that fossils are sorted in hydrodynamic and ecological order, that a great catastrophe is the best way to account for the earth's past. They claim various great flood legends represent historical memory; they insist the Bible is trustworthy testimony about our past, independently confirmed even in its fantastic details by historians and archaeologists. They then say that initiating a Flood fits the character of a supremely holy God confronted by a terminally corrupt world. If this God had to suspend the regular operation of nature to accomplish this purpose, so be it. This is not an arbitrary intervention, but an act with moral reasons behind it. The end result is a scenario for our past which does not look like the sort of scientific explanation we are used to. It is more like an explanation in human history: a narrative involving the actions of personal agents. But this difference in style does not mean the claims of flood-geology cannot be addressed by science and history.

The Flood miracle could have happened, and our legitimate scientific and historical knowledge could have confirmed it as true. Of course, in our actual world, it is false. Compared to mainstream science, flood-geology is a monumental joke. Our fossils are not arranged by hydrodynamic sorting, the Grand Canyon was not carved out by a catastrophe, and the Bible is not a trustworthy record of a God's dealings with people. We understand what a global Flood would do, and we find none of the signs. Creationists must misrepresent the evidence, or resort to increasingly ludicrous excuses. They might, for example, invoke extra miracles to dispose of their many physical difficulties. But this sort of miracle is obviously a measure of desperation, not something that reveals divine purpose in history.

Creation could have been true. Life could have been radically discontinuous, with "kinds" separated by unbridgeable gaps. Nature could have

exhibited a moral order intertwined with human history. There is no philosophical knock-out punch we can deliver creation; we just have to argue about how our world happens to be. Our best arguments show how thoroughly evolution succeeds in making sense of biology. These scientific arguments are all we have, and, if we are not beguiled by the promise of Deep Philosophical Distinctions, they are all we needed anyway.

Order and Chaos

Some creationists disdain evidence, relying only on scripture. But *creation* is true or false independent of styles of belief. So creation-scientists roll their sleeves up, and attempt to show the world makes better sense from their perspective. While they push a half-baked "creation model," they spend more energy trying to undermine evolution. This is understandable. For with evolution firmly entrenched, creation looks not only false but ridiculous.

Creation-scientists would also like some quick ironclad arguments to rout the opposition. First of all, they have their own brand of Deep Philosophy. For example, they say creation and evolution are equally unscientific, because no one can directly observe or experiment with events so far back in the past. While evolutionists too often rely on an outdated Popperian philosophy of science, creationists use a *way* outdated Baconian philosophy: scientists should gather facts and make generalizations, scrupulously avoiding theoretical "speculation."[9]

Eventually, however, creationists also have to come down from the clouds and try their hand at some real-world arguments. Again, they would love something ironclad—like an indisputable physical law which precludes evolution. Thermodynamics, according to creation-scientists, does just this.

Unlike much in science, basic thermodynamics is comparatively easy to translate to commonsense language. As the old textbook description goes, the Three Laws of Thermodynamics say "you can't win, you can't break even, and you can't get out of the game." Energy is conserved; the amount of energy available to convert to useful work always decreases; there is no cheating by cooling things to absolute zero. Left to themselves, systems get more disorganized in time. The books and papers on our desks will, through the haphazard interactions of everyday life, get strewn about to create a mess. But our clutter will never spontaneously organize itself into neat piles.

We can now draw commonsense conclusions from thermodynamics. First

of all, the three laws seem to mean the order we see can only have degenerated from a more perfect past state. As Henry Morris puts it,

> The Second Law (the law of decreasing available energy, as the universe heads downward toward an eventual "heat death," with the sun and stars all burned out) tells us that there must have been a primeval creation, or else the universe would already be "dead"! The First Law (law of energy conservation) tells us that no energy is now being created, so the universe could not have created itself. The only scientific conclusion is that *"in the beginning God created the heaven and the earth"* (Genesis 1:1).[10]

Mindless, impersonal processes can only maintain order or create chaos. In everyday experience, only living, intelligent beings act on dead matter to order it. When we see a neat desk, we infer an intelligence who cleaned it up.

This is an effective argument for creation. It enlists our common sense, soothes our cultural prejudices, and backs it all up with Science. It smoothly connects to the basic supernaturalist intuition that intelligence and personality stand beyond the merely material world. And it is not something to dismiss with charges of unfalsifiability or miracle-mongering. Morris argues that our natural laws break down when explaining order. At face value, thermodynamics presents evolutionists witha real puzzle.

The conventional wisdom, however, tries to work around the question instead. As Michael Shermer says, "The Second Law of Thermodynamics applies to closed, isolated systems. Since the Earth receives a constant input of energy from the Sun, entropy may decrease and order increase (although the Sun itself is running down in the process). Thus, because the Earth is not strictly a closed system, life may evolve without violating natural laws." In other words, entropy increases globally. The local entropy in one part of a system (the Earth) can decrease, as long as it is compensated by a greater increase elsewhere (the Sun). "Evolution no more breaks the Second Law of Thermodynamics than one breaks the law of gravity by jumping up."[11]

This is all true, and relevant. But it is also a rather weak reply; it does not dispel the common-sense intuitions creationists exploit. Consider a refrigerator, preventing objects from reaching thermal equilibrium with a hot room. The refrigerator operates in an open system, drawing energy from power lines to pump excess heat out into the room. It reduces entropy locally at the cost of increasing global entropy, but this does not bother creationists.

They do not claim the Second Law makes refrigerators impossible. They ask, rather, how a refrigerator can come into existence. After all, a heat pump is a fairly complicated device. The Second Law seems to tell us such things cannot pop into being by accident. An operating refrigerator does not violate the Second Law, but a system which includes devices which locally reduce entropy is more complex than one which is not so blessed. We can always step back and ask how, in a world which tends to disorder, this functionally complicated arrangement came about. Continuing to step back, we soon end up asking cosmic questions. For naturalists, the material universe must be a closed system. Without an outside Intelligence intervening, how is it that locally entropy-reducing systems exist? Life is not the only puzzle—why, for example, is matter clumped up in galaxies? From thermodynamics, it seems we should expect an uninteresting mush instead.[12]

Since creationists can claim intelligence is a non-material creative principle, they have an answer. In the case of the refrigerator, we know engineers designed it for a purpose. Bits of plastic and metal would never spontaneously arrange themselves into a refrigerator. But add intelligence to the picture, and voila! Such an explanation is easily generalized. The bodies of the engineers are themselves complex devices which export entropy to their environment. They too must be created by intelligent design. The universe is not a formless chaos. It too must be designed.

Evolutionists now seem to be caught in a tight spot. Open systems do not help, since a creationist can always place them in a larger closed system and ask how an arrangement allowing for local entropy decrease can exist. An evolutionist has to explain complexity in the face of a universal tendency to decay. Worse, evolutionists claim once there was only atoms and the void, and now we have mind-bogglingly complex systems like horses and humans. It seems we need a principle of progress behind increases in functional complexity. But physics has no such principle. Evolutionists are metaphysically committed to impersonal, mindlessly mechanical explanations—and so they are stuck. Creationists, in contrast, can call on Intelligent Design. Creating local order out of global chaos is exactly what a non-material intelligence is all about.

This is a good reply to the open-systems defense. Even if we look at only the Earth-Sun system, we have to explain *how* entropy decreases locally. Evolution might not strictly violate the Second Law, but if that is the best an evolutionist can offer, it looks like an excuse—speaking in might-well-be's and not-inconsistent's. And as we look at larger and larger systems, the

existence of order is problematic at every step. Furthermore, this argument is not just the obsession of a few sectarian pseudoscientists. A creationist invoking the Second Law taps into the venerable Argument from Design, firmly entrenched in Western intellectual culture. A Platonic theist who could not care less about the Bible or the age of the Earth can still appreciate the intuition that order requires an active non-material intelligence. The creationist version of Design stands out in two ways. First of all, it does not compromise. Unlike half-measures like guided evolution, it allows practically no domain for impersonal forces to construct functional order on their own. Secondly, it avoids an ethereally metaphysical Design in favor of concrete scientific claims about our world. Both these features make the creationist version more attractive, not less.

In other words, creationists have a real argument here. They do not always express it very well—it is easy to find embarrassing thermodynamic mistakes in the creationist literature. But if we take creation seriously, we find some substance besides the nonsense. Creationists deserve a real answer—not a slogan about open systems.

The Second Law is actually one of the more difficult concepts in physics. So let us start with a seemingly unrelated complaint about evolution. A famous textbook illustration tells us how a moth population during the Industrial Revolution developed a darker color, blending better with the newly soot-covered bark of trees. Creationists object to this example, calling it a change within a kind without creative novelty. They are partly correct. After all, after the air got cleaner, light color was selected for and the moths got lighter again. We did not have a new species of moth at any time; the change in color was *reversible*. But speciation, as biologists see it, is an irreversible change. A daughter species may go extinct, but once it branches out, it will not evolve back into the ancestral form. Mechanisms like natural selection, however, are reversible—as with the moths. So, as creationists love to ask, how does microevolution add up to irreversible macroevolution?

This problem is familiar to physicists. Our dynamical laws are almost all time-reversible. No one can tell if a movie of a collision between billiard balls is being run in reverse, just by watching it. Of course, to be completely general, we have to replace everything with its anti-particle and go to a mirror image world besides reversing time. But this "CPT" switch is still a simple symmetry. Our macroscopic world is a very different place. A dropped glass shatters. Watching a movie of a thousand shards gathering to

make an intact glass and rising to someone's hand, we know it is in reverse. Going to a mirror-image antimatter world still will not make the glass come together. Macroscopic physics, particularly thermodynamics, is irreversible. Yet all this must somehow be a result of directionless microscopic laws.

The solution to this puzzle is rather interesting. Physical systems often haphazardly wander through their possible states, *if* they have an element of either randomness or dynamical chaos. In that case, any information we have about the system's exact state degrades over time. We can still find equations for its overall statistical properties, but this macroscopic description will now be irreversible in time.[13] Irreversibility comes about because we live in a world full of accidents.

Imagine a game with 10 players seated in a circle. One player starts with 100 chips, others have none. Every turn, they roll a die for each chip they possess. If they roll a 6, they pass the chip to their left; a 1, to their right; anything else, they keep it. Now, the game run backwards in a mirror-image world has the same rules. But events still progress irreversibly. We cannot predict the exact course of the game, but we can tell things will even out. The person with all 100 chips will lose them, until the game settles down to a point where each player has about 10, with some small fluctuations around that number. The game does not have a built-in chip-equalizing tendency; the rules say nothing about a fair distribution. But if we *start out* from an state where one player has everything, we know where the game will go. At each turn, the game can attain many more equitable states than the one where chips move back to the original owner.

Evolution works similarly. A daughter species, for example, might itself give rise to a new species which exactly resembles its own parent. But among all the possible new branches, one identical to the original parent is a remote possibility. Speciation is irreversible, and extinction really is forever.

As in our game, the trends in evolution also reflect our starting point rather than a progressive principle. Stephen Jay Gould gives the example of a lineage of marine species originating in shallow water. On average, more and more species will be found inhabiting deeper waters over time. But this is because new species are free to branch out only in one direction—away from the already occupied shore. Deep water need not be intrinsically advantageous, it is just where newcomers can eke out a living. Likewise, we find a trend towards complexity because, and only because, life started out simple. In fact, Gould argues it is a mistake to say life progresses, since complexity appears in the tail end of a distribution still characterized by

bacterial simplicity.[14] Microscopic physics does not include a principle of decay, and biological evolution does not need a principle of progress.

This does not fully answer creationist concerns. After all, our most notable macroscopic physical trend is still decay. We have to explain why any order we have does not crumble into the featureless mess of thermodynamic equilibrium. Evolution can produce complexity, but only because it can build on what is already there. Locally entropy-reducing structures will form only in systems driven away from equilibrium.

An untended desk gets messier, until it cannot get any worse. Say we suddenly double the size of our desk. Now, relatively speaking, the desk is orderly: the old mess covers only half the desk. The mess will creep and conquer the new area, reaching equilibrium again. But now imagine our desk continually expands, at a rate faster than the mess can creep. Since the maximum possible messiness grows faster than the mess, the system moves away from equilibrium. We have an increasingly sharp idea where the mess is concentrated on the overall area of the desk.

This is a crude example, but the principle is important. When the possible states a system can occupy grows in time, *both* entropy and order can increase. Since creationists like to raise cosmic questions, and since starting points set irreversible trends, let us look at the beginning. The Big Bang starts at maximum entropy, or complete chaos. Such a singularity produces random results—we cannot infer anything about what geometrically precedes it, or what sort of universe it will give rise to. To confuse matters, a singularity is also very simple. Its maximum and minimum entropies coincide. As the universe expands, however, we find a situation much like our inflating desk. The universe's entropy increases, but its maximum possible entropy grows even faster. The difference in between is space for order to spontaneously form.[15] The nature of our microscopic forces makes this possibility an actuality. Gravity is a purely attractive force, so at cosmic distances, thermodynamic equilibrium is unstable. Even the tiniest fluctuations in density will tend to grow. In an expanding universe shaped by gravity, matter will clump up in structures like galaxies.

Locally entropy-reducing structures arise quite naturally in physics. Still, creationists remain unimpressed by non-equilibrium thermodynamics; once again, not entirely out of perversity. Talk of instabilities or "self-organized criticality" is all very fine and correct, they might say, but this only highlights their original puzzle. Physics can certainly explain many intricate arrangements of matter. But such explanations only show how what we once thought

was complex is a consequence of simple laws. The functional complexity we see in life is qualitatively different.

Physical constraints can produce order. For example, our planets do not careen haphazardly around the Sun. They orbit in the same plane, in the same direction. While a few centuries ago this too would have been a sign of Design, we now look for physical reasons why planets form in the same plane. But a constrained system cannot convey much information, because few other arrangements are possible. Something like the genetic code is not so constrained. The DNA of a viable organism is not more stable than a strip of DNA which is biochemical gibberish. This is an important property of information-carrying media: they *must* allow many arrangements. Physically, printing a meaningful message on paper and printing "higfejkfjgpopp..." is much the same; the price for being able to print all sorts of messages is that nonsense is just as easy. And nonsense possibilities vastly outnumber meaningful messages. Monkeys at a keyboard will *not* produce Hamlet. The Second Law argument might still apply to functional complexity in unconstrained conditions: in such conditions, a system can easily decay to one of its functionally meaningless states. Blind physical processes may form galaxies, but never a butterfly.

However, increasing both entropy and order works best in relatively unconstrained systems. Evolution is like a process which not only varies the letters printed, but can increase the number of letters in a message, even come up with new alphabets. In the course of evolution, the possibilities open to life grow much faster than the diversity which is actually realized. We again have something like the inflating desk.[16] Thermodynamics is no obstacle here, though imagining an impersonal, unprogressive mechanism to drive the diversification may be.

Enter Darwin. Among the locally entropy-reducing structures which form naturally in an accidental world, we just need one special kind of structure. Something which replicates itself, using the energy available in its locally open system. In a world where entropy increases, where things often break down, there will be random imperfections in this replication. Most variants will, of course, be nonsense arrangements. But some will replicate better in some local environments. Our replicators will compete with one another to commandeer energy, or food, to reproduce. Each generation will bring new random variations, a few which may do quite well somewhere. Since we start with crude replicators, some variants will be functionally more sophisticated. Under conditions where they replicate well, we will see more of them. Blind

variation alone would not do the job; as creationists suspect, it would usually produce failures. Replication makes all the difference, because now we have populations with a memory of what works. Variation becomes a source of creative novelty, occasionally producing a wild success story.

Nothing here violates the Second Law. As the conventional wisdom points out, life and evolution can proceed quite nicely in an open system. The origin of open systems where entropy can locally decrease is no problem; we only need systems where the available states grow faster than the entropy. Our universe, for example. And where physical constraints are loose, we know of at least one irreversible process, natural selection, which can drive life to explore increasingly complex arrangements.

Creationists do not commit an elementary blunder quickly set straight by a lecture on open systems; they raise a good question. And we have a good answer. We can connect biology to physics, and find out that evolution is not a strange exception to universal decay but a consequence of the same sort of physics that gives rise to the Second Law. Strange as it seems, order comes out of chaos.

A Question of Authority

The anti-creationist conventional wisdom is not all bad. Creation is a consistently inferior explanation of our world, and evolutionists usually do a good job pointing out why. But some of our favorite arguments are definitely flawed. This is mildly disturbing, since we like to think we stand for science and reason while creationists are anti-intellectual pseudoscientists. *We* should be getting our arguments right.

One reason for our mistakes must be that creation is so hard to take seriously. We would not waste time on such a blatant mistake if it did not threaten science education. So we want to dismiss creation with a few well-chosen slogans, and worry instead about the nasty political battles creationists force us to fight.

The problem is, our slogans are *not* all well-chosen. There is nothing wrong with a snappy sound-bite or a one-paragraph position statement listing the basic reasons creationists go wrong. We can always expand on these when the occasion calls for in-depth explanation. But when we take a closer look, "creation is banned from science because it is supernatural" is inaccurate; it is not an approximate statement which just needs some technical details to

improve it. "Evolution is OK because we live in an open system" does not answer the deeper creationist concerns about order and intelligent design. When they get a hearing, creationists can make themselves look good by hammering on such shortcomings. So why do we remain enamored of these particular slogans?

We might find some answers in the wider cultural context of the Creation-Evolution wars. That creationists hail from the religious right while evolutionists tend to be religious modernists hardly needs comment. There is also a less obvious but important difference. In debating origins, creationists act like populists and evolutionists assert authority. If we understand this difference, we will also know where the persistent mistakes in our conventional wisdom come from.

At first, it may seem creationists should be the ones pulling authority. After all, the religious right's social ideals are frighteningly rigid, and submission to authority is quite a moral preoccupation with them. Intellectually, they judge everything by a well-thumped Bible. Nevertheless, creationists have a populist view of knowledge.

From a historical perspective, this is not surprising. Relying on scripture alone was a stand against Catholic authority. The Word of Truth would set us free, if not monopolized by a specialized priesthood. Yet everyone interpreting scripture their own way invites doctrinal chaos. One solution to this perennial Protestant dilemma is to go Catholic Lite and constrain the chaos by Protestant-brand tradition and institutional authority. Another path is religious populism. God must have made his saving revelation accessible. The Bible must be fairly clear to a straightforward reading; indeed, God would create us with the sort of common sense ensuring most of us can understand the Word correctly. Christians, then, do not need Popes. Common sense will help believers converge on roughly the same truths.

This view of religious truth fits in nicely with commonsense theories of secular knowledge. Protestant thinkers had to find a middle path between Enlightenment rationalism and Catholic authority. Rationalism was attractive, but it threatened to ditch religion altogether. Catholics often responded by denying autonomous Reason could give us any secure knowledge. This protected religion by setting knowledge on a foundation of faith, but Catholics sought cognitive security in traditional authority. However, if knowledge was firmly anchored on commonsense reality, skepticism could be defeated. We could obtain reliable knowledge, particularly if we avoided theoretical speculation and stuck to observing this reality. The results were most gratifying:

plain common sense would let us properly read the Book of Nature as well as the Book of Revelation. Naturally, these two could not contradict one another. It was obvious that the intricate complexity we observed in life must have been purposefully designed. A watch implies a watchmaker. Bacon had tried to put science and religion in separate boxes, but Protestant common sense united Baconian observation and populist religion.

America has been very hospitable to this commonsense view of knowledge. In the popular view, true science is tested by common sense and technological application, and so it is available to any industrious person. Early 20th century Fundamentalism was squarely in this populist tradition. As historian James Gilbert observes, respected political leader and anti-evolution crusader William Jennings Bryan saw science this way:

> Science and religion were just complementary methods of understanding God's design. A corollary that followed described science as democratic in character and meaning. Just as every person could read and understand the Bible, so each could understand and appreciate the workings of nature. To suppose otherwise would undermine the democratic nature of Protestant culture and invite in a priesthood of interpreters of science and maybe even religion. True science would naturally affirm true religion. The common man understood this unity that American society was based on. To deny it would undermine American democracy itself.[17]

Today's creationists echo Bryan. To the frustration of scientists, they rely almost entirely on popular appeals, resting their case on the intuitive appeal of creation. They point to their performances in public debates, not their refereed publications. Common sense reveals the fatal flaws in evolution to the non-expert, who has the advantage of not being blinded by an authoritarian ideology.

Even more frustrating, creation *is* more intuitive; creationists mostly win their debates. We need our intelligence most to negotiate a complicated social realm. This is what our brains are good at, not the peculiarly impersonal reasoning which has turned out to be so successful in natural science. We are at our best reasoning about purpose and design; we see an intent behind every falling leaf.[18] Common sense and everyday experience equips us with "folk theories." Folk psychology holds that supernatural spirits animate us; folk biology leads us to creation. Creationists only need a few paragraphs

to express the basics of their Second Law argument. It is considerably more difficult to explain how evolution fits physics, and even then it remains counterintuitive.

Modern science is no respecter of common sense. This first became obvious in physics. Physics today is an enormously technical enterprise, from its alien-seeming experimental equipment to theories like quantum mechanics which resist all easy conceptualizing. After Darwin, biology also acquired a counterintuitive central theory, and continued to evolve into a professionalized practice beyond the reach of an amateur naturalist. Today, doing science often means learning to go against commonsense habits of thought, and battling to achieve elite status in order to exercise the privilege.

As if that were not bad enough, especially after World War II, science became entrenched as a powerful institution which ate up a fair amount of public money. It handed down knowledge non-experts were expected to passively accept. Science also had a nasty habit of producing religiously uncomfortable results. But what really set religious populists off was public science education. This realized their worst nightmare—an unaccountable elite now had the means to determine truth for everyone. Of course, science had too much technology-derived prestige to oppose directly. Hence creationists needed something they could call science, and a way to revive a popular vision which affirmed technology but rejected irreligious speculation. Whitcomb and Morris wrote *The Genesis Flood,* and "scientific" creationism exploded upon unsuspecting supporters of science.

This is our situation today. We cannot ignore creationism; at the least, we have to give reasons why only evolution belongs in the science classroom. We do not, however, have many arguments with the quick commonsense resonance of creationist favorites. Perhaps our best bet is to present scientists as the proper experts. Science may have an elite flavor, but it is also an open enterprise. Scientists come from diverse cultural backgrounds and work in many independent disciplines. And they converge on evolution; among those who ought to know, support for the basic facts of evolution is virtually unanimous. Such agreement is a good sign the scientists are correct, unless there is some incredible conspiracy or mass delusion at work.

This is, of course, an appeal to authority. But it is a legitimate appeal. Critics can check if scientists really do know what they are talking about. We do not close off further discussion when we point to the scientific consensus. Unfortunately, our usual response to creationism has been much more crudely authoritarian. Our mistakes reflect this. When we take Second Law worries

to be a simple error about open systems, we are dismissing creationists as incompetent amateurs. What *we* say is science, what *they* say is not worthy of attention—so we do not have to interpret creationists charitably and see if they really have a point. This note of authority is even more grating when we decree creation out of bounds to science. We do things like round up Nobel scientists and have them declare *ex cathedra* that the supernatural is beyond the pale.[19] The power to define is the power to exclude; we end up declaring we have the Big Names on our side, and so we will not even consider whatever creationists might have to say.

Simply asserting authority is not enough. After all, the United States is culturally still rather democratic. Appeals to equal time resonate far beyond a sectarian creationist audience. So we try to make our authority more palatable by narrowing its scope. Teaching only evolution is not a religiously neutral policy; it endorses a naturalistic explanation over widely held religious beliefs. We need some overriding secular reason to support such a policy. So we offer a few platitudes about students being cheated if they do not learn the central principle in modern biology. But then we immediately start drawing Deep Conceptual Lines between science, philosophy, and religion; and insist none shalt trespass on the others. By the magic of definition, we can now pretend we are being religiously neutral as well. We can say, for example, that we only require students to learn about evolution, we do not demand they accept it.[20] Or we say that we are only excluding creation from science, it might still be factually true. True enough, science is fallible, but that goes for garden-variety fact claims as well. Do we seriously mean we want evolution taught, but this has nothing to do with it being our best stab at the truth? Our authoritarian style paints us in a corner. We abandon "truth" to the realm of metaphysical choice, which in a pluralist society we are effectively relativists about. In return we get to define "science" without being contested.

Since creationists are religious populists, religion gives evolutionists the greatest opportunity for mistakes. We depend on a broad anti-creationist coalition. Many people vaguely agree life developed from simpler forms over long ages of time, but they do not take this to be the blind, impersonal process most biologists envision. "Theistic evolution" invariably means some kind of guided, progressive evolution. Evolution is a process by which the latent spiritual potential of creation unfolds. We have a line of progress from blobs to bodies which are suitable to house specially created souls.

So to minimize friction between different views of evolution, we have to

prevent religion from ever coming up. We go back to the defining board, and discover "good science" and "good religion" do not step on each others' toes. We insist evolution has no bearing on fundamental religious issues; after all, science cannot say anything about the supernatural, one way or the other.

This keeps us focused on opposing creationists, but it also means we have trouble recognizing legitimate debates involving evolution. The Second Law business, for example. When we misunderstand it as just creationist drivel, we do not need to explore sensitive territory. But if we take it seriously, we find the intuitions behind the Second Law argument are not just the property of the Noah's-Flood-was-real crowd. This splits the anti-creationist coalition. Some of us will affirm intelligent design, manifested in the progressive unfolding seen in evolution. Evolution is God's way of creation. Others will tie evolution firmly to physics, and argue it is an impersonal, accidental process. In that case, "evolution is God's way of creation" sounds like saying a house is haunted; the wind is just the ghost's way of producing eerie sounds.

Strictly speaking, such arguments go beyond biology. But we cannot avoid asking how to connect evolution to our other knowledge. Along the way, some traditionally religious fact claims come into play. Again, take the Second Law issue. If creative novelty does not require supernatural design, we can wonder if Darwinian ideas help us understand our own intelligence. A common objection to the prospects for machine intelligence is that rigid rules, whether in the form of physical laws or computer algorithms, cannot capture human creativity and flexibility. It turns out randomness is the key to avoiding this objection. Our physical world is awash in randomness. And Darwin gives us an elegant mechanism to use accidents as a source of creative novelty. Our brains are looking more and more like "Darwin machines."[21] What, then, happens to the notion of a soul or a supernatural intelligence?

Artificial intelligence is not evolutionary biology, nor is the physics of accidents. But the connections are there, and they obviously raise religious questions as well. This is not a matter of arbitrary metaphysical commitments; the debate is continuous with science. In this wider debate, Darwinian thought tends to lead us to a thoroughly naturalistic view of our world. Creationists realize this, and exploit it. It would be nice if we could deny them the opportunity. Nevertheless, the debate concerning evolution and religion exists, it is legitimate, and attempting to define it away is an exercise in futility.

Perhaps I am being heavy-handed. After all, some hamfisted philosophiz-

ing and a few instances of superficial science do not mean there is something terribly wrong with the way we usually defend evolution. This is true. Still, we should correct our mistakes, and maybe explore some other worries while we are at it. I am not alone in noticing that defenders of science often pull authority and close off debate. For example, in the 1970's a group of Big Name scientists came together to issue a statement denouncing astrology. Philosopher Paul Feyerabend responded scathingly, pointing out that the scientists had not actually argued against astrology or even pointed to an argument. They had simply asserted authority, and in effect asked for astrologers to be silenced.[22] Feyerabend had a very democratic view of knowledge, promoting "methodological anarchism" and calling for "separation of science and state." At times, he went so far as to assert that witchcraft was as good as science.

I am not saying Feyerabend was right all the way. There is too much postmodern posturing these days about how science is about nothing but power, and how claiming objectivity is just a way of asserting political authority. But without indulging in wretched excess, we should recognize that the critics of science have a point. When joining public debates, we too often rely on authority. I suspect this hurts science's place in our culture. Our anti-creationist conventional wisdom is a case in point. It hardly helps the popular perception of elite science as arrogant, and it commits us to some rather dubious arguments.

I think that with some care, we can avoid the battle over authority. At hopelessly idealistic moments, I believe science has democratic possibilities which might satisfy even a Feyerabend. In any case, we are at our best not when we are defending our turf, but when we are trying to discover how our world works. So let us start, first of all, by taking creation seriously. As a claim about our world, it is a mistake. But finding out why evolution is a fact is also a process of understanding how creation is false. When we do not acknowledge creation as a legitimate possibility, however remote, we also obscure the merits of evolution.

Next, let us accept that both as an intellectual and as a public debate, creation vs. evolution ranges all over the place; we cannot keep it confined in neat little boxes marked "science" or "religion." It is not a debate we can control. And if we are interested in inquiry first, we will not be bothered by this. Talking about evolution will lead us down strange avenues, even Platonic philosophy or medieval interpretations of Genesis. So be it. If all goes well, we might learn something interesting.

Science education is different; it is basic preparation. No course can

attempt to chase after every issue connected to evolution. But we need do no more than recognize this fact. Without closing off debate permanently, we can see that sometimes it is not the time or the place to discuss a certain issue. For example, when teaching evolution, we do not delve deeply into how life originated. This is not because chemical evolution has no connection to biology. It just happens not to be the subject at hand. There is plenty to struggle with while learning evolution without digressing that way. Similarly, biology classes are not the place to go deeply into nonequilibrium statistical physics, never mind the history of theological arguments from Design. There are plenty of real-world, practical reasons not to get entangled with such matters. We do not have to invent Deep Conceptual Distinctions to justify limiting the scope of a biology course.

The Creation-Evolution wars will continue, even if we begin to take creation seriously. However if we do so, our position will be a bit freer of mistakes, and perhaps somewhat stronger. We have a much better explanation of our world than anything creationists offer. Let us do a better job presenting it.

Notes

1. Michael Shermer, *Why People Believe Weird Things: Pseudoscience, Superstition, and Other Confusions of Our Time* (New York: W.H. Freeman, 1997), pp. 143–145.
2. William R. Overton, reprinted in A. Montagu, ed., *Science and Creationism* (Oxford: Oxford University Press, 1984), p. 380. For criticism, see Larry Laudan, "Commentary on Ruse: Science at the Bar—Causes for Concern," in Marcel C. La Follette, ed. *Creationism, Science, and the Law: The Arkansas Case* (Cambridge: MIT Press, 1983), pp. 161–166; and Michael Ruse, "Response to Laudan's Commentary: Pro Judice," p. 168.
3. Karl R. Popper, *Conjectures and Refutations* (New York: Harper & Row, 1968), chap. 1.
4. For a critique of Popperian falsificationism, see W.H. Newton-Smith, *The Rationality of Science* (New York: Routledge & Kegan Paul, 1981), chap. 3. On why falsificationism is inadequate where creationism is concerned, see Philip Kitcher, *Abusing Science: The Case Against Creationism* (Cambridge: MIT Press, 1982), pp. 36–46.
5. This is a classic example; W.H. Newton-Smith, *The Rationality of Science*, p.

73.

6. Phillip E. Johnson, *Darwin on Trial* (Washington: Regnery Gateway, 1991); and *Reason in the Balance: The Case Against Naturalism in Science, Law and Education* (Downers Grove: Intervarsity, 1995).
7. See contributions by Stephen Hawking in S. Hawking and R. Penrose, *The Nature of Space and Time* (Princeton: Princeton University Press, 1996)
8. This does not preclude history being reducible to physics; in fact, this is probably the case. See Michael Shermer, "The Chaos of History: On a Chaotic Model that Represents the Role of Contingency and Necessity in Historical Sequences," *Nonlinear Science Today* **2**:4 (1993), p. 1; "Exorcising Laplace's Demon: Chaos and Antichaos, History and Metahistory," *History and Theory* **34**:1 (1995), p. 59.
9. George M. Marsden, "Understanding Fundamentalist Views of Science," in A. Montagu, ed., *Science and Creationism,* pp. 97–98.
10. Henry M. Morris, "The World and the Word," *Back to Genesis* **93** (1996).
11. Michael Shermer, *Why People Believe Weird Things,* p. 150.
12. Duane T. Gish, *Creation Scientists Answer Their Critics* (El Cajon: Institute for Creation Research, 1993), chap. 6.
13. E.g. Pierre Gaspard, "Diffusion, Effusion, and Chaotic Scattering: An Exactly Solvable Liouvillian Dynamics," *Journal of Statistical Physics* **68** (1992), p. 673. Of course, some very prominent scientists like Ilya Prigogine and Roger Penrose think the "arrow of time" is so fundamental to our world that it must be based in fundamental microscopic physics. However, so far we have no good reason to believe this is so. See Joel L. Lebowitz, "Boltzmann's Entropy and Time's Arrow," *Physics Today* September 1993, p. 32.
14. Stephen Jay Gould, "On Replacing the Idea of Progress with an Operational Notion of Directionality," in M.H. Nitecki, ed., *Evolutionary Progress* (Chicago: The University of Chicago Press, 1988); also *Full House: The Spread of Excellence from Plato to Darwin* (New York: Three Rivers, 1996).
15. See Victor J. Stenger, *The Unconscious Quantum: Metaphysics in Modern Physics and Cosmology* (Amherst: Prometheus, 1995), pp. 227–230.
16. Daniel R. Brooks and E.O. Wiley, *Evolution as Entropy: Toward a Unified Theory of Biology* (Second Edition, Chicago: The University of Chicago Press, 1988).
17. James Gilbert, *Redeeming Culture: American Religion in an Age of Science* (Chicago: The University of Chicago Press, 1997), p. 30.
18. Stewart Elliott Guthrie, *Faces in the Clouds: A New Theory of Religion* (Ox-

ford: Oxford University Press, 1993) chap. 3, 4.

19. See Michael Shermer, *Why People Believe Weird Things,* chap. 11.
20. For a critique of this tendency, see Brian J. Alters, "Should Student Belief of Evolution be a Goal?," *Reports of the National Center for Science Education* **17**:1 (1997), p. 15.
21. Taner Edis, "How Gödel's Theorem Supports the Possibility of Machine Intelligence," *Minds and Machines* (forthcoming in 1998). On the relevance of Darwin to AI, see Daniel C. Dennett, *Darwin's Dangerous Idea: Evolution and the Meanings of Life* (New York: Simon & Schuster, 1995).
22. The statement and Feyerabend's response are reprinted in Patrick Grim, ed., *Philosophy of Science and the Occult* (Second Edition, Albany: SUNY Press, 1990).