Theses on Johnson: Some Thoughts on the Design V. Evolution Controversy

Ethan Akin
Mathematics Department
The City College
137 Street and Convent Avenue
New York City, NY 10031

May, 2001
revised January, 2007

Introduction

A spectre is haunting biology in America - the spectre of Creationism. We scientists believed that this religious intruder had been fatally wounded in the aftermath of the Scopes trial. Sharing the 'fifties prestige of science with Our Friend, the Atom, the biology profession had, so we thought, nailed its coffin shut. But now, risen, garbed in the raiment of Intelligent Design, this poltergeist is banging about the country. This, despite our attempts to exorcize it with incantory applications of the religion clause of the First Amendment.

Myself an orthodox Darwinian, I enthusiastically profess the Evolutionists' Creed. As with others of my secular background, I had taken my picture of this struggle from the movie Inherit the Wind. Between the decent but pathetic Bryan figure and the cynical nastiness of the Mencken stand-in, Spencer Tracy seemed to represent a quiet and sensible balance between science and religion (Darrow would have been amused).

I began to consider these matters seriously when I finally read the Jehovah's Witnesses tract *Did Man Get Here by Evolution or by Creation?*. I had been aware of the book, but I had assumed that its argument consisted of: the Bible says such and such, so evolution is wrong. What I discovered was much more interesting. The first half of the book criticizes current biology, appealing to arguments internal to science. Only after they have shown to their satisfaction that the standard picture is inadequate, do the unnamed authors turn to the Bible for an alternative view. I believed that the criticisms could be answered and I didn't share their undisguised belief in the authority of Scripture, but I was impressed by the boldness and breadth of their arguments.

My beliefs were further stirred, if not shaken, by Norman Macbeth's book *Darwin Retried*. Its criticisms of evolutionary theory were entirely unrelated to religion. Macbeth was a lawyer who had read widely and thought carefully. Again I felt I could answer his arguments, but they were subtle and thought-provoking.

As a result of this earlier reading, I was a prepared mind for Philip Johnson's *Darwin on Trial*, which I discovered soon after it appeared in 1991. Since then our friendly lunches have been highlights of my visits to Berkeley. I have read his later books with interest, as well as those of his Intelligent Design colleagues Michael Behe, William Dembski and Jonathan Wells. I think that many of the philosophical claims that Johnson makes are correct, that the problems pointed out by Behe are real and serious and that some of the textbook errors described by Wells are scandalous. Despite all that, I still believe that the theory of evolution by natural selection, Darwin's theory, is correct. These notes represent my attempt to respond to the fascinating issues that its recent critics have raised.

Professionally, I am a mathematician. While I have done some work in biology, I am only a well-read amateur concerning evolution, just as Johnson is. I am not qualified, and I do not attempt, to provide a detailed presentation of the data and arguments which support the theory of evolution. My focus here is on what I think of as the philosophical issues which have been churned up by the current scuffle.

The strategy which scientists have used to confront these dissenters has been one of demarcation. Science is said to be separated from religion by the distinction of fact vs. value, or of scientific method which accepts only testable, empirical results vs. religious faith with its unquestioning appeal to authority. This strategy has proved to be legally successful in that, relying

on the authoritative evaluation by scientists of their own practices, the courts have accepted this demarcation and ruled that 'scientific creationism' is an attempt to disguise the intrusion of religious beliefs into the public schools.

In my opinion these distinctions are only superficial. I don't believe that they withstand intellectual scrutiny and I think that they will eventually lead to legal problems, as well. Phil Johnson is, after all, a lawyer. In the end, I believe that the defense of the teaching of evolution will have to rely instead on an open claim of authority on the part of the biology profession. This is politically risky at a time when the word "elite" has become an insult. Ultimately, I believe that it is possible to craft a compromise which accepts the deference due the consensus view of the profession and which also responds openly to the criticisms which have largely welled up from outside.

The compromise which I have in mind mirrors, in the large, what I take to be the appropriate relationship between professionals and amateurs on the individual level. The authority of a professional comes from education and experience which leads, one hopes, to a broad vision of the subject and a deep feel for some specialized areas of it. On the other hand, an amateur may have a more superficial picture but may also ask questions which a professional might not have thought to consider. Several of my readers, including my wife, a chemist, have observed that some of my own arguments benefit in their scope by floating free, unencumbered by any heavy ballast of fact.

What is wanted here is a sense of mutual respect, for the experience and commitment of the professional and for the enthusiasm and imagination of the amateur. I continue to disagree with Phil Johnson, but my respect for his thoughtfulness and intellectual honesty has only deepened over the years. While I believe that their views about the world are at least inspired by their religious faith I also believe that Johnson and his associates share with the scientific community a common interest in the truth. It is in the spirit of that common interest that I present these notes.

1 Religion as a Matter of Fact

Some authors attempt to avoid conflict between science and religion by assigning these human concerns to the separate domains of fact and value, respectively. This is Stephen Jay Gould's strategy in his book *Rock of Ages*. Even if we ignore the role of value in science, we quickly notice that the claim that religion makes no factual assertions is false. The Apostles' Creed, for

example, is entirely an assertion of belief about the world, broadly construed, and about persons and events in its past and future. There are several less specific beliefs which are common to many religions and which are especially relevant to science:

(1) The world and its contents have been created by a powerful being, God. The acts of creation might be direct or indirect just as I can make an artifact either by fashioning it directly or by constructing a machine which produces it some time later.

(2) God is personal in that we can, in some sense, attribute to him such human characteristics as knowledge and intention.

(3) Among the animals, human beings are created by God to play a special role and so have been endowed with special attributes of mind and spirit. This design feature explains the coincidence described in (2) above. It is not that God happens to be like us but instead we have been created "in His image" to be like Him in certain respects.

(4) God is benevolent from which follows the essential goodness of His actions and, in particular, the goodness of His creation of the world.

(5) While He exists beyond our sense of Time, God interacts with the world in general and with humanity in particular, and this interaction has a historical dimension.

The first three of these can be regarded as simple claims of fact. The religious regard them as true and we atheists assume, at least, that they are false. The fourth is a bit different. It is the reason that the fact/value distinction means something completely different for the religious believer.

Most scientists are realists about science itself. We believe that there is a world out there, independent of us, but also including us, which we intend to describe. This is the world of facts and our descriptions are true when they correspond, in some sense, to how things are. However, at least the atheists among us are social constructivists about values, believing that they are imposed by us, as individuals in societies, upon a morally indifferent universe. Pleasure and pain exist as factual experiences for us and other animals. The judgments that some pleasures are good and most pains are bad are evaluations made by us. Religious believers, on the other hand, are realists about both fact and value. Both the factual structure and the moral structure of reality are created by God and exist independent of us. God is the source of both intellectual intelligibility and moral meaning in the world and it is our intended purpose, at least in part, to understand this comprehensive structure. Notice that, in addition to an appealing symmetry, the religious

position provides an explanation for the otherwise puzzling susceptibility of the world to our explanations. We materialists have to use evolution to do God's work here, as in several other places.

Thus, for the religious believer the chasm between fact and value does not occur. The linguistic boundary between "is" and "ought" is bridged by assumption (4) above, although the distinction persists in such theological puzzles as whether something is good because God wills it or vice-versa.

Observe, finally, that the modern emphatic fact/value distinction is associated with David Hume whose atheism was notorious in his day. All this suggests that the use of this distinction to distinguish between science and religion presupposes an atheist perspective like Hume's.

Consider the assumption of conflict which motivates this entire diplomatic project of negotiating a modus vivendi between science and religion. Gould's careful demarcation recalls the Papal subdivision of South America into separate spheres of influence, resolving the dispute between Spain and Portugal.

It is certainly true that modern science in its rapid growth since Galileo's time has often been in conflict with religion. From both directions this conflict has been both real and reasonable. Following Francis Bacon, the pursuit of science has explicitly confronted the authority of traditional beliefs. Scientific growth has been seen as the liberation of the human mind from the encumbrances of superstition. Thus, with intention this intellectual struggle tears at the traditional structures of thought within which human beings feel at home and so "everything solid melts in air". An historic growth rooted, by contrast, in past events, established religion, especially the Catholic Church, viewed the new science, and the new economics, with some critical reserve.

On the other hand, science and religion are not opposed in principle. I leave to historians the natural alliance between the new Protestant religions and the new science. I have in mind the prior fit between the two subjects during the Middle Ages when the natural world was part of the scope of theology. The view that creation comes from God provides encouragement to science, especially the Augustinian corollary that what exists is therefore good. Investigation of creation provides an avenue by which humanity can understand God's intentions. Assumption (5) above suggests that the enlightenment acquired along the road will be gradual and progressive. An aspect of man's historical encounter with God, reason applied to the natural world complements interpretation of direct revelation or Scripture as means to approach understanding of the character of creation. In other words, by

studying the world we see God's intentions expressed in the details of His works.

The belief in an omnipotent, benevolent God leads inevitably to the Problem of Pain, the demand for an explanation of the existence of evil and suffering. The Zoroastrian and Manichean view is that our world is the arena of conflict between active forces of Good and Evil. This view is rejected in Catholic theology following St. Augustine. He defined evil strictly negatively as the consequence of sin, a willed distancing from God. A version of the alternative view survives in the portraits of Satan as an active force.

In some religious traditions the entire world is regarded as evil and detachment from it is the only true way to God. Clearly, if worldly things are delusions and snares, and engagements with them are sinful, then the detailed investigation of such things should be discouraged. On this view the passion for science is just another form of carnal lust. This theme also occurs to some extent in Christian thought within the traditions of asceticism.

Nonetheless, the main line of Christian thought has a balanced picture, more encouraging for science. The world, created by God, is to be lived in appreciatively. However, it is important not to be completely absorbed by worldly pleasures, thus forgetting their divine source. For example, with the exception of Envy, the seven deadly sins, Lust, Gluttony, Anger, etc. are characters which are sinful by an intemperate cleaving to otherwise salutary objects. On this view, science, like sex, is a good activity but one which bears the risk of losing sight of its purpose.

The Medieval proofs of the existence of God provide a nice example of the concordance between secular reason and theological belief. As formal deductions these proofs are not as logically compelling as their Euclidean models. They do not seem to me to be effective in providing a compelling justification of religious faith from a prior confidence in human reason. In particular, the recent attempt by Mortimer Adler to revive them is doomed. Their utility seems to me to be in the reverse direction. They demonstrated a coherence between faith and reason which served to justify the latter. In modern parlance they served as calibration devices. Yielding the independently known results of faith, secular reason could be used with trust to study the unknown in the world.

The split between science and religion, exemplified by the attacks on Bruno and Galileo, began during the Reformation when the Catholic Church was under attack from within. The relation between the religious establishment and the growing scientific community has continued to be often

conflicting but remains also one of mutual inspiration.

Returning to Gould's proposed truce, we can see that it simply presumes certain question-begging attitudes of rather recent vintage: "God's intentions and actions are a religious matter and so have no place in science." Believing that the purpose of science is the description and explanation of the natural world, most scientists would regard this quote as a truism. I agree about the purpose of science but for that very reason I regard the comment as false, even absurd.

Suppose we wish to explain why, in a terrarium I have constructed, there are a whole lot of newts. Part of the explanation consists of the biology of newt reproduction, but surely my affection for newts and my placement of a breeding pair in the tank when I set it up deserves mention. Suppose I said: "Meteor impact is not a scientific explanation for the Cretaceous extinctions because such impacts are chance events while scientific explanation requires the action of continuously operating natural laws." The correct response to such foolishness would be: "Science requires not careful demarcation from nonscience but a determination of what is true."

We dismiss lines of research because we regard their premises as likely to be false. If the reports of space aliens abducting large numbers of people to have sex with them were in fact true, then investigation and response would be desirable, even imperative. Our complacency in the face of these reports is a result of our skepticism about them.

Similarly, for evolution the issue is not one of demarcation between science and religion. The issue is what is true. We Darwinists believe that we have in hand a materialist explanation for the history and structure of the living world, an explanation which is sufficient and which does not require any explicit appeal to divine action. The philosophical and evidentiary basis for our religious skepticism is an interesting matter, but we shrug off creationists' claims because we believe they are mistaken. If in fact they are right and we are wrong, then theirs is the true description of reality and calling it religious won't save our incorrect theories.

2 Philosophy of Science (Wrong)

In the current science vs. religion debate many of the arguments reflect what I take to be an outdated and incorrect picture of science. Participants on both sides use this shared view for rhetorical advantage. To describe this picture

I want to consider a classic problem of epistemology, that of describing the difference between knowledge and belief.

I believe that this distinction arose from the religious view which separates the world into aspects which Marcea Eliade calls the sacred and the profane. The profane world is the hum-drum reality of ordinary existence. This is the world of belief, of opinions which we obtain from and share with our surrounding culture and which we modify by reflecting upon our own experience. But behind this, and underlying it, is the world of the sacred. While it is only occasionally revealed directly, the sacred aspect is the more real, more true because it is directly reflective of God whose intention is the source of meaning in the world. Hence, knowledge is directed toward the sacred. Thus, on one view, knowledge is a learned activity requiring practice to see the hidden and esoteric. Alternatively, knowledge is the natural result of seeing clearly, of attending to ultimate reality while ignoring the distractions of ephemera.

In Greek philosophy this distinction appears in Parmenides' description of the two ways: the way of appearance and the way of truth. In the former mode one gazes upon the illusions of change while in the latter one apprehends unchanging Being. Notably the distinction itself and the nature of Being are revealed in Parmenides' great poem by a Goddess-narrator.

For Plato the object of knowledge is the structure of Forms or Ideas which underlie the structures of our apparent world about which our beliefs are formed. In Plato's simile of the Cave, the Forms produce the objects of appearance in the way that objects cast their shadows on the wall. We can understand the Forms because we have an inborn knowledge of them which we can use reason to recollect within the muddle of beliefs and opinions in our own minds. Significantly, it was a mathematical proof which was used by Socrates in the Meno to demonstrate how such recollection can occur. Mathematics was then, and continues to be, the model of the certain, infallible truth which is characteristic of actual knowledge. Among the Greeks the use of mathematics as the description of true reality was initiated by the Pythagoreans. Their number theoretic program was inspired by musical harmony and applications to geometry, e. g. some special cases of what is now called the Pythagorean Theorem. It foundered on the technical problem of the irrationality of the square root of two, i. e. the length of the diagonal of a square cannot be expressed as the ratio of whole number multiples of the length of the side. Euclid's treatise, a product of Plato's Academy, described the competing geometric program.

Aristotle disagreed with Plato's view of the Forms as objects of contemplation. Knowledge consisted instead of the discernment of essential qualities which determined the nature and behavior of mundane objects. Apprehension of essences required the use of reason, regarded by Aristotle (and by Plato) as a faculty analogous to, but separate from, vision and the other senses.

In all of these cases, the goal was knowledge regarded as a structure of inerrant truths. The objects of such knowledge, what the truths were about, were completely different from the ordinary objects apparent to our senses. Hence, the need for reason as a faculty, a special sense for the mind, beyond the ordinary bodily senses.

The Scholastic philosophers of the Middle Ages continued to search for this sort of knowledge by the coherent use of faith and reason. Notice that the acquisition of a piece of certain knowledge provides an authoritative base upon which to build without fear that the foundation work will later have to be revised. Following Aristotle, they looked for essential, the sacred, underlying the profane world of earthly existence.

However, the object or goal of knowledge gradually shifted toward the mundane for reasons of utility. Francis Bacon's New Science sought to control and to use the natural world. Bacon regarded the source of error to be unquestioned reliance upon authority, especially that of Aristotle. Instead of what he regarded as Aristotle's detached reason, engagement with the world by observation and experiment was required. Now there was a new emphasis on method, on procedures for obtaining knowledge. Bacon and later Locke believed that nature would reveal her truths directly but only to the recipient whose mind had been cleared of superstitious opinions, the residue of unscientific tradition. Still the model of inerrant truth was mathematics, the language of the book of nature according to Galileo. Hence the triumph and enthusiasm felt for the Newtonian synthesis which explained in a common way both heavenly and earthly motion by using the new mathematics of calculus.

Problems arose despite the acclaim for the Newtonian description. Berkeley criticized the metaphysical preconceptions which appeared to be necessary for calculus. More seriously, Hume questioned the entire possibility of empirical justification for any general theory. His celebrated attack on the method of inductive reasoning demonstrated, for example, that a causal connection between two kinds of events could never be demonstrated, in the sense of mathematical proof, by any number of successive occurrences.

It was this argument of Hume which awoke Kant from what he later called his "dogmatic slumber". Kant was originally a natural philosopher accepting normal science within the Newtonian paradigm. His response to Hume was to focus his attention to the problem of knowledge. Assuming, as he did, the truth of the Newtonian theory, he asked what was required to demonstrate that truth. Beyond the observations from astronomy and from earthly experiments, what axioms were necessary to complete the proof and how could they, in turn, be justified? His revolutionary answer was that our entire experience was in part the creation of the human mind. That the world consists of bodies which interact causally is the a priori structure of phenomena by which the mind organizes our experiences. Underlying this experience - but not causing it - the noumenal world of Kant's Thing-in-itself is literally indescribable for us because all our descriptions use the structure of synthetic a prioris of the human mind. Because this structure is fixed and built-in, the world is experienced as objective existence shared by all humanity and so communication between human subjects is possible.

Notice the resemblance between Kant's a priori structure and Plato's notion of recollection. Under the influence of Bacon's utilitarian views, however, the object of knowledge has changed. It is the mundane world of experience towards which scientific knowledge as well as ordinary belief is directed. No longer is knowledge the result of a redirection of attention away from common experience or the product of a special faculty to look beyond it. Instead, knowledge has to be sifted out from among the erroneous beliefs which provide competing descriptions of the same reality. Hence the continuing emphasis on method. Kant's noumenal world is perhaps comparable to Parmenides' Being but it is irrelevant to scientific knowledge, although Kant applied it to morality as a basis for freedom of the will.

Kant's philosophy was built, recall, to justify the universal confidence in Newtonian physics. Consequently, the falsification of the Newtonian theory and its replacement by Einstein's theory of relativity reverberated through philosophy as well as science. This upset of what had been taken to be firmly held knowledge prompted a renewed attention to the foundations of knowledge, as people now asked: "If we could be wrong about that how can we be certain of anything? How can we avoid repeating such a deep and subtle error?" It is perhaps a coincidence that mathematics itself was suffering serious foundational difficulties of its own as Frege's attempt to axiomatize set theory collapsed when Russell's Paradox was discovered.

The search for firm foundations inspired the school of Logical Positivism.

Returning to Bacon's emphasis on method, the positivist program was modeled on chemistry's vision of the nature of matter, in turn inherited from the Greek atomists. First, atomic facts about the world are observed and collected. The intention is that these sense data are so focused and specific that it is, in principle, possible to be certain about them. These facts are then compared and assembled to produce inductive generalizations, eventually laws of nature. The positivist program solves what Popper referred to in his Logic of Scientific Discovery as the "demarcation problem". It allows us to separate science, consisting of empirical descriptions of the world testable from the reservoir of observable facts, from speculations which, despite their apparent content are really meaningless nonsense (Ayer's description) or at best important nonsense (following Wittgenstein). Science is distinguished by its care and discipline. From the attentive reception of empirical details, to the succeeding logically precise theoretical induction the whole process is justified by a self-conscious methodological rigor.

The positivist picture still has a lot of appeal. It provides useful rhetorical armor for scientists confronting the public in political debates: "Don't look at me. I am merely a conduit, communicating irresistible conclusions derived from indisputable facts. In particular, opposition to these conclusions results from ignoring these facts, a denial motivated by ideology and prejudice." Similarly, the demarcation criterion is useful in the politics of control of education:"This is what science is. That is why it should be in science classes. What they are talking about isn't science and so it shouldn't be in science classes."

Most professional philosophers of science, as well as many amateurs like me, regard the positivist program as a failure. It seems impossible to reach a level of atomic fact upon which to build error-free foundations. Of course, there are always facts in science which are not controversial and to which we appeal in making our tests. However, the judgment about what is fact and what is theory is itself part of current science. This is the Quine-Duhem thesis that what we call facts are theory-laden".

But that's not the real problem. Suppose we accept the current heap of uncontroversial facts as the theory-free foundation upon which our science is built. Then, a large scale theory like evolution is then usually untestable in the simple sense that the positivists require. The gap is too large between the data and the comprehensive claims of the theory to span with any sort of inductive "proof". This allows critics like Johnson to turn the rhetoric of positivist neutrality back on itself: "Sure there are fossils and DNA but

the leap from these facts to the claims of evolution by natural selection is greater than can be justified by any notion of induction of a theory from the supporting evidence. Instead, the Darwinian view is a metaphysical superstructure motivated by a secular worldview and maintained by such naturalistic preconceptions, i. e. by prejudice rather than empirical support."

The importance of the logical positivist quest is that it is the latest, and perhaps last, version of the attempt to apply the mathematical model to scientific knowledge. Here I am not thinking of the use of mathematics in science but rather the rational decidability of mathematics which accounts in large part for its clarity and appeal. A proposition in mathematics is either provable from the axioms of set theory or its negation is provable or it is independent of the axioms. (The third alternative means that we can introduce the proposition or its negation as an additional axiom and neither choice will yield any (new) contradictions into the system.) We may not know which of the three possibilities holds, or we may think we know and be wrong. But in principle everything is clear and there is no possibility for philosophically interesting disputes at this level. Let me illustrate by describing a philosophically uninteresting mathematical dispute.

Around the time I was in graduate school, Zahler and Toda produced conflicting computations of certain objects called homotopy groups of spheres. From the conflict it followed that at least one of the computations was wrong. Furthermore, in principle an expert in the field could work through the two proofs and find the mistake. Such a mistake, once discovered, would be clear and the resulting consensus would have the boring quality of a fancy version of $2 + 2 = 4$. It is fancy only because you have to learn the subject. Thus, "A compact subset of a Hausdorff space is closed." sounds like drivel to the uninitiated. But shortly after you have learned in a topology course what the various words mean you learn the proof and then the result is seen to be true, "clearly and distinctly" as Descartes might say.

In the case of the Zahler v. Toda dispute the subfield had very few experts and the computations were very hard. So the dispute remained unresolved for several years. Zahler became disgruntled and left mathematics (ironic since I believe he turned out to be right). However, no one worried about the unsettled argument because the situation was, in theory at least, so very clear. It was in fact that complacency which so annoyed Zahler.

The positivist hope is that by using empirical atomic facts to supplement logical axioms scientific disputes would become similarly resolvable in principle. For each such dispute a rational consensus could be established, given

sufficient data. That is, the consensus would be compelled by reason in the sense that to dissent would be unreasonable. What dissent remains would be a phenomenon to be explained psychologically or sociologically rather than as an argument to be confronted. For example, amateurs still attempt to solve the classical geometry problem of trisecting an angle via ruler an compass. Such attempts result from ignorance of either the existence or meaning of the nineteenth century proof due to Galois that the task is impossible.

This hope in both its appeals and dangers recalls the similar hopes of universal religions. The appeal lies in the sense of open-armed tolerance: "Come in. See the truth and it shall set you free. It is open to all and together we share it." This absence of exclusiveness, the sense of tearing down walls is liberating. However, as the consensus becomes larger it risks becoming more intolerant and coercive toward those who choose to remain outside instead of sharing it. Dissent is seen to be irrational and willful and finally evil. One sees this in the honestly held view of many scientists that creationists maintain their views only by an irrational denial of obvious elementary facts.

3 Philosophy of Science (Right)

In contrast with the positivist view I take the following to be the correct picture of epistemology.

A child develops his picture of the world by organizing it according to certain built-in categories which are tested against expectations and refined by interactions with adults and peers. The stability of objects is a developmental achievement which leads to testable expectations. The ball rolls behind the door, he reaches for it or looks for it and lo, it is there. At a higher level consider pain language. I suggest that its use is learned by means of such dialogues as: "Why is Daddy making that noise?" "He hit his thumb with a hammer and it hurts him." "What does 'hurts' mean?" "Remember last week when I told you not to touch the burner on the stove and you did anyway? It hurts like that." The reply is: "Oh. Poor Daddy." not "No, it's not like that. I don't feel bad now." In other words, human beings, social animals that we are, come with a wired-in faculty for generalizing outward from our own feelings, attributing to others feelings 'like' ours. The range of appropriate generalization is refined culturally via authority. We learn that other people feel but that chairs do not. Perhaps some animals do, but

for the Teddy bear it is "just pretend". Thus, attribution of other minds is something we are born prepared to do and the existence of other minds becomes for us an obvious fact.

On this view the categories by which we organize are built-in, biological givens. This biological version of the Kantian view is expressed most clearly in Konrad Lorenz's paper *Kant's Doctrine of the A Priori in the Light of Contemporary Biology*. The correspondence between this structure and the world, the success of this organization of our experience, is an evolutionary success, the result of natural selection. That is, for me evolution provides an explanation for the correspondence between my preexisting categories and the external world they interpret. For a creationist this correspondence would be a design feature explained by divine intention, but he could still accept my picture of our creative construction of the experienced world by using inborn features of human nature.

From these initial stages I, for example, developed as I matured, a structure of expectations, beliefs and theories, many of them unconscious ("tacit" is Michael Polyani's term). I hold these beliefs with different degrees of certainty. At the deepest level are beliefs I cannot even imagine being false. I have in mind the elementary laws of logic and the belief in my own current existence. I do not claim that they could not be false or even that I could not possibly come to regard them as false. Only I cannot now imagine such an alteration. At the next level are things of which I am completely certain but which I can imagine to be false. The whole world as I experience it could be a dream; I could be a brain in a vat. I can imagine this. It is a classic science fiction plot device (e. g. the movie *Matrix*). But not for an instant do I entertain it as a serious possibility.

My initial knowledge of a scientific field like biology is quite analogous to my acquisition of history or horsemanship. Each is a complicated mixture of general theories and individual facts which I largely obtained from books or from other people whose judgments I took to be authoritative. This was supplemented by some direct experience - potted experiments, museum trips, riding lessons - and some tentative criticism following reflection on those beliefs. In both science and religion I learn by authority not just a collection of beliefs but a network of connections among these beliefs and between them and my experiences. Between the beliefs I have acquired, the expectations I have formed from them and the experiences I have had there is a continuous interaction which justifies my retaining some beliefs and modifying others.

Let me illustrate with a little parable: A pair of twins, John and Francis,

were separated at birth and adopted by different families. John's family consisted of deeply religious Christians. As he grew up he learned to see God made manifest in the world around him, to experience the sinful appeals that evil has for our fallen nature and, perhaps, to apprehend at a few precious moments the direct experience of God's grace. Meanwhile, Francis was raised by a secular family of scientists.

He learned to see the natural history of the world exhibited in the streambeds and rocky outcrops near his home and to connect these observations with the inheritance from generations of naturalists that is current science. Now the two brothers are reunited in college. They begin to argue. "How can you believe that the earth is so old?" demands John. Francis does not say "My parents told me so." Instead, he cites chapter and verse from reference books he knows and, pointing to fossils in a nearby rock, he begins to discourse upon Carbon-14 dating. But when Francis asks his brother to defend his belief in God, John does not refer to his parents either. He describes his own religious experience and refers Francis to Chesterton's *Orthodoxy* where materialists are described as a class of madmen, myopically logical but blind to phenomena which are obvious to every farmer in his field.

I don't intend to suggest that the twins' beliefs are deterministically fixed by the initial family decision. John could grow up to find his childhood faith intolerably restrictive and, enlightened by a larger world, come to store his earlier belief in God in the attic of memory next to the Tooth Fairy and Santa Claus. On the other hand, Francis may come to regard his secular worldview as sterile and absurd and to find meaning in a religious conversion which adopts his brother's abandoned faith. Neither brother is the passive outcome of impressions from social training or observational stimuli. Each of us can reflect upon and criticize our own beliefs, just not all our beliefs at once. But although we stand firm on some views and use them to criticize others, all of them come from our past training and experiences, acting upon the faculties we were born with.

All of this undercuts the idea that evidentiary justification of our beliefs is the hallmark of rationality. In fact, for most of our beliefs in every subject the reason that we believe is that someone told us, or wrote it in a book we read, and no particular reason for doubt has since turned up.

Does this mean that our structure of belief is irrational? If not, then of what does rationality consist? I take from Karl Popper and W. W. Bartley the view that it is in the willingness to subject our beliefs to serious criticism. Justification is required only in response to proposed flaws. The

question "Why do you believe that?" can be reasonably shrugged off unless it is expanded, at least implicitly, to "Why do you believe that in the face of the following objections?" On this view reason is always part of an argument. Of course, one might raise objections to one's own beliefs so that the argument can be entirely internal.

Once a rational argument is engaged, how does it proceed? I share with most people, and certainly with most scientists, the correspondence theory of truth. That is, there is a world 'out there' separate from us and a description of part of it is true if it corresponds, in some vague sense, to the way things are, i. e. a proposition is true when it corresponds to the facts.

However, our arguments are always coherence arguments in the sense that the ground upon which the disputants stand is the vast amount of area about which they agree. Reason is then employed to show that from these common assumptions the opposition view leads to a logical contradiction or at least to implausible results. A variation occurs when I argue 'on your ground' accepting by stipulation certain beliefs of yours with which I am really in disagreement.

Recall that part of the positivist project, the last gasp of the rationalist or empiricist hope, is to reach grounds of indubitable solidity upon which an edifice of properly justified knowledge can be constructed, layer by layer, eventually immune from rational attack.

Here I believe that the postmodern antifoundationalists like Richard Rorty and Stanley Fish are correct. There are no such ultimate foundations. Everything is in principle up for grabs and no belief is beyond the possibility of criticism. On the other hand, each of us has a firm foundation of beliefs the truth of which we are completely certain. I see a cat across the room and I know that it is my cat, the one I stroked and set down a few minutes ago. As I walk along the path leading to my car I know that the ground will support me and so I need not attend with care as I shift my weight from one foot to the other as I walk. I also know that a compact subset of a Hausdorff space is closed and that a molecule of water consists of two atoms of hydrogen bonded with one of oxygen. Finally, I know that the law of gravity is not going to be repealed overnight.

Now the world could change in ways so that the first pair of certainties become doubtful. The local geography could change so that pits of quicksand pop up randomly where I live. I should then have to test the path to my car with a stick as I walk and check to see that the car is still on the ground before I walk out to it. My wife might install delightful new technology which

causes authentic looking holographic images of our cats to appear all over the house. I should then have to pat the cat again to distinguish it from its image. However, under any set of circumstances I would have a continuing foundation of firm expectations about the ordinary world around me or I would not be able to live.

The bit of topology I quoted is something whose simple proof I know well. For that and for various more complicated bits of my professional knowledge I have the sort of strong justification which allows me to be the authority whom others might cite. The chemistry of water, on the other hand, I know in the dim way that I know what chemistry I know. That is, I accept the authority of teachers and books. Also, my wife is a chemist and she says it's true. She may have at some point done experiments in a course which verify the chemical formula for water but perhaps not. She certainly has done experiments which directly check large chunks of the chemistry she knows and knows in principle how to check other bits.

Finally, my belief that the laws of physics I learned yesterday will continue to hold tomorrow is a piece of metaphysical faith, comparable to the belief that I share a world with other people somewhat like me. That is, I do not share the views of the lady who delighted Bertrand Russell by declaring that she was a solipsist and she couldn't understand why everyone else was not. A skeptic would point out that I cannot provide arguments which would successfully refute odd "brain in a vat" alternatives to these beliefs.

The vulnerability of these articles of faith to skeptical attack doesn't shake my confidence in them at all. But notice that I maintain them because of what seems to me to be their overwhelming plausibility, their utter obviousness. A deeply believing Christian might be moved to say: "Just so."

The unchanging character of the Kantian categories served to explain the certainty of Newton's theory. The collapse of the latter allows the kind of biologizing of the categories that Lorenz suggested. From our inborn faculties, from our instruction by our surrounding culture and from our own experiences we obtain an organized structure of beliefs and expectations which are criticized and adjusted as problems arise. These range from deep metaphysical preconceptions like a belief in God or in determinism to routine classifications and recognitions in the world around us.

One consequence of all this for epistemology is to dissolve the distinction between knowledge and belief. On this view 'knowledge' is just a label for certain firmly held beliefs. Technically, there is a difference in that the word 'knowledge' implies truth. Thus, if yesterday I said "I know that P" and

today I find out that P is false then it would be correct to say "Yesterday, I believed that P but today I know that notP" or "Yesterday, I thought I knew that P but I was wrong." but it would not be correct to say "Yesterday, I knew that P but today I know that notP". On the other hand, the distinction no longer has the interesting quality that it did for those who regarded knowledge and beliefs as aimed at different aspects of reality or who regarded infallibility as an achievable goal.

For example, in the current squabbles about creationism, Johnson is correct to claim that evolutionary biology is built upon deeply held metaphysical preconceptions, because this is true of every aspect of knowledge. Furthermore, such preconceptions are revisable and so it is legitimate for Johnson to confront those of biology and to raise arguments against them.

The preconceptions which Johnson has in mind are methodological naturalism, i. e. the search for purely material explanations ignoring the possibility of supernatural intervention, and the associated metaphysical naturalism, i. e. the faith that such explanations will suffice. These are part of the consensus upon which the current version of biology rests. So, too, are large scale theories like the theory of evolution, the organization of living matter into cells and the general role of DNA. Within these structural theories there is dispute and revision. There are competing evolutionary explanations for the occurrence of altruistic behavior, e. g. William Hamilton's kin selection and Amotz Zahavi's Handicap Principle. The discovery of RNA viruses falsified what James Watson had called molecular biology's "central dogma" that information proceeds always from DNA to RNA to protein.

If I work in some subfield of biology, these large scale theories are part of my background knowledge. Suppose I study the biology of snails in a particular location. I have examined them in the field, dissected some of them and have become familiar with their physiology and life-cycle. Insofar as a grand theory like evolution impacts upon these snails I am able to criticize or defend the theory by referring directly to my experience with them and to the data I have gathered about them. In my previous visits I have observed stability in some aspects and changes in other characteristics. These memories underlie my expectations of what I will observe on future trips. My observations provide the foundation upon which I can build arguments and interpretations. This simply means that I do not expect dissent from such observational claims as: "Here are ten snails among which one can observe the following banding patterns."

Actually, I have no experience with snails beyond various suburban yards

and some French restaurants. It is Stephen Jay Gould who is the snail expert. I read what he says and accept his authority. I believe that had I accompanied him on a field trip and I could have seen what he saw. I expect that with his experience he would observe variations which I would not notice though I believe I could recognize them were they pointed out to me.

Similarly, in other fields far from his own, Gould reads of data acquired or experiments performed and believes them. Furthermore, both he and I believe that given sufficient time and training we could duplicate the observations that we read about. This is the "intersubjective testability" of scientific results. But in fact we don't attempt the futile project of duplicating all the work that others have performed. Our confidence that we would see what they see is another way of saying we believe them when they say they see it. Thus, the practice of science is dependent upon a network of beliefs which are accepted on the authority of other practitioners.

In a large subject like biology we would expect that there exist errors and occasional frauds. Many of these results will never be reconsidered or corrected. However, some results are important, namely those which disturb the expectations of others. Interested experts are then likely to attempt to repeat the work, confirming or refuting the surprising claims.

The network of belief in science is maintained by these tests of marginal claims. I use the word 'marginal' as in economics. When the price of a product is raised, not everyone responds. Just a few buyers may cut back on their purchases or undertake the search for substitutes. But the behavior of these few, marginal, consumers reduces the total demand and so imposes some price discipline upon the seller, a discipline which benefits all consumers.

Although I defined rationality to be a willingness to respond to critical attack, I must admit that this rational response often occurs at the group level rather than at the individual level. Many criticisms of my background views I will simply shrug off, confident that they are answered by others. For some questions I will be able to point out where in the literature the argument is being carried out. For others I won't even know, I will merely assume that the questions are considered and answered out there somewhere. Only for certain areas which interest me will I grapple with the criticisms directly.

For example, most biologists simply ignore creationist criticisms of evolutionary theory, except to deplore the associated political squabbles. If pressed they would refer to Gould, Lewontin, Dawkins and Mayr. However much they differ among themselves, these authors agree that creationist ar-

guments are anachronistic expressions of religious prejudice, utterly without intellectual merit.

On the contrary I think the arguments of Johnson, Behe et al. are very interesting and are well worth confronting. But this is a special interest of mine in the boundary between biology and religion. On such subjects as ESP and alien abductions I am no more open minded than my colleagues are about creationism. Each of these topics has a collection of enthusiasts and is structured (especially now on the Internet) somewhat like more orthodox areas of research. That is, data, evidence, arguments and theories are exchanged among a group of believers who form a little consensus that they are addressing true and important phenomena. Furthermore, I agree that either, if true, is important and I admit that I have not investigated the claims of either in detail. But I reject them because they seem implausible. Ignorant of the details as I am, I really can't criticize them directly. Instead, I defer to the authority of those skeptics who have, I believe, examined the claims.

However irritating it is to the dissenters, I think that this Billy-Goats-Gruff ("Talk to him about that, not to me.") approach of distributed rationality is a reasonable division of labor applied to the work of responding to criticism. If a biologist isn't interested in reading Johnson and just wants to get on with his work, that's fine. But if you do respond, then you have to respond reasonably and address the arguments. While I believe that both scientific and religious views can be defended rationally, both can be held irrationally as well. Trying to separate religion from science by definition and thus to insulate the latter from religious criticism is a mistake which can become an irrational refusal to consider any but internal arguments.

Of course, religion has been at times hostile to engagement with the world and so with science. Some religious leaders appear to regard even the acknowledgment of criticism of religious doctrine as blasphemous. There are aspects of such views in every religious tradition. However, most religions have also a tradition of response to critical questioning. In the Catholic Church, for example, this tradition leads from Augustine and Aquinas down through Newman and Chesterton.

What is lost when one adopts my version of rationality is the hope that all arguments can be reasonably settled. That is, the hope that reason can provide a decision procedure which can build a consensus in a science so compelling that dissent from at least the core elements is possible only by some kind of irrational move, either by ignoring obvious data or by denying

clearly valid arguments.

Because rational argument requires initial agreement upon a groundwork of common assumptions, an insufficiency of such common grounds can leave disagreements undecidable by reason. The two sides regard each other as trapped in a world of fantasy, beyond the reach of reason, the opponent is, in the words of Pauli, "Not even wrong."

I used to believe that if you began to argue with an apparently rational man who was in the grip of a delusional scheme, your exposure of the inconsistencies among his beliefs would just make him angry and he would break off the argument. When a friend of mine did in fact have a paranoid breakdown (he believed that the Nazis had won the war and were ruling the world from a base in Brooklyn) I discovered that his world-view was as internally consistent as my own. He denied a great deal of "what everyone knows" which I attempted to introduce into the argument. Furthermore, each of us had an explanation for the other's views. I thought him mad. He believed I was duped.

The critical rationalism which I espouse, following Popper and Bartley, does mean that it is at least possible that one might change one's views in response to rational criticism. However, a critical argument need not consist of a logical deduction leading to a previously unnoticed contradiction in one's beliefs. It can consist of an invitation to view mutually acknowledged facts in a new way, to reinterpret the world. An argument or description can change one's sense of what the world looks like. Such a change in conviction is more akin to a religious revelation than to a geometric demonstration.

Another little fiction, this one takes place in the year 1850:

> My brother and I share ownership of the small plantation in South Carolina on which we were born and raised. One late summer afternoon, we were sitting on the verandah of our nearest neighbor, an old friend with whom we have already sipped several bourbons. Our discussion turned to slavery and to the abolitionist agitation which was so embittering our national politics. We agreed that, lacking as they did our experience with the Negro, the Yankees simply did not recognize the depth of the difference between the races. The Hand of Providence could be seen in how the differences between white and black fitted together so well in the institution of slavery. The white sense of Christian responsibility- admittedly sometimes sinfully lacking- instilled a

> sense of obligation requiring us to protect our bondsmen. But especially unrecognized by Northerners was the fundamentally different emotional nature of the Negroes which was masked by their superficial similarity with ourselves. Their moods so enthusiastic, but so fleeting; their attachments demonstrative, but not deep. How many times had we seen it? A slave mother wailing when economic necessity required the selling away of her child and yet a few days later she was working with the same verve as in the past, her loss forgotten, or at most, a small thing, tucked away. This kind of biological adaptation to slavery would be simply impossible for a white woman to bear...Our discussion concluded in amiable, if somewhat tipsy, agreement and my brother and I climbed into our carriage for the short trip home. Our horse well knew the path and trotted briskly along, eager himself to get home, while, half-asleep, I sat with the reins slack in my hands. Suddenly, a little brown figure, one of our own slaves, burst from the bushes by the road. The boy froze in the path of the oncoming horse. Shocked awake, I could not react in time, but someone else had rushed out and snatched the child away. His mother, for such it was, held him, screaming and weeping in the anger and relief that any parent would feel at such a moment. I had halted the horse and I gazed back. As I watched them I felt my mind shift like a tree falling suddenly in a storm. I had been wrong. That woman's feelings for her child were every bit as deep as any white woman's or as mine for my own child. While I could remember the certainty I had felt about the difference between the races, I could no longer imagine how such a view had seemed even plausible. I carefully picked up the reins and we resumed the journey home. While I stared forward, stunned, I could see from the corner of my eye, my brother looking at me as though puzzled by some alteration he could not understand.

The change in beliefs described above was not irrational, although it may have seemed so to the narrator's brother. Under the pressure of some new experience an entire structure of previous belief suddenly seems implausible and a previously dismissed alternative now appears obviously true. The change is not irrational but it is not compelled by reason either. Personal id-

iosyncrasies might explain why the narrator experienced his revelation while his brother, sharing almost the identical experience, did not. Perhaps the former was nearly trampled in his own childhood or perhaps the two had different experiences with their own mother. While it is not the result of an argument, this kind of change can be examined by using reason and argument. Imagine when the pair got home. They shared an entire history of common experiences which provided data for each to use in pressing their now divergent views.

In science as well, there can occur competing plausible descriptions of the world. The resulting dispute can be susceptible to argument but is not necessarily resolvable by argument. Such a description underlies the hopes and beliefs that motivate a research program like Artificial Intelligence or Intelligent Design, to cite examples upon which differing degrees of academic respectability are conferred. In each case, a researcher is guided by intuitions about the world and an entrepreneurial faith in the fruitfulness of a line of investigation. He commits himself to a particular program, investing his time and effort, but he continues to argue with critics over the reasonableness of the choice. Some he may convince to join his project while others remain true to their previous, competing view. In retrospect he may be regarded as having wasted his time but for science as a whole such diverse commitments are not wasted. Alternative possibilities have been investigated and each position provides a platform for useful criticism of the competing view.

4 The Design Argument

For me the great appeal of Phil Johnson's writings lies in the issue upon which his arguments focus. I share his view that the most important problem which Darwin addresses is that of adaptation. In Dawkins' terms, what is the explanation for the appearance of design throughout the biological world? Even today our language for the precision, purpose and efficiency of biological mechanisms is taken from our description of human artifacts: machines, tools and computers.

To the religious believer there is really no problem. Appearance of design results from the intentions of a Designer. The delicate and beautiful fit relating biological phenomena occurs because they were crafted that way by God. This is a version of the classical Argument from Design for the existence of God. While this argument goes back via Aquinas at least to

Aristotle, the most influential summary in Darwin's time was the Reverend William Payley's Natural Theology. This combined the argument with a lovingly detailed description of those biological adaptations, e. g. the eye, upon which the argument was based.

Earlier Hume had attacked the argument from design in his Dialogues Concerning Natural Religion by criticizing the analogy between biological phenomena and human artifacts. I believe, however, that Payley's argument escapes these criticisms if you regard it not as a logical deduction for the existence of God, but instead as the suggestion that the best explanation of biological adaptation is the one suggested by the beliefs independently provided by religious faith.

We can phrase this version of Payley's argument as follows: Confronting the facts of biological adaptation you can imagine no explanation of their origin other than as the designed result expressing the intentions of their Creator. The stubborn atheist's reply had to be: You are right; I cannot imagine any alternative explanation but that may result from limitations upon my imagination rather than upon the productive capacities of the natural world. However, this unrealized possibility of an alternative provides rather weak grounds for rejecting the best explanation at hand.

But where did the impulse to reject design come from? Why did Payley need to provide such a detailed argument for the salience of religious belief for description of the natural world? Of course, there was the Enlightenment impulse to provide natural explanations following Newton's great success. But Newton himself was deeply religious (although heretical) and he believed that occasional action by God was required to maintain the stability of the solar system. Laplace's bon mot "I have no need of that hypothesis" was his response to Napoleon's question about the role of God in his celestial mechanics. He intended to eliminate the need for God to repeatedly stabilize the system. But this search for intellectual elegance was compatible with the deist view of God as the Author of the universe.

Parallel to the unease with the design argument was the growth of ideas of evolution in the modern sense of transformation of species. The word was adopted from an earlier use referring to embryological development. Ideas of evolutionary transformation were aired by Lamarck and by Erasmus Darwin, Charles' grandfather. Why was the community of natural philosophers at all receptive to such ideas? They represented, after all, an attack on some of the best and most exciting science of the day, namely the elaboration of the science of biological classification due to Linneaus. What Ernst Mayr calls

the typological species concept which underlies the Linnean scheme depends on the idea of fixed, separate species. In addition to its solid foundation on classical philosophy as well as common sense these ideas represented a reaction against the silly mythology of chimera and griffins, of matings between eagles and lions and between men and monkeys (or men and Klingons to cite a more modern myth).

To some extent, in England at least, the issue was political. The transformationists were allied with Dissenters and radicals in attacking the power of the established Anglican Church. But I believe there was an intellectual impetus from within biology itself which came from the discovery, via the emerging study of fossils, of the extinction of species and the continuing appearance of new species in time. The changing array of fossil species through time became especially important for the developing historical view of geology. A priori this doesn't contradict the theory of special creation, i. e. a creative act for the appearance of each new species. In fact, because geological strata were dated in part by using the fossils they contained, the fixity of species was rather useful to geology. In his exposition of Charles Lyell's theories, Time's Arrow, Time's Cycle, Gould points out that it was these scientific considerations, rather more than his religious views, which motivated Lyell's reluctance to adopt the theory of his friend Darwin.

The problem with special creation is that there are a lot of species. A mysterious initial creative act and rare miraculous interventions of great significance, like the Incarnation of Christ, seem to be apt expressions of God's grandeur. Contrast the seemingly endless parade of new species, the vast majority of which died out before the appearance of humanity. The special creation view seems to require a kind of constant, inappropriate mucking about. In the words of one of Darwin's early, private notebooks: The Almighty - personally creating "a long string of vile Molluscous animals - How beneath the dignity of Him". Compare Apollo's hauling the sun around the earth every day with Newton's glorious picture of astronomical orbits derived from the universal law of gravity. Perhaps some natural law analogous to gravity underlies the progression of species. In Laplace's celestial mechanics the divine origin of the law of gravity became irrelevant to the closed system of astronomical behavior. Similarly, a law of species progression held out the prospect of a purely material explanation for the historical architecture of life.

I believe that it was this unease with the theory of special creation of species through time which prepared for the alternative of evolutionary trans-

formation and the associated possibility of a material explanation for biological change without the immanent action of a designer.

However, neither Lamarck nor Erasmus Darwin provided any kind of material mechanism which would suggest how evolution might occur. Then came Charles Darwin's The Origin of Species. It should be noted that the book is almost entirely devoted to a critical attack upon the theory of special creation with the theory of evolution by natural selection introduced as an alternative.

When T. H. Huxley first read Darwin's manuscript his reaction was: "How extremely stupid not to have thought of it!" The interesting question here is: To what does the pronoun 'it' refer? Not evolution because the idea of evolution, while controversial, was not new. The new idea is the mechanism of natural selection. What is odd here is that historians like Peter Bowler have revealed that biologists of the period in general, and Huxley in particular, did not adopt or use natural selection. Natural selection remained largely a minor theme until the population genetics of Fisher, Haldane and Wright united evolutionary theory with genetics in the early twentieth century. The puzzle is that Darwin's book converted the biological community to evolution but failed to convince in its most original aspect. In part this success came from Darwin's detailed criticisms of the competing theory of special creation, criticisms which were supported by immense amounts of carefully analyzed data. But the theory of natural selection did play an important role.

Recall that Payley's argument for design claimed that a material mechanism which could produce biological adaptation was unimaginable. No more. As many have pointed out, Darwin's natural selection extended to the world of biology the success of Adam Smith's 'invisible hand' in economics. In each case a pattern of organized structure could be explained by a mechanism which did not require a central organizing intelligence. For Huxley and others Darwin's theory of natural selection (what Darwin is always referring to when he speaks of "my theory" and what its co-discoverer Wallace always generously referred to as "Darwin's theory") breaks the argument for design. It provides a material, mindless mechanism which could account for adaptation. Huxley and others did not assume that it was the mechanism by which all adaptations did in fact originate. Darwin himself forthrightly described the problems associated with natural selection. It requires a succession of small changes, each adaptively superior to its predecessor. Huxley emphasized the reality of the jumps which appeared in the fossil record and

so he was inclined in his own work not to depend upon natural selection as an explanation.

This combination of enthusiasm with skepticism is easily explained. Darwin's imaginative leap provided a previously unthinkable mechanism for evolution. The limitations of natural selection would become unimportant as other alternative mechanisms were found as they surely would be now that the ice of the design argument was broken. Indeed, the late nineteenth century abounded in proposed alternative mechanisms: a justification of the inheritance of acquired characteristics, orthogenesis which was a kind of inertia applied to evolutionary change, and large scale advantageous changes perhaps directly induced by environmental need. However, all of these have been abandoned. After a fruitless search a century and a half long, no alternative to natural selection has turned up.

The modern neo-Darwinian synthesis is entirely built upon natural selection: Inheritable variation is increased by such things as genetic mutation, recombination and genetic drift, i. e. statistical variation in the production of small subpopulations. These sources of variation are undirected. That is, even when the amount of variation is increased due to some environmental stress, e. g. radiation and some chemicals can increase the mutation rate, the phenotypic effect of these changes is likely to be unfavorable and when favorable is likely to be unrelated to the kind of environmental stress which induced it. Certain large scale sources of variation have now been recognized: Transspecies hybridization sometimes occurs in plants; viruses and other "alternatives to sex" (Haldane's phrase) move blocks of genes about especially in bacteria; the evolutionary role of symbiosis is now, thanks to Lynn Margules, seen to be of great importance. In all of these cases it is the test of reproductive success which determines whether a new pattern fails or replaces an older one. Natural selection is the cumulative change made up of such successful tests. The neo-Darwinist view sees this as the only mechanism which explains adaptation.

The search continues for higher laws of evolution like orthogenesis: Kaufman's principles of self-organization in matter, Prigogine's nonequilibrium thermodynamics and the complexity theory championed by Goodwin. I think it is fair to say that none of these ideas has as yet provided any sort of mechanism convincing or otherwise. Each phrase is a label on a hope of future success rather than on any already realized accomplishment.

Natural selection is the survivor of an extensive failed search for alternative mechanisms. From this perspective, one tends to regard with rueful

amusement the triumphalism of Dennett and Dawkins concerning natural selection. On the other hand, some of the attacks on them from within the Darwinian community are just confused. One of the advantages of viewing this community from Johnson's outsider position is the realization about how minor are the differences within it.

Consideration of some famous disputes in biology will illustrate my contention that everyone involved shares the same neo-Darwinian view.

Gould, Eldredge and Lewontin label Dawkins and Dennett as pan-selectionists and ultraDarwinians for their alleged overemphasis on the role of natural selection. The primary stress in Gould and Eldredge's phrase "punctuated equilibrium" is supposed to rest on the noun, emphasizing the conservative nature of natural selection. Evolutionary change is supposed, by contrast, to be relatively rare in the geological timeline and mainly occurs when small subpopulations become isolated from the main group. Such a subpopulation may become a separate species which outcompetes the original one. As the predecessor becomes extinct, its replacement may expand into its old range. The older, adaptive landscape picture emphasized evolutionary change within a single population as gene frequencies changed. Notice that in both cases any adaptive change is still due to natural selection. The disagreement between the two views is certainly important. However, it concerns not the significance of the action of natural selection but rather the level at which selection acts, whether between or within populations.

The actual span of disagreement from the views of Gould and Lewontin to those they label "panselectionist" is startling in its insignificance. There are two issues.

First, not every complicated behavior in a species is the result of direct selection for that behavior. The contrary assumption can lead to searches for selective pressures and behavior specific genes, pursuits which can become bizarre as well as unnecessary. For example, human beings have confronted pianos only recently in their evolutionary history. It would be silly to search for the reproductive advantage conferred by piano-playing (Chopin and all those women!) which would account for its having been selected for in the human species. Similarly, don't hunt for the piano genes on which selection acts. Instead, piano playing co-opts various physical and mental skills which were selected for in human prehistory but for other reasons. Since such qualities are probably under some genetic control, there probably is genetic variation in piano-playing ability. Incidentally, this means that we could select for such ability. If we only allowed reproduction by those who master

Für Elise we could probably quickly increase the general level of piano-playing ability in the species.

Dawkins, Dennett et al. would, of course, grant the point hammered home by the above example. Admittedly, there are examples of seriously intended evolutionary musings about psychology and morality which are just about as silly. However, the adaptationists would suggest as a methodological point that faced with some complicated character in a species it is useful to assume initially that it is adaptive and so the result of selection. One reserves as an unhelpful, but real, possibility the suggestion that it is instead what Gould and Lewontin call a "spandrel", an accidental consequence of selection acting elsewhere.

Note, however, that all participants to the dispute agree that adaptation, when it occurs, is the result of selection.

The second issue concerns contingency.

Gould especially emphasizes the role of chance in evolutionary history. When he refers to the phenomenon of evolutionary 'contingency', he means that historical accidents account in large part for the distribution of species which happen to exist. For example, had some meteor which hit the earth happened to miss instead, then perhaps dinosaurs would not now be extinct and mammals would still be represented by small, fugitive species.

Contingency is sometimes described by saying that if the tape of history were rolled back then from the same beginnings tiny, random changes would lead to a wildly different suite of species than we have today. I believe that Dawkins, Dennett and Maynard Smith would agree with this view or at least accept that it is possible in some sense. After all, the sources of variation in classical population genetics, e. g. mutation and drift, are regarded as random events, so one need not look to the heavens for chance. However, they would emphasize that any adaptations which developed over this new alternative history would still be the result of selection and selection alone. Different species might then occupy various ecological niches but their fit would be due entirely to natural selection, and Gould would agree.

Thus, when Gould says that natural selection is not sufficient to account for evolution, he is speaking about the actual history of the succession of species on earth. The effects of chance must be included. I would conjecture that this is the consensus view in biology. On the other hand, the vast majority of biologists including Gould would agree with the Darwinian position that the history of adaptation, meaning the explanation of how adaptive characters occur, is entirely a matter of natural selection. The link between

the two ideas is that selection acts on a species as it exists as a result of its contingent past history and uses variation produced by mutation, recombination, etc. Thus, does chance play a role in the action of selection. There is no real disagreement here as the two ideas are completely compatible. Political and personal animosities appear to account for the bitterness with which this campaign of misunderstanding has been pursued.

Contingency is an important idea. It represents one side of a dichotomy, stability vs. instability, which people apply in many different contexts. In child-rearing, the unstable vision emphasizes the long term traumatic effects which even apparently small events can have. The picture here is of small events in childhood which are seen in retrospect to echo through an adult's life. The stable vision emphasizes children's resiliency. They fall out of trees and laugh. They adapt. They abide. They seem to slough off the effects of horrors which would crush an adult.

In science-fiction writings, both visions are recurrent in time travel stories. In the stable version, you try to go back to change the past and little events keep canceling out the effects of your attempts. The classic representative of the unstable version is *The Sound of Thunder* by Ray Bradbury in which a crushed butterfly in the past radically changes the future. I had thought this the source for the 'butterfly effect' which meteorologist Edward Lorenz uses to label chaos in the dynamics of weather. (In his *Essence of Chaos* he mentions being told about the story long after he had begun talking about the butterfly effect.) 'Chaos theory' itself, in many of its popular uses (though not in Lorenz's excellent book), is just a fancy label for this ancient intuition of instability.

The widespread agreement among biologists on the reality of contingency in evolution is an acceptance that instability is the correct view for evolutionary history. However, the hope that there exist as yet undiscovered effects in evolution which would stabilize its history motivated in part the search for large scale evolutionary laws. Some, a small minority, still expect to find mechanisms which would buffer the succession of species against the random perturbations introduced by mutation and other chance effects.

This agreement within the biological community renders more stark the disagreement with much of the public. Contingency is the rock on which Gould builds his conclusion that progress is a human illusion. Actual history as it has occurred is largely the result of a sequence of pointless accidents. Consequently, it is useless to search for moral meaning in the succession of events in either natural or human history.

To put it mildly, Johnson disagrees with this view. In fact, it is such issues of moral meaning rather than, say, our kinship with apes which accounts for the sense of urgency with which the modern American attack on evolution from Bryan to Johnson has been prosecuted.

In contrast, the vigorous biological dispute over Kimura's Neutral Gene Theory is largely irrelevant to the religion vs. science argument. Kimura proposed that a high percentage of the genetic variation newly discovered at the molecular level was largely selectively neutral and so changed randomly, unaffected by selection. This accounts for the relatively constant rate of change observed in what has been called the 'molecular clock'.

This dispute about the extent of neutrality is not yet entirely resolved, although the center of gravity of the debate is now much closer to Kimura's position than it used to be. However, all parties in the case have always agreed that adaptation is entirely the result of natural selection acting on that part of genetic variation which accounts for significant selective difference.

5 Defending Darwinism

In criticizing the Darwinian explanation of adaptation, Johnson and others direct our attention principally to the problem of macroevolution, that is, the evolution of complex biological organs and behaviors. The evolutionists' usual response is to point to examples of microevolution, e. g. experimental tests of selection and field data on finch beak variations in time. The critics accept these examples, at least in principle, but demand evidence that the same process, admittedly effective for small scale changes, can produce evolutionary novelties.

On the one hand, this demand seems a bit unfair. By dismissing such examples as ring species and Darwin's finches the critics eliminate by fiat any action by natural selection which could occur in a time-scale comparable to a human life span. On the other hand, it does seem legitimate to distinguish between the two processes. So-called microevolution appears to be a continuous, reversible process whose reality nicely fits our theoretical description of the action of natural selection, i. e. the alteration over successive generations of the distribution of gene frequencies in a population. In the large, evolution proceeds by jumps and seems to us not only irreversible but so directional that Gould (and Darwin himself) have to keep reminding

us that the appearance of progress is an illusion imposed by our prejudiced interpretations.

The difficulty here is the saltatory nature of the evolutionary evidence. To some extent this appearance of discrete change has to be a reflection of reality. Microevolution encompasses the genetic response within a species to environmental change. Macroevolution refers to changes sufficiently large to designate separate species. It is change between species. We continue to accept the Linnean picture of the reality of discretely separated species. As Darwin was aware from the very beginning, using natural selection to explain a change required that the two endpoints be connected by a sequence of steps with each an adaptive improvement. Furthermore, with very few exceptions like hybridization or the associations leading to the evolution of a symbiosis, the change across each step has to be quite small. This is just another way of saying that, in the main, macroevolution is just microevolution writ large across time. It was this demand for continuity which led nineteenth century morphologists like Huxley to ignore natural selection in their work. Their complacent hope that something else would turn up has been dashed. So we modern Darwinists have to insist upon the continuous process of natural selection.

I have to pause here to for a digression, or, more precisely, a rant.

I think that these criticisms of Darwinism are quite interesting and I will return to them below. Lately, however, Johnson and his associates have been claiming that a proof exists which suggests that natural selection is completely impotent. This argument is alluded to when one sees the phrase: "Information (sometimes 'meaningful information') cannot be generated by a random process." I do not really understand what is meant here and I haven't seen the argument itself. But I don't have to. It is reminiscent of the old wheeze about aeronautical engineers proving that bumblebees can't fly.

If computer simulations don't convince, then look at the vast number of experiments and field studies which document the success of natural selection (the microevolution examples mentioned above) to say nothing about artificial selection. It has been clear from from its initial description that natural selection could, in principle, produce adaptive improvements. Hence, Huxley's forehead-slapping delight: "How extremely stupid...etc." The only theoretical difficulty presented by macroevolution is the gap problem described above. If you can get from A to B by small steps each of which is an improvement then in theory natural selection can accomplish the transition.

The proposed information theory argument might have some interest but no real bite. Just as the engineering argument might suggest some problems with our theory of flight but doesn't ground the bees.

I think that Johnson and his friends are being seduced by mathematical flim-flam. Information theory, like cybernetics, game theory, catastrophe theory and chaos, is a mathematical subject whose technical vocabulary has a lot of sexy, real world resonance. Like the physics of relativity and the Uncertainty Principle, these vocabularies have inspired dead forests of printed garbage.

Propelled by the royal authority of the queen of the sciences this pseudo-mathematical meme seems to be spreading. In the controversy about new science standards, the Kansas board of education inserted the phrase "Natural selection can maintain or deplete genetic variation but does not add new information to the existing genetic code." Similarly misconceived was the attempt to nail Dawkins by using the phrase "the information content of the genome" (described in the Information Quandary chapter of Johnson's The Wedge of Truth). Let me illustrate why I think all of this is just confused verbiage.

Suppose we are following a population of points which live on the number line. Think of 100 dots which live sitting on a meter stick each at some point between the 1cm and 2 cm marks. The life cycle of these dots has two steps: (1) Reproduction: each dot is replaced by two offspring dots. Each of the two new dots is placed within 1/10 cm of the position of the parent. This is mutation, undirected because we assume that moves up and down are equally likely. (2) Selection: Half of the young dots die off so that the new adult generation again consists of 100 dots. Following the American Principle that bigger is better, it is the 100 dots at the lowest positions on the stick which are killed. If we kill them because we like high ranking dots then this is artificial selection. If the higher level dots outcompete the lower ones, say in the search for food, then this is natural selection.

Now look at each step separately. During reproduction variation is increased. Perhaps the maximum occupied position is 1/10 cm higher than before but maybe not. In any case, because mutation was undirected the average position is not expected to change. That is, the center of gravity of the 200 offspring is as likely to be lower as higher than the center of the 100 parents. On the other hand, the selection step certainly adds no novelty. All 100 members of the new adult population were already members of the offspring cohort. However, the new center of gravity is almost certainly higher

than the old one. Furthermore, over several generations the population of dots marches predictably up the stick.

Even this simple example illustrates several facts. Selection of any sort always reduces variation. Random processes like mutation increase variation but in an undirected fashion. The combination of the two can yield strongly directional effects.

These dots have no internal structure to which our imaginations can attach the word 'information' which we usually reserve for a long list of symbols like the words in a book or the bases in a DNA molecule. Again it is the random processes which increases the stock of such items. Sexual reproduction is a random process with respect to the parent zygotes. A baby begins as a novel zygote. The process of natural selection again reduces variation but changes the character of the population.

All these are micro examples. The word 'information' when used in this context by nonmathematicians refers instead to not just another boring organism but something really novel. Instructions for a new organ. But if you could build the required novel DNA one base at a time in an adaptively increasing way then there would be no problem. How would that work? It doesn't seem possible. Right. But with this puzzle we are back at the micro/macro problem again. Information theory has nothing to do with it.

We have returned to the serious challenge presented by such complex adaptations as the eye. Modern evolutionists do have a response. Because soft tissues don't fossilize, the historical record is lost. What is sought instead is a collection of related, current species which display eyes of different quality with the hope of ranking these in an order analogous to the historical order. It won't be the historical order because these species are contemporaries rather than successors. Similarly, men did not evolve from any current monkey species but instead they share a common ancestral species. Our ranking is also distorted because the organ in each current species is a successful adaptation to current circumstances rather than a transitional stage.

Konrad Lorenz used a similar cataloguing of current patterns to investigate the evolutionary origins of certain stereotyped behaviors.

The resulting arrangements may appear to some to be still too gappy to be convincing. However, for several types of complex organs enough current analogues for proposed intermediate types exist to hang a hypothetical sequence of evolutionary stages upon them.

Behe has revived the Design Argument by aiming the macroevolutionary challenge at a different class of adaptations, not multicellular organs but

patterns within the cell: complex biochemical processes like the Krebs cycle and molecular structures like the flagellum.

Behe illustrates his concept of irreducible complexity with the familiar mousetrap. If any of its few simple parts are removed then the remaining assembly is nonfunctional. The same appears to be true a fortiori for the complicated arrangements of enzymes which make up the biochemical processes he considers.

The phrase 'irreducible complexity' is just a new label for the old gap problem of macroevolution. The old question "What good is half an eye?" was raising exactly this issue. This is not a complaint. A good expository device for an old idea can be helpful in refreshing our thinking about it. On the other hand, while Behe's view of complexity is not at all novel, the deployment of his biochemical examples is both new and striking in this context.

Recall the Design Argument in the form I attributed it to Payley. Behe is saying that one can't imagine a sequence of small adaptive steps leading up to a process like the Krebs cycle. He means that not only can he not imagine it but no one else has either. Leave aside, he says, how convincing are the hypothetical series of stages which have been proposed for the eye or for electric organs in fish. Behe claims that a literature search reveals no proposal, however tentative, for an evolutionary sequence leading to one of these biochemical complexities. He suggests that evolutionists are in the position of the author who, discovering that his hero was irrecoverably trapped, wrote, "With one bound, Jack was free."

Johnson has sometimes objected to the purely hypothetical reconstruction of evolutionary stages for the something like the eye. Since direct evidence for such soft tissue change seems impossible to obtain (no fossils) such an imagined sequences is the best we can do. More important, it is all that is needed to counter the Design Argument in the form I have described it ("You cannot conceive of any explanation for such an adaptation other than design.") This is just why Behe's argument in Darwin's Black Box is so powerful. He is proposing that for a whole class of adaptations, namely those at the intracellular level, no biologically adequate story using natural selection has been told nor, in his opinion, can any be imagined. His arguments revive the Design Argument with a stark challenge more dramatic than the skeptical grumbles about 'Just-So Stories'.

With these critical attacks in mind, we should recall here the intellectual power of the Darwinian theory. Otherwise, its overwhelming acceptance by

biologists will seem inexplicable. Or rather it will appear to be, as Johnson sometimes suggests, a stubborn prejudice, originating in a prior commitment to materialism and blindly maintained by ignoring its devastating weaknesses. He occasionally claims that biologists are aware of the intellectual bankruptcy of the theory of evolution but refuse to admit it because of antireligious prejudice, i. e. if they retreat from the shaky intellectual ground upon which they stand then someone will show up and build a church on it. This sort of overstatement is uncharacteristic of Johnson who usually demonstrates a pretty clear understanding of the opinions he is criticizing. His lapse is however an understandable tu quoque since mainstream biologists dismiss his writings as the ignorant vaporings of a religious nut who is ignoring whole libraries full of factual evidence.

Johnson's lawyer predecessor, Norman Macbeth, suggests in his *Darwin Retried* that scientists stand by the Darwinian theory despite its weaknesses simply for lack of an alternative. Macbeth refers to this as the "best in field fallacy". First, I would say that it is not irrational to believe a theory for which one has no alternatives. Recall the similar appeal in the version I presented of the Design Argument ("You can imagine...etc."). On the other hand, evolution by natural selection is not the only theory on offer. The major alternative is that of special creation which Darwin's theory replaced and which the Intelligent Design folks propose to revive.

It should be remembered that Darwin's Origin was framed as a critical attack on special creation. The rapid conversion to the theory of evolution effected almost single-handedly by Darwin was accomplished by the success of his argument. In light of the failure of later biologists to find evolutionary mechanisms other than natural selection it might be reasonable to reconsider some of the nineteenth century arguments against selection. However, such intellectual archeology will then have to confront the imposing edifice of Darwin's original criticisms.

Supported by carefully collected empirical data, Darwin described a large number of biological phenomena which appeared to be puzzling or even inexplicable from the viewpoint of special creation. Each has a simple explanation using Darwin's competing view of evolution by natural selection. For example, species in similar habitats on widely separated islands appear not to be similar to one another but, instead, to be related to species living in different situations on the adjacent mainland. The latter resemblance is to be expected if the mainland species are ancestral to the island species which have in turn evolved to adapt to their altered circumstances.

Another argument raised by Darwin has been revived by Jacob in his *Evolution As Tinkerer* and by Gould in the title essay of *The Panda's Thumb*. This concerns adaptations which, while successful, are rather inefficient from the engineering point of view. While the many exquisite adaptations in nature may suggest a perfectionist Designer, for these rather clunky mechanisms a historical explanation seems much more reasonable. Similarly, the action of natural selection seems the best explanation for vestigial, nonfunctional organs like the eyes of moles.

Modern confidence in the Darwinian theory is also based on the -almost accidental- vindication of the theory against several initial objections which seemed at the time to be unanswerable. For example, Lord Kelvin's estimate of the age of the earth implied that not enough time had passed to allow evolution to occur as Darwin suggested. With the discovery of radioactivity the estimate of the earth's age was revised upward because of heating due to radioactive decay occurring in the earth's core.

Another serious objection was described by Fleeming Jenkin in an early review of the Origin. He pointed out that under the then universally accepted picture of blending inheritance, the variation necessary for selection to act would halved in each generation. In modern terminology, an unreasonably high mutation rate would be required to sustain the action of selection. One of the few important contributions of mathematics to the modern evolutionary synthesis was R. A. Fisher's proof that the particulate nature of Mendelian inheritance implies that, in the absence of selection, genetic variation is maintained rather than blended away. Thus the rediscovered Mendelian theory was shown to be complementary, rather than competitive, with Darwinian evolution.

The revolution of molecular biology provided further results which supported the confidence in the Darwinian theory. For example, in the Darwinian view the classification tree of species, the classical work of systematists using morphological data, is hypothesized to arise from historical, ancestral relationships. This pattern of common ancestry is the 'fact of evolution' so-called to distinguish it from the 'mechanism of evolution', which is natural selection. By using molecular data the relationships could be reexamined and the results, in general, support those obtained from morphology.

It is sometimes objected that this is not an especially strong confirmation of common descent. After all, if the tree represented merely logical or aesthetic relationships between separately created species then the coherence between the molecular and morphological relationships could still happen.

That is quite true but special creation is also compatible with two entirely different patterns of relationships. On the other hand, if common descent is the underlying explanation for the tree then the two patterns must agree. In other words, a negative result would have been very damaging to the theory of common descent in a way that it would not have been for special creation. That is why the positive result provides confirmation for the former view.

Another great result was the experimental confirmation that mutations favorable under special environmental conditions were not induced by those conditions but occurred randomly and were then selected by the environments in which they suddenly provided advantage. The Lederbergs' replica plating experiment is so elegant that it is worth describing here.

First, on a large, flat glass dish containing agar gel and nutrients one spreads a solution containing several million bacteria. These are allowed to reproduce so that the dish contains several million colonies of clones. If a solution with an antibiotic like streptomycin is added, the bacteria are all killed except for the very few colonies which carry strep resistant mutations. After additional growth these rare colonies are visible on the plate. Are these mutations induced by the stress produced by the antibiotic or were they there earlier? The experiment consisted of pressing a piece of velvet first onto the original carpet of bacteria and then onto several fresh agar plates. After a few more generations, strep is added to the fresh plates. The strep resistant colonies were observed in the corresponding locations in all the replica plates. This showed that the mutations had occurred earlier so that each resistant clone had been 'Xeroxed' onto the corresponding positions on the fresh plates. They were revealed rather than caused by the addition of streptomycin.

These are just examples of results from which Darwinists draw a sense of support. In general, the appeal of Darwin's theory lies in the host of successful explanations which are obtained throughout biology by assuming it.

I can't resist an autobiographical remark about Behe's favorite example of irreducible complexity. At a lumberyard near my home I was amused to notice, nailed up to the wall, a mousetrap, but not an entire mousetrap. The wooden base, the spring and bar were there but the pieces which held the trap open were missing. As Behe observes such an assembly is useless as a trap (also, only a Fred Astaire among mice could have reached it on the wall). However, it served quite well as a temporary holder of order slips for current jobs. I grant that this proves nothing as the mousetrap had not evolved from

the paper holder, but it did tickle my Darwinist's fancy.

Let me conclude this section by discussing computer simulations of natural selection and similar models. Johnson is confident that the sort of illustrative computer search procedures which Dawkins uses have design already built in. Using one author's example as a typical case, he labels these misleading examples "Berra's Blunder".

There is an extremely silly version that you see in movies sometimes. Suppose there is a six digit target number which unlocks the sinister front door of MacGuffin and Krupp: 200489. Our hero attaches a computer gadget to the lock and numbers begin to flicker on its screen. Suddenly, a 2 appears and remains in the first place. A moment later the 4 stabilizes in the fourth place. The two 0's appear, then the 8 and when the final 9 clicks into place, the door opens. If the key could actually be found this way, it should take a dime-store computer less than an eye-blink. A diligent child, working manually, should succeed in under a minute. After all, at most 60 trials are required. First, hunt through ten digits to find the initial 2, then through the ten digits to find the 0 in the second place and so forth. What is silly about all this is the notion that one could detect the digits separately. In fact, an electronic lock would be built to respond at all only to the entire correct list of six digits. Thus, the guess 200488 would evoke no more response than 111111. Hence, one may have to search through the entire list of one million sequences of six digits to find the key (pausing at each sequence for the lock to respond).

The old fashioned safe, cracked with educated fingers or a stethoscope, is a slightly easier job. When the first pair of digits, 20, is found, the first set of tumblers clicks into place. There follows a similar search for the second and third pairs. In principle, this requires up to three hundred trials. Of course, the best solution is to guess the combination. As James Mason said to his host, the German ambassador, after guessing the above combination in the movie *Five Fingers*, "Hitler's birthday probably opens half the German safes in Europe."

Dawkins and Berra use some target phrase and then show that using selection one can home in on the target. This will work fine provided that a list of letters is better (i. e. more strongly selected for) if it has more places of agreement with the target. Johnson wouldn't deny that such a simulation will work but would suggest that it looks like the silly movie scheme. It begs the question why some gibberish with a few letters in the right places would be selected by any process which did not already have the goal phrase

built in. The latter set up suggests design rather than selection. Of course, they are both right: given the fitness function which ranks the population of trials the simulation will perform as Dawkins and Berra predict, but the fitness function appears rather ad hoc just as Johnson suggests. Rather than attempt to adjudicate this misunderstanding, I would like to describe a card game, no computer required, which illustrates these issues.

Consider the five card poker hand drawn from a standard deck of cards. The rules provide an ordering of what beats what in poker: high card, one pair, two pair, three-of-a-kind, straight, flush, full house, four-of-a-kind and straight flush. Within these classes there are further orderings: three A's beats three 10's (A=ace, K=king, Q=queen, J=jack, in what follows)and a royal flush (an A high straight-flush) beats any other straight-flush. There are various hands of equal strength, which tie. For example, according to Hoyle: "The suits of which the hands are composed never makes any difference."

We will illustrate all this with two versions of a little poker solitaire game.

Deal out five cards. At each round we shuffle the 47 cards remaining in the deck, pick a card from the deck and then discard one of the six we hold back to the deck. Thus we get the next five card hand.

Design: Our goal is a royal flush in spades (A,K,Q,J,10 of spades). Whenever you pick up one the five cards which make up that hand you keep it and discard one of the six cards in your hand which is not in the goal hand. Within about a hundred rounds, you will have the required royal flush. In mathematical parlance the expected time until you reach the goal is about 105 draws. I call this the design option because at each stage the choice is made using the final goal. Dawkins could call this selection by using as fitness function the number of cards in common with a royal flush in spades. Again Johnson would say that the design is hidden in the fitness function.

Selection: When you have drawn a new card from the deck and hold six cards, there are six different five card hands you can get, each by discarding one card. Regard these six as competing against one another. Discard to keep the best hand among the six, i. e. in the local competition the strongest hand wins and proceeds to the next round. If there is a tie for the best among two or three hands then discard randomly so that any of these best hands is equally likely. This is like real natural selection in that it is myopic. Competition occurs only among the current alternatives. Furthermore, the whole process is much more interesting than the above Design version. For one thing, evolution takes a long time. Once you hit a straight, the high card

will evolve rapidly to an ace. That is, if you hold a 7 high straight then the probability of drawing an 8 is 4/47 and so in about twelve rounds (expected time = 47/4) you will hit an 8, and discard the 3 to hold an 8 high straight. Soon you will hit a 9. Once you have an A high straight you will continue to hold it. But the suits will evolve randomly. If you are holding a K of spades and draw a K of hearts then you will randomly discard one of the K's, holding the new K with probability one half. After a long time (expected time = 2155), by accident, all of the suits will agree. This is a royal flush and it is an equilibrium. That is, you continue to hold it, discarding the sixth card as soon as you draw it. Similarly, a flush will evolve rapidly to a royal flush in the same suit. However, it is interesting to observe that you may not evolve to a royal flush. In fact, you probably won't. You will very likely hit two pair before a flush or a straight and then you won't ever reach a royal flush. From two pair you evolve to a full house and from three-of-a-kind you evolve either to a full house or directly to four-of-a-kind. In either case this happens with an expected time of about ten rounds. From a full house you go to four-of-a-kind though the route might be indirect. Suppose you have two A's and three 8's. If you draw an 8 then you discard an A to hold four 8's. But if you draw an A then you discard an 8 to hold the better full house of A's and 8's. When you draw the fourth A then you discard an 8 to hold four A's. Once you hold four-of-a-kind you never discard one of the four. In actual poker, unless there's a whole lot of cheating going on, two hands of four of the same rank never meet (e. g. AAAAK vs AAAAQ). So the rules of poker do not specify which wins. Let us just assume they tie. Then the fifth card will continue to change randomly, neutrally, forever. In this setup, each of the thirteen four-of-a-kind types is a evolutionary peak which will not improve under selection. The royal flush peaks are higher but unreachable.

6 Arguments and Tests

I mentioned earlier that viewing the Darwinian position from Johnson's outsider location provides some useful perspective on some of the squabbles about evolution. For example, consider the so-called 'tautology argument': selection proceeds via survival of the fittest but fitness is defined by survival and so the whole theory is a tautology. This argument is so weak that I think of it as the Stupid Argument. When someone brings it up, I tend to assume they are joking. When Johnson mentioned it and I started to sneer,

he pointed out that his people didn't invent this argument, mine did. He's right about that, which only annoyed me more.

First of all, no one should like this argument. Since a tautology is true the antiDarwinists shouldn't adopt it. On the other hand, a tautology has no empirical content. It says nothing about the world. So Darwinists shouldn't take comfort from it either. Darwin didn't spend all that time and effort to come up with a logical equivalent to "A is A".

What the theory of evolution proposes to explain is adaptation, all the ways in which the parts of nature fit together, ranging from the complex physiology of an individual organism to the elaborate ecology of a region. Payley's examples are merely typical descriptions of what even Dawkins refers to as the appearance of design. Our wonder at the amazing interactions in living systems has only deepened with our increasing knowledge of biochemistry and molecular biology. This then is our problem, to explain all this fit, in the lock and key sense, this fitness, in the sense of healthy function. The Darwinian theory proposes as the explanation natural selection, the differential survival of inherited variation, as the mechanism which produced adaptation. This is an extremely strong claim of great imaginative power for which Darwin and Wallace deserve all the praise which has been heaped upon them. Just as the glory of Newton's mechanics survives after its replacement by relativity, biologists will retain their pride in the Darwinian theory even if it should prove wrong. The theory is no more a tautology than is Newton's Universal Law of Gravitation.

The Stupid Argument obtains its surface plausibility from a related issue of real scientific merit. Suppose a biologist like John Endler wishes to test the theory by observing selection in the wild or experimentally. This requires teasing apart the phenomena of adaptation and survival. An operational definition of fitness and practical ways to measure it can be hard to obtain, but they are not impossible. Consider Kettlewell's experiments on industrial melanism in the peppered moth. He showed that the gray morph was more vulnerable to predation on the dark trees where the light colored lichen had been killed by pollution His data have lately been the subject of some criticism, but even if it was not successful, the experimental setup illustrates the sort of thing which has to be done. It separates survival (differential predation rates) and adaptation (the predominance of the cryptic morph).

Related to this tautology business is the argument from mathematical necessity. Whenever you have heritable variation and differential survival

natural selection will occur and so Darwin's theory has to be correct. I think of this non sequitur as the Not Quite So Bad But Still Pretty Stupid Argument.

Creationists, like horse breeders, are aware that selection occurs. But while a Secretariat could occur as the result of luck and careful breeding, a Pegasus could not. Physiological constraints prevent the evolution of winged horses. The extent of such constraints on selection is exactly the key issue. Johnson et al. believe that natural selection is constrained to act within species boundaries in the fashion epitomized by artificial selection. If they are right then it is not a mechanism which accounts for adaptive differences between species.

One doesn't have to be religious to look beyond natural selection for an explanation of macroevolution. Hoyle and Wickramasinghe in their book *Evolution from Space* argue that there has been insufficient time for selection to accomplish the task of macroevolution. Recalling Lord Kelvin, evolutionists tend to shrug off such negative rate arguments as computations mired in ignorance. Hoyle and Wickramasinghe propose that organized bits of DNA occur in outer space, occasionally dribbling into the atmosphere whence they are picked up and incorporated in the genome of some species, thereby producing a leap to a new species. Hoyle was a distinguished astronomer, as well as a popular science fiction author. He deeply resented being dismissed as a crank but biologists do tend to regard his theory as more akin to his previous fiction than to his past science. Since he hypothesizes that the DNA bits in space are manufactured by aliens, his is a form of intelligent design theory.

Odd though the theory is, it helps us with another of those internal arguments. It has sometimes been claimed that Darwinism is not a scientific theory because it is not 'falsifiable'. That is, there is no experiment or observational test whose outcome would force you to give up the theory. In fact, Darwinists are uneasily aware that we find it hard to imagine circumstances under which we would give up the theory.

Consider the ultimate nonDarwinian animal, the shmoo. The biology of this animal was portrayed by Al Capp in his monograph *The Life and Times of the Shmoo*, which described data obtained by Capp's research assistant, Abner Yokum. While they reproduce enthusiastically and rapidly, the shmoos' lives are otherwise entirely dedicated to the satisfaction of members of other species. They respond to cooking in a great variety of tasty ways and when gazed at hungrily, they immediate expire out of sheer happiness. They also lay eggs, in cartons, which are unrelated to reproduction

since they produce young by -instantaneous- live birth. Much of our enjoyment of the shmoo comes from our sense that it contradicts a lot of what we know about biology, evolution by natural selection, in particular. Faced with actual shmoos, however, a biologist would not immediately abandon the Darwinian position. I imagine that a lot of ad hoc hypothesizing would precede such a retreat.

In fact, the unfalsifiability of a large scale theory, as well as its stubborn defense in the face of anomalies, are not the scientific sins they are sometimes taken to be. A theory like evolution provides convincing explanations of aspects of the world and suggests further lines of research. The attachment that the scientific community has to a plausible theory is justified by such past successes. On the other hand, scientific theories should be subject to rational criticism. It should be possible to at least imagine a situation where the theory would be replaced. Hoyle and Wickramasinghe enable us to imagine the story of such a replacement.

Look ahead a hundred years to when when space travel, at least within our solar system, is routine. Suppose that little packets of DNA are occasionally discovered floating in space. At first, the discovery is just regarded as one of those weird phenomena of which the exploration of space has revealed many. But some bibliophile eventually digs up a yellowed copy of Hoyle and Wickramasinghe's long forgotten book. A few Young Turks in biology, on the lookout for academic novelty, are inspired by the observations in space to tentatively adopt its theory which is still dismissed as preposterous by the biological establishment. As part of their research program they analyze the space DNA and its virus-like packaging. Using their analysis they are able to show how the packets can be incorporated into several different species. Eventually, they are able to produce rapid speciation under laboratory conditions. In the excitement generated by this revolutionary experimental work, Hoyle and Wickramasinghe's previously dismissed theory begins to look much more plausible. Soon refinements of the theory are used to explain some long standing puzzles in the Darwinian theory. Finally, the vibrant neoHoylism comes to replace the shaky Darwinian theory which is now seen in retrospect to be littered with gaps and problems.

This is not an outcome which I regard as likely, to put it mildly. But it illustrates how the Darwinian theory could be falsified.

Let us now reverse our gaze and look at the Intelligent Design community from the outside, that is, from a Darwinist's perspective.

The obvious question to consider is just what alternative do they suggest

for Darwinism. Johnson is especially forthright in his refusal to propose a replacement. On the other hand, he doesn't deny the need for a replacement. I already mentioned that I regard Norman Macbeth's "best-in-field fallacy" as a fallacy itself. Darwin's theory provides a number of plausible explanations, solves many problems and directs our thinking in various useful ways. The problems about macroevolution, gaps in the fossil record and the origin of life are just that. They are problems which we hope and expect will be solved in the future in ways which will prove largely compatible with the current theory. Perhaps we are wrong. Perhaps in time this faith in Darwinism will come to seem naive, the flaws in the theory will appear obvious and central rather than subtle and peripheral. However, such a perspective will be part of the achievement of a theory which replaces the current view. Such a theory will have accounted for the successes of Darwinism and, in addition, solved some problems which ours could not.

While this is the outcome which Johnson expects, he does not have an alternative ready. But it is not his job to produce one. He is not a biologist and his mission is to criticize the current theory and to expose its metaphysical preconceptions. Production of a replacement is the task of others. Furthermore, he is understandably reluctant to speculate in public. In The Wedge of Truth he briefly remarked on the relevance of the Gospel of St. John to science. He was then accused by one reviewer of attempting to deduce the Christian faith from scientific principles. This description reverses his purpose which was to respond to challengers who demanded that he demonstrate how religious belief can be at all relevant to scientific thinking.

The question of an alternative theory is properly directed to a scientist like Behe. I believe that he would admit that the intelligent design people have as yet not produced such a theory. However, he would say that his arguments justify a search for alternatives following the antiDarwinist line that design suggests.

Addressing critics of design, Behe can point to the strong analogy with the current origin-of-life research program in orthodox biology. Despite some claims to the contrary there exists no proposed description of the origin of life which in any way succeeds in spanning the vast gap from chemistry to biology. What exists are some suggestive experimental observations and some exciting speculations. All these are organized by an expectation of what a finished theory should look like. These expectations and guesses guide a research program and support the hope of its participants that the program will eventually succeed. In a similar way, Behe and Dembski would say that

their arguments justify a research program to develop an intelligent design description of the origin of species.

Such a proposal faces misguided resistance from some members of Johnson's own religious cohort. When evolutionists demand details of the operation of design, the correct response is: "We're working on it." However, one sometimes sees, instead, the claim that to investigate the mechanism by which a miracle occurs is to assume the very secular materialism which the miracle contravenes. This is simply wrong.

Of course, at the heart of a miraculous event there will be questions we cannot answer, but the same is true of every atheist theory as well. The triumphant Newtonian theory of gravity cannot answer the question of why gravity occurs. On the other hand, any particular miraculous event generates material questions. Suppose you abandon your debunking attitude and accept the miracle of the loaves and the fishes. You can still ask: where did the fish come from? Were they transported from the sea, floating in on the tide or suddenly appearing, or were they created at the moment of their appearance? If the latter, are they all different fish, or copies of the same fish, i.e. a clone? From the religious viewpoint such questions are a bit off point. They sound like a sneer because such questions are usually raised as a debunking device by skeptics, but they need not be such. They don't deny the wonder of the event. They just plumb for details.

In addition to their own religious obscurantists, the intelligent design folks confront scientists who, in their least imaginative mode, claim that because of its religious preconceptions no research following design is possible even in principle. The design people sometimes fall into the trap by responding that religion and science are indeed completely separable. This undercuts Johnson's useful point that the tenacity of the hold that Darwinism has is at least in part because of materialist preconceptions. That is, if you are an atheist then design is an utterly implausible explanation for purely natural phenomena. On the other hand, the design people are all religious (surprise!) and they are receptive to design because it fits well with the religious views they otherwise hold.

The attempt to separate religion and science this way leads into the swamp where dwells 'scientific creationism', an intellectual monstrosity, the fruit of a mating between the politics of education and the peculiar precedents of current church-state constitutional law in the U. S. It is the sort of thing you have to stand up and propose in a courtroom but you shouldn't attempt it with a straight face anywhere else. The claim that the creationist

theories are unrelated to the religious views of its proposers is an obvious falsehood which has rendered the position vulnerable in court as well.

The proper response to the accusation of religious inspiration is to dismiss the issue as irrelevant by deploying the classic distinction between context of discovery and context of justification. It doesn't matter if every task undertaken by Behe is the result of his close readings of Genesis. What counts is the scientific value of his results, not the beliefs which motivated him.

Let me illustrate the kind of thing an Intelligent Design researcher might examine.

Since extinctions are continuing now and since new species have appeared recently in geological time (e. g. humans) let us assume that new species are still originating now. On design principles what should we be looking for? How might a designer produce a new species?

The whole benefit of design as a process is to leap in a single organized jump across macroevolutionary gaps which appear unspannable by the step-by-step process of natural selection. One would conjecture that such a newly designed species could not be represented by a single member. Consider Shel Silverstein's poignant:

> This is Donald,
> A Long-Necked Preposterous,
> Looking around for a
> Female Long-Necked Preposterous.
> But there aren't any.

That is, if the new type is reproductively isolated from the parent species then several representatives must appear at once so that a population of mating pairs can exist.

One can imagine two ways that such a cohort of new organisms could be obtained. One possibility is that they just appear, created from energy or dust. The second possibility is the appearance in what would otherwise be ordinarily produced offspring, a collection of mutations occurring all at once and functionally related. Furthermore, the same pattern of mutations occurs in several offspring at about the same time.

The first process would appear as a spectacular form of spontaneous generation, i. e. the generation of life from non-living matter. The second, a directed mutation process, seems less fantastic to the modern secular mind, but as a suite of mutually supporting mutations occurring simultaneously

in more than one individual, it is still beyond the Darwinian pale. In fact, the second suggestion recalls ideas of Darwin's American contemporary Asa Gray. The deeply religious Gray communicated his ideas about what we would call directed mutation to Darwin who rejected the suggestion.

I don't offer the search for such phenomena as a serious research proposal. After all, I am a Darwinian and so I would sooner suggest hunting for unicorns than pursuing these fantasies. Also, while one would expect a developed design theory to have some picture of the origin of species, it might be that, while real, such moments of creation are as difficult to observe as we Darwinians have found the process of speciation by selection to be. (I will allow myself a bit of carping here: Our process is supposed to be very slow whereas theirs is supposed to be saltatory. One would expect such a discontinuous process to be more noticeable.)

The point of these examples is to show that the design program is not barren. It yields, for those who accept it, paths to pursue which no Darwinian would tread.

It is interesting to use this example to imagine again how science might work in practice. As a hypothetical (or even counterfactual) case, let us suppose that their search was successful and the design theorists turned up examples of such spontaneous generation or simultaneous adaptive mutations. At first, we Darwinians would refuse to believe it. Suppose the data remained incontrovertible despite our best debunking efforts. We would then seek an explanation of the data compatible with the Darwinian theory instead of the design view. Nonetheless, exactly because the design theorists had found evidence where no Darwinian would expect it, the results would be a spectacular confirmation of design and a corresponding setback for the Darwinian view. But it would not be a refutation of the latter. It would remain rational to hold on to the Darwinian theory in the light of its previous successes. But the stunning confirmation of design would shift the burden, not of proof, but of plausibility. The new results would magnify the weaknesses and diminish the strengths of the Darwinian theory. However, the outcome of the struggle between the two, now well-matched, contenders would depend upon the results of further exploration and analysis. As in the Hoyle story above, the result could be, but need not be, the replacement of Darwin's theory.

7 Politics

The debates on these subjects are often conducted with an attitude of grim acrimony. Not especially hidden by the intellectual disagreements are issues of politics and money.

The big political question concerns control of education. At issue in the evolution struggle is the content of high school biology courses. As a Darwinian, I am convinced that evolution is a core idea in modern biology and that its detailed presentation is an essential element in biological education. Honest biology teaching should be inspired by Dobzhansky's great quote: "Nothing in biology makes sense without evolution."

On the other hand, in the actual fights which have recently occurred, the teaching of evolution has been defended on what I regard as the wrong ground.

The popular strategy has been one of demarcation. We separate science, recognized by its reliance on empirical facts, experimental testing and falsification, from religion, recognized by its reliance on revelation, traditional authority and faith. I don't believe that this demarcation between science and nonscience really works. The erection of this tattered bit of fencing is nonetheless tempting because of the peculiarities of current interpretation of the constitutional boundaries between church and state.

The grain of truth behind the strategy is that teleology and design are plausible explanations for those who begin with a religious belief. They seem to be fantastic speculations for those who lack it. Furthermore, at least some of the creationists are clearly obtaining their descriptions of natural history right out of Genesis, as they would be happy to admit were it not that such an admission would disable their legal position. Thus, the division between science and religion appears clear and it allows us to prosper in court.

The whole structure is nonetheless vulnerable to a two stage argument which Phil Johnson has been developing. No surprise here since Johnson is a lawyer with an open interest in undoing what he regards as the current legal impasse.

First, he cruelly takes the demarcation criteria literally. A large scale theory like evolution by natural selection is not the outcome of an induction from a collection of directly observed facts. It isn't science in the positivist sense. Nor can one describe some crucial experiments which might refute the theory. So it isn't science in the falsificationist sense of the revised standard version of positivism due to the early Popper. However, these are the

descriptions of science which are used in the demarcation arguments.

So what, instead, is the theory of evolution? It is a structural theory which successfully organizes the currently known facts of biology and which fruitfully suggests directions for future research. Of course, it is comfortably compatible with the materialist preconceptions which form the unspoken metaphysics of the culture of modern science.

By nourishing our demarcation arguments on all this cheesy positivism, we trip the spring of Johnson's complex trap. It is a live trap and we are offered release in either of two ways, a choice which I think of as the Johnsonian Dilemma:

(1) If you want to retain the Dragnet, "Just the facts, ma'am" view of science in order to separate it from religion then you have to give up most of evolutionary theory. You can keep the observable, within species selection response to environmental change, e. g. finch beaks and antibiotic resistance. But the link with between species macroevolution is broken. Teleology and design are religious speculations for which there is no place in the science classroom, but all talk of contingency and the indifference of the natural world to our concerns goes out as well. Most of the popular writings of Gould, Dawkins, Mayr and Simpson have to be designated as personal speculation, as irrelevant to the substance of science as the musings of Payley. Adaptation is a brute fact the source of which science is completely ignorant.

(2) If you want to keep evolution then you have to admit that it is linked with a prior materialist metaphysics. The materialist sense of the universe plays the same presuppositional role here that religious faith does for the believer. It provides a sense of the underlying way things are organized and suggests preliminary judgments of plausibility for particular theories. Thus, it is not just analogous to, but is a form of religious faith. Recall the prison warder who, when Bertrand Russell described himself as "agnostic", replied: "Well, there are many religions but I suppose they all worship the same God." While Gould believes that evolutionary history illustrates that progress is an illusion which we impose upon the past, the alternative metaphysical framework provided by some religions suggests that progress is a fundamental reality.

It should be clear that I am somewhat sympathetic with Johnson's position. I think that the criteria which are used to distinguish science are always bound up with the current sense of what science is. Ultimately, science is a special part of the human project to describe the world in which we live and to understand our role in it. We look at what evidence we have and try to

make judgments about what is true. Criticisms of these judgments suggest refinements to, or alterations of, the theories which organize our thinking and which direct our searches for further evidence.

Everyone shares this picture. The disagreements concern the interpretation and plausibility of various sorts of evidence. Take the Young Earth Creationists for example. Their disagreement with standard science concerns the source of best evidence. Which is better evidence of the origin of the earth: (1) complicated and indirect human judgments about rocks using an elaborate scientific apparatus, or, (2) the description of Creation obtained from inerrant Scripture certified by the God who performed the act in the first place? Put that way, the question answers itself. Of course, the Genesis description contradicts vast chunks of science beyond evolutionary theory. Those of us who accept the standard scientific description do not accept the authority of the Bible as literal description. Even many committed Christians do not assume such descriptions are literal, not to mention inerrant, truth. For Biblical literalists the structure of standard science is a critical problem.

However, accepting as we all do that there is a single truth about these matters, they believe that eventually the truth will emerge and scientific theories will develop to correct the standard accounts and finally cohere with the Genesis description. In the process scientific study will reveal the ways in which current views have comprehensively misinterpreted reality. I have every confidence that such a theory will not appear, or, if dreamed up, it will prove totally inadequate. But make no mistake; the purpose of science is the true description of reality. If the fundamentalists happen to be right then they are closer than we are. We dismiss the Biblical literalists' view of geology for the same reason that we dismiss the - completely nonreligious - phlogiston theory of heat. Not that it is nonscience but that it is wrong. Religion only seems relevant as our psychological theory of why someone might be moved to champion a theory we regard as so obviously inadequate. It is not relevant to theories, though it is relevant to the background assumptions used to weigh the evidence, e. g. how much authority should be granted to the Genesis account.

In passing, I can't resist noting that there are various academic descriptions of why people believe in God. The sociological account points out the historic power of the priesthood as one of the loci of power in the politics of society, e. g. religion as Marx's "opium of the people". The psychological account points out the role of God in individual development, e. g. for Freud

He is the internalization of the father. The one account which tends to be missing among all these is what might be called the appeal of brute fact, i. e. God actually exists and so people believe in Him for the same sorts of reasons that they believe in Mount Everest. (To dot the i here: I pick this example assuming that most of my readers have not, in fact, been to Mount Everest and so they believe in it because they regard others' accounts of it as unproblematic.)

Having given up the demarcation argument, how do I propose to argue that evolution should be central to the teaching of biology? It should be taught that way because it is that way. The theory of evolution and its position in biology are part of a strongly held, widely accepted consensus in the biological community. It is part of what biology is right now. As a fellow traveler with this consensus, I accept that the theory is true. That is, it describes the way the world is. However, its truth is what all this argument is about. What is not controversial is that most biologists believe it. What I am doing is appealing to the authority of the biological profession.

In philosophical terms, I am a nominalist rather than a realist about the nature of biology as a science. I do not believe that the science of biology is separable as a matter of reality by virtue of its special objects, materials, methods, etc. Instead, I regard biology at this time as the practice of a professionally, internationally organized group of people who interact through personal communications, organized meetings and specialized journals. Together the biologists of this community define their subject. It includes various consensus views. The so-called 'fact of evolution', i. e. common descent, is almost entirely accepted and the 'mechanism of evolution', i. e. natural selection, is largely noncontroversial. Biology so defined does have its special objects, methods, etc. but these are part of the current practice in that they change with it rather than providing preexisting criteria by which the subject can be defined. For example, two hundred years ago the analysis of God's intent as expressed in the natural world was an accepted part of the natural philosophy which was the biology discourse of the period. Now such a topic is dismissed as an extra-scientific irrelevancy.

In short, I take current biology to be what current biologists say it is and so I appeal to them to determine how biology should be taught.

This may seem a bit unfair, even anti-intellectual. After all, it means that the profession of biology not only presents theories, like evolution by natural selection, but also provides the criteria by which the theories are to be judged. So against the dissident amateurs the biology professionals not

only get to field a team with all kinds of advantages of prestige and position, but they get to keep score and referee the match, not to mention writing the rule-book.

Instead of claiming that this picture is inaccurate, I propose to defend the sort of scientific hegemony it portrays, but before doing so, I do want to point to one respect in which the picture is misleading. This Darwinists' United Front view makes biology, or any other scientific discipline, appear more monolithic than it is. It misleads by ignoring the essential role which competition plays in the structure of science. The way to get ahead in science is to criticize currently accepted ideas. The bigger the target of an attack, the larger are the rewards for success. Of course, the consensus imposes structure on the competition and so provides boundaries within which most disputes occur. This is essentially Kuhn's picture of normal science. Occasionally, a central, structural theory falls and is replaced by an alternative. The resulting large-scale reorganization of the subject is what Kuhn calls a revolution. Such replacements are quite rare, but they do occur.

I must admit that under ordinary circumstances core theories are maintained without controversy and dissents are shrugged off rather than refuted. The term used to describe such a dissenter is 'crank'. The Intelligent Design views of Dembski and Johnson, the evolution from space of Hoyle and Wickramasinghe as well as the young earth creationism of Whitcomb and Morris' *The Genesis Flood*, these are all crank views. I don't mean that any of them are stupid or irrational, but that they all attack foundational beliefs upon which current biology stands firmly with no real sense of uncertainty. Even a professional like Behe can't get much of a hearing for his criticisms.

Unkind though it may seem, I defend this dogmatic scientific approach. Perhaps if I had any unconventional scientific views I would exhibit more sympathy. While the possibility of overthrowing core beliefs keeps a scientific tradition from stagnating, the largely automatic maintenance of these foundational theories provides a stability which allows the building of elaborate structures upon the foundations. Furthermore, portions of such erected structures often survive, in revised form, revolutionary replacements of the core.

On the other hand, cranks are sometimes right. Wegener's theory of continental drift, initially regarded as a crank position, is now an accepted part of the theory of plate tectonics. Of course, successful cranks are very much the exception. As Damon Runyon remarked in reference to the observations in Ecclesiastes: "The race may not always go to the swift nor the battle to

the strong, but that's the way to bet." But because long shots do occasionally pay off, censorship of crank views is never appropriate. In academic locations the audience for Johnson's speeches frequently contain some evolutionists who respond with blithering, Blimpish outrage to the mere fact that he has been invited to appear and air his outrageous views. Johnson is amused by such blorts while I find them painful. All the standard John Stuart Mill free speech arguments apply here: the advantage of refreshing our thinking by responding to criticism, the possibility that the dissenters might be right, etc. In addition, the absence of reasoned response makes his, admittedly thought-provoking, arguments appear utterly compelling. Such attempts at censorship are morally wrong and intellectually cowardly. In addition, they are public relations disasters.

As I mentioned earlier, I regard it as perfectly reasonable to dismiss the dissenters' claims and shrug off their arguments. Finite and mortal, we must ration our time and attention. What is unreasonable and improper is the attempt to suppress dissent in order to save others from corruption by heresy or save ourselves from the taint of association.

In fact, Mill's arguments suggest that we all benefit when heresies are supported rather than suppressed. Accepting these arguments leads to an odd practical problem mentioned by Freeman Dyson. Even crank science costs money and money is limited. It would be nice to put aside a bit to support interesting lunacies, but such a proposal is unfeasible.

As a specific example, suppose that a student of Behe submits a grant proposal to the NSF to look for the sort of suite of simultaneous mutations that I proposed in Section 6 as a design event. If such a proposal were submitted to me for review I would have to reject it. No matter how well thought out, the proposed quest appears to me to be futile. I would similarly reject a proposal to study the biology of unicorns. In each case I am called upon to exercise my, admittedly fallible, judgment which informs me that these grants propose the investigation of nonexistent phenomena. My duty as a reviewer is to save the money for more plausible ideas. The purpose of peer review is exactly to obtain this sort of professional judgment.

Happily, in America at least, there has evolved a solution to the problem of the nurturing of cranks. It is the Looney Millionaire Solution. There is no idea so bizarre but there is some rich American who will back it with enthusiasm and who has, in fact, established a foundation for that very purpose. Echoing Martha Stewart, I say of the proliferation of such eccentric little foundations: "It's a Good Thing."

Passively at least, some support for dissent is provided by the institution of university tenure. That hypothetical student of Behe would be well advised to leave his proposal in a drawer and engage in more conventional research at the early stages of his career. Once protected by tenure he will have much greater freedom to pursue what his colleagues will regard as a ridiculous endeavor. Of course, he will be accused of subverting the university where he works. Alas, poor Harvard, a formerly significant institution reduced to a worldwide laughing stock because Mack, a tenured psychologist there, believes in alien abductions. Alas too, for Baylor, its science department irrecoverably tainted by association with the nest of intelligent designers at the Polyani Institute. (I wrote this last before the scientific Pharisees at Baylor accomplished their expulsion of Dembski.)

These narcissistic worries about reputation can have poisonous effects. The heir presumptive to the Amateur Scientist column at Scientific American was rejected for scientific deviationism because of such concerns. He had written frequent guest columns during the transition period preceding the retirement of the column's long time resident. It was discovered that the putative successor was a creationist, but he promised to keep such heresies out of his column. No self-censorship was really required as the Darwinian theory is irrelevant to the sorts of things which turn up on the Amateur Scientist page. He was nonetheless rejected for fear that his creationism, when he spoke of it elsewhere, would obtain extra cachet if he were identified as a columnist at Scientific American.

I believe that we defenders of the conventional should demonstrate a bit more faith in our orthodoxy. An attitude of condescending superiority may be appropriate, if unattractive, but one of anxious outrage is not. In our view creationists are wasting their lives, pursuing the ghosts of abandoned myths, but they provide us with valuable challenges to our settled ideas. If some uneducated readers are seduced by their arguments, then our modes of education are thus revealed to be inadequate and we should seek to improve them. Above all, it is our belief in the self-correcting quality of science, as it is currently practiced, which gives us our confidence that scientific truth will eventually triumph over the mistakes, frauds and corruptions which occur within it. A fortiori we should be tolerant of the lesser challenges by agitations from without.

About high school biology I propose a compromise modeled on Gerald Graff's "Teaching the Conflicts", his response to analogous agitations in the humanities.

The first and fundamental principle is that the biology which should be taught is the biology of biologists. Although it is unpopular these days to say so, most of early education consists of transmission of stories, ideas and techniques from people whose knowledge gives them the authority to teach what they know: "I know it. You don't. So, I'll tell you about it." Evolution by means of natural selection is the backbone of modern biology. Some textbook publishers used to attempt to avoid controversy by omitting mention of evolution. This filleted version of the subject should not be acceptable to anyone. The primary judgments concerning the biology curriculum should be made by the biology profession.

In this country the control of public education is separated from this professional authority and lies instead with various state and local political bodies representing the citizens in general and the parents of students in particular. As I redundantly recommended above, the power over the biology curriculum has largely been delegated to the biology profession, at least since effective science education became a matter of public concern in the 'fifties (thank you, Krushchev). Biology textbooks became less timid and they describe evolution in a confident, perhaps even dogmatic, way. Recurrent challenges by fundamentalists have been dismissed as reruns of Inherit the Wind and have been fended off with the help of now sympathetic courts.

However, such delegated power is always subject to recall when political controversy arises. When experts have disagreed about methods or content in the teaching of reading or mathematics, the lay political bodies have had to make their own decisions, subject to the best advice they can get. Outcries against current school policies are always occurring. A government body responds when the challenge has enough political force. Organized loosely behind the strategy that Johnson labels the Wedge, the Intelligent Design crew is beginning to pull together an effective public profile. This explains the impolitic rage with which the some evolutionists have greeted public appearances of Johnson, Behe et al. The success of the dissidents on such occasions has redoubled their enthusiasm. Phil Johnson's wide smile is that of an underdog who feels he has gotten in some effective and well-deserved bites.

I think that the way to deal with this controversy is to bring it into the classroom. In those constituencies where this dispute has become a real issue, a significant number of people have heard these questions raised and think they deserve an answer. So address them. Without giving up the text's commitment to evolution (I am using the textbook as a proxy for the

biology profession) it would be worthwhile spending some time describing the criticisms which have been raised to Darwin's theory and the responses which biologists make to them. Furthermore, some teachers share these qualms and I think it is wrong to censor them. I would be prepared to stand up and recite the Evolutionists' Creed (if there were one) but I don't demand that my students make any such profession of faith. I insist only that students (1) know in detail what Darwin's theory says and (2) know that the vast majority of biologists believe the theory for they regard as good and sufficient reasons. That's plenty these days.

Suppose a group of astrologers distributed pamphlets criticizing current astronomy and raising objections against some standard astronomical arguments. If in some community these arguments appeared convincing to a fair number of people, I would spend some time on them as well. The issue is one of responding to arguments and addressing criticisms which the students are likely to run into as evidenced by the local popularity of the astrologers' claims.

While I believe this approach would be politically effective, I intend it as a matter of intellectual honesty rather than political judo. I am assuming in each case that there are arguments being raised which are worth an answer. If some people simply disapprove of and disbelieve Darwin's claim that we are related by common descent to other animals, then no answer is possible or required. I am completely intolerant of the demand to be protected against exposure to opinions whose content offends. There is an intellectual threshold which must be reached before a grumble becomes an argument worthy of rational response.

I regard it as obvious that the neoPayleyians have more than met such a minimum requirement. Some who deny it have used some pretty peculiar arguments themselves. A reviewer of Jonathan Wells' *Icons of Evolution* attributed Wells' writing of the book to a desire to please the Reverend Sun Yun Moon. It should be clear that it is irrelevant to the content of the book's arguments what Wells' intention was: whether it was to please Rev. Moon, to make money, to become a big deal on the lecture circuit or even to publicize what he regards as some important, unnoticed truths.

In my own, unprofessional, opinion all of the issues which Wells raises are interesting. While I believe that adequate responses can be given to his critical arguments about evolution, I think he demonstrates that, as a matter of educational history, students have been provided with oversimplified and in some cases deliberately misleading descriptions whose purpose has been

to make the criticisms of evolution appear weaker than they in fact are.

In short, I do not think these arguments are simply ignorant misunderstandings, worthy only of dismissal as expressions of religious prejudice. They are thoughtful criticisms of the current theory which deserve detailed answers, if for no other reason than that they provide a competing picture which seems quite plausible to the general public. We should be grateful for the educational opportunity which the carefully marshaled arguments of Johnson, Dembski, Behe and Wells provide. I would be happy to see textbook supplements which respond with detailed confrontation rather than dismissive condescension. If indeed these attacks are largely reworkings of the critical responses to Darwin's original work, then we have an opportunity to refresh our acquaintance with the replies which Darwin, Hooker and Huxley gave when these controversies were young.

Let us engage these arguments with an intellectual honesty which we may assume our opponents share. We have some common interest here. None of us knows for certain what's true and all of us want to find out.