EDITORIAL

THE DISADVANTAGE OF COLLECTIVE IGNORANCE

World War II was a monstrous event. The most dominant figure was Adolf Hitler, who by persuasion and military power gained control of much of Western Europe. In persuading friend and foe of his worthy motives, Hitler had a powerful ally in his friend Dr. Joseph Goebbels, who became his Minister for Propaganda and Public Enlightenment.

Goebbels had a lavish lifestyle, including fancy homes which he could ill afford. However, one of his representatives explained to newsmen that the Minister was really an extremely modest man who put up with the inconveniences of such an opulent life because of the needs of his official position. Using his persuasive talents, Goebbels was effective in convincing France, England, and the United States that, regardless of appearances, Hitler's actual goal was to control Bolshevik expansion from the east. Goebbels' craftiness is reflected in one of his often-quoted statements: "We can do without butter, but, despite all our love of peace, not without arms. One cannot shoot with butter but with guns." His approach to conquering a country was to first establish a friendly neighborly relationship with the country. After this relationship was firmly established, a program of criticizing the policies and leaders of the country was begun. This was followed by threats of violence and of the need for the people to get rid of their leaders and to capitulate to his demands. The last stage was to allow deliberate confusion to grow, followed by invasion and taking control of the nation's radio stations.

Eventually, after many conquests, the tide of World War II started changing, and conditions went from bad to worse for Hitler. Many of his associates, perceiving unquestionable defeat, deserted him. Finally Hitler and his wife, whom he had just married the day before, along with Goebbels, his wife and their six children, all took their lives in an underground bunker in Berlin as the Russians were overtaking the city. Despite this tragic ending, the success of Hitler and Goebbels, which had lasted for a number of years, remains as one of the puzzling events of human history. How could

the stratagems that led to plunder and mass murder be justified and engender the loyally that they did? A significant factor in that success was Goebbels' crafty promotional endeavors which took advantage of the pervasive ignorance of humanity.

On a less dramatic scale, but more insidious in its effects, a similar problem exists when experts on a given subject are instructing laypersons. Typical settings would be the public lecture hall, the classroom, the convention hall, or the church. There the lecturers or teachers are at an advantage over their audience, because they are much better prepared and know, or should know, much more than anyone else in the audience about the topic under discussion. Often the listeners have the same philosophical "flavor" as the speakers, because they have come to hear about a subject they are already interested in, or they want to have their worldview affirmed. In the classroom the instruction can reflect a particular political, nationalistic, or religious viewpoint. The type of books and journal articles emphasized can stimulate a particular bias that the innocent reader does not recognize. With the specialist-laymen arrangement, the eagerness of the laymen to learn and the enthusiasm of the specialist to promote a particular view can generate a not-so-healthy synergistic enthusiasm in which the expert takes advantage of the ignorance of the listener. In life we are too often at the mercy of the experts whose credentials may be impressive, but whose integrity, wisdom, and knowledge remain unevaluated by the listener.

A very heavy responsibility rests on the experts. They need to be especially careful not to misguide their more ignorant listeners. While all of us frequently exercise our right to believe or not believe the experts, our discernment may lose objectivity as we are exposed to continuous repetition of the same authoritative statement, or as public opinion wields its subtle influence on us.

The problem of ignorance can be particularly severe in the important task of trying to establish a correct basic philosophy or worldview. Concepts of our origin can dramatically affect our ideas of the meaning of reality. Whether we believe that we were created in the image of God, or that we evolved from simpler forms, can dramatically affect our value system, and those important questions about purpose, duty, and destiny. Likewise, the various views

intermediate between creation and evolution, such as theistic evolution or progressive creation, can imply a very different kind of God and ensuing worldviews.

Our worldview, or as some prefer to call it, our personal basic philosophy or religion, usually extends beyond simple facts as we address the more complex questions such as the meaning of existence and the ensuing implications about life beyond the grave. These deeper, complex and extremely important questions are easily influenced by the pronouncements of experts, and because of this they especially need to be sheltered from the pitfalls of collective ignorance. The fact that worldviews are complex and not as easily evaluated as simple facts makes them particularly susceptible to the innocence of collective ignorance. In this area we can easily be deceived.

It turns out that our collective ignorance has the collective disadvantage of mass delusion; whether it be the influence of Goebbels, the specialist of Madison Avenue, or a host of what we respectfully call experts. The solution is to be constantly on our guard lest advantage be taken of our ignorance, of which we all have an abundant supply.

Be independent.

Ariel A. Roth

ARTICLES

THE PARADIGM OF NATURALISM, COMPARED WITH A VIABLE ALTERNATIVE:
A SCIENTIFIC PHILOSOPHY FOR THE STUDY OF ORIGINS

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WHAT THIS ARTICLE IS ABOUT

As Thomas Kuhn (1970) pointed out, when a new paradigm is suggested there will at first be only a few persons who think that it is worthwhile. The paradigm's chance of success depends on the few individuals who demonstrate that they can do effective research under it. I propose that there are many similarities between Kuhn's general concept of scientific revolutions and specific application to the discussion of naturalism (science that will accept only hypotheses which do not imply a Designer) and interventionism (a paradigm that recognizes God's activity in history). The naturalistic paradigm has successfully guided science for a long time. Another paradigm based on informed intervention and catastrophist geology is now being applied as a guide in selected cases of field and laboratory research. There is evidence that in these cases the newer paradigm is successful. Consequently, it is beginning to be developed as a competing paradigm.

This article proposes that with careful analysis of the issues, we can show that interventionism is a valid approach to scientific investigation. There is a constructive way to relate science and faith so that each benefits the other, without inappropriate interference between them. When this method is used, it contributes to an improved understanding of earth and biological history.

For nearly nineteen hundred years most of the Christian world without question accepted the creation account in the book of Genesis as literal history. Charles Darwin and his supporters broke down this broad acceptance in only a few decades. Today the creation story may be credited with having some spiritual value, but to many people macro-

evolution is the only valid account for the origin of living things. Why did Darwin's theory have such an impact? Has it made the Christian's belief in a Master-Designer untenable? Or have some factors been overlooked? The following pages outline an approach to these and similar questions that affirms the integrity of the scientific process while maintaining a context of faith.

To understand the impact of Darwin's theory of evolution, we must first recognize that it has been very successful in doing what a good scientific theory does. Some years ago an article was published entitled "Nothing in biology makes sense except in the light of evolution" (Dobzhansky 1973). That article illustrates the scientific community's confidence in the evolution theory and the extent to which this theory has been successful in organizing and explaining a broad range of biological data. An effective scientific theory will have the following characteristics:

1. Organizes and explains previously isolated facts
2. Suggests new experiments to be done; stimulating scientific progress
3. Is testable — can potentially be disproved if it is not correct
4. Is based on repeatable experiments
5. Predicts the outcome of untried experiments, thus increasing confidence in the accuracy of the theory.

Chipmunks provide an example of the success of the evolution theory in the study of microevolution and speciation. Only one species of chipmunk, *Tamias striatus,* lives in the eastern half of the United States, but the western states have 21 species of chipmunks (Figure 1). Why are there so many species in the west but only one in the east? The evolution theory provides an answer. The west has a great variety of habitats suitable for chipmunks: dense brush, semidesert Pinyon Pine forests, Yellow Pine forests, high altitude Lodgepole Pine forests, etc. Many natural barriers of unsuitable habitat such as deserts or grassy plains separated small populations of chipmunks in isolated geographic pockets. As each isolated population became adapted to its habitat, some populations became different species through the action of natural selection. However, in the eastern United States the original forest environment was relatively uniform in relation to the needs of chipmunks, and there were few natural barriers adequate to isolate small populations of chipmunks, and thus to produce new species.

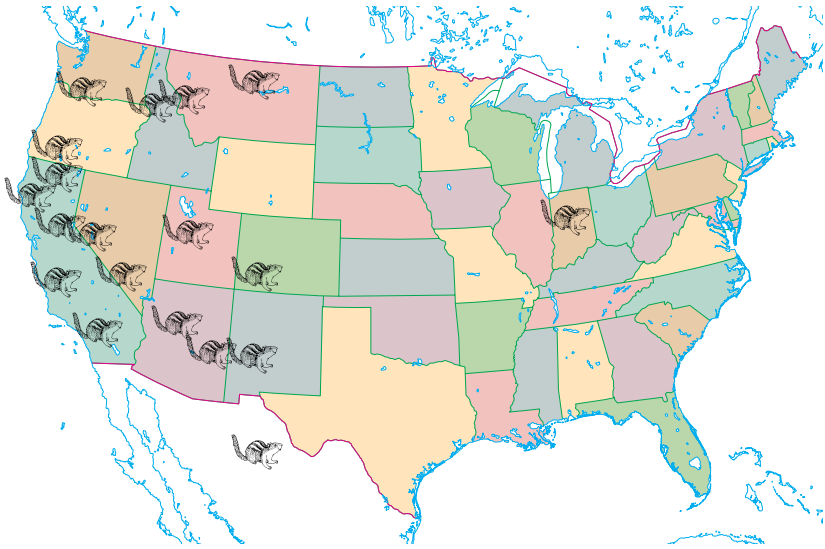

Figure 1. Diagrammatic illustration of the distribution of chipmunk species in the United States. Each symbol is in the center of the range of one species.

Microevolution not only provides explanations for the origin of new species and adaptations to new environments; it also has been highly effective in suggesting experiments to test these explanations. In many cases the theory successfully predicts the outcome of the experiments, often enough to give scientists great confidence in the theory of evolution. These are fundamental reasons why the theory is so widely accepted by the scientific community.

The history of science shows that even very successful theories sometimes need improvement or replacement, so it is always appropriate to continue examining the foundations of evolution theory, asking hard questions. Are all parts of the theory equally well supported? Have we overlooked or underestimated some important lines of evidence? Are there aspects of our logic that need to be improved? This critical analysis could benefit both science and religion if it is appropriately conducted. We must be honest with the data and with the uncertainties in the data, and careful to distinguish between data and interpretation. We must approach the task with humility and open-mindedness, and treat each other with respect, even if we disagree on fundamental issues.

In discussing these issues I will often use the term interventionism, rather than creationism, because it is a broader term — it includes the

possibility of divine intervention in geological history as well as in the creation. The paradigm of interventionism as presented here also proposes alternative interpretations in such things as rates of change in living organisms and in geological processes.

The general theory of evolution is based on the philosophy of naturalism (everything can be explained without reference to God), with its unwillingness to consider any hypotheses that involve divine intervention in the history of the universe. Is it possible that an alternative philosophy which accepts the possibility of divine intervention (interventionism) could also be successful in guiding scientific research?

Many diverse areas of science today build on the common underlying paradigm of naturalism (or materialism). People in medieval times were quite mystical in their thinking, and commonly appealed to the supernatural to explain things they did not understand. As understanding of nature improved, many of these mysterious phenomena became understood. This led scholars to shift toward the philosophical position of naturalism, which attempts to explain everything in nature through known natural laws. That is where science is today; it will only accept hypotheses that do not imply any divine action in earth history (Johnson 1991). This philosophy is a key element for understanding the relationship between informed intervention and science. In a discussion on the issue of teaching creation in the public schools, I heard a prominent scientist state that "even if creation was right I would have to deny it to be a scientist." To understand why a reputable scientist would make such a statement, it is necessary to understand the role of naturalism in science. Naturalism has become part of the definition of science:

> *If there is one rule, one criterion that makes an idea scientific, it is that it* must *invoke naturalistic explanations for phenomena, and those explanations must be testable solely by the criteria of our five senses* (Eldredge 1982, emphasis in original).

Science cannot do experiments to test the supernatural. This concept is clear enough and is accepted by interventionists, but science has gone a step further and decided that it will accept only theories which do not imply or require any supernatural activity at any time in history.

What basis is there for this concept? When we observe the world around us we see that predictable natural law is in effect. Modern science has convinced most of us that normally God does not cause unexpected events to occur in the universe. The data are consistent

with the proposal that He has established a set of laws, and the universe operates according to these laws. Consequently a scientist, including one who believes in God as Creator, can function on a day-to-day basis without referring to supernatural activity; and science has achieved much success by following this approach. However, some scientists acknowledge that God could have acted in history in ways which we would call miracles, such as creating the first living organisms. Science cannot test the concept of an informed intervention in history, but it should not reject a theory just because it implies an event that is outside our testable hypotheses.

From the naturalistic point of view, the idea that one who believes in informed intervention (an interventionist) can also be a scientist seems to be a contradiction. How can informed intervention, which by definition involves supernatural phenomena, be scientific, since science by definition excludes God's intervention? Can this seeming contradiction be resolved? We have discussed the characteristics of a good theory, and we have seen that evolution theory has these characteristics. Can there be any type of informed intervention theory that also has the same characteristics? I believe the answer is yes.

It is often implied that because interventionism originates from religion, it is for that reason unscientific. Does the source of a theory affect its validity? No! A theory is not scientific or unscientific because of its origin; it is scientifically useful if it can be tested. If it cannot be tested, it is outside the realm of science (even though it may be true).

TESTABLE AND UNTESTABLE HYPOTHESES

Some readers may conclude that the above explanation eliminates interventionism from the realm of science, since the hypothesis of informed intervention cannot be tested. Perhaps it is not that simple, since there are testable aspects and untestable features of both interventionism and naturalistic evolution. Scientists would generally agree that the hypothesis "God created life" (Table 1) cannot be tested by science. We cannot define an experiment or set of observations which would potentially falsify that hypothesis. This leaves us with the alternative hypothesis, "life was not created by God," which is more likely to be accepted as valid science.

In the light of our definition of a useful scientific theory as one that can be tested, can an experiment or set of observations be formulated

Table 1. Testable and non-testable hypotheses. Evidence supporting the testable hypothesis does not demonstrate the truth of the corresponding nontestable hypothesis, but does allow it to remain as a feasible possibility.

Nontestable Hypotheses	Testable Hypotheses
• God created life.	• All living and fossil organisms fall into discrete groups, without series of evolutionary intermediates between major groups.
• God did not create life.	• Series of intermediate forms between major groups of organisms have existed in the past.
• Vertebrates originated by evolution from the echinoderms. • Echinoderms and vertebrates were both created by God.	• The simplest vertebrate animals have more similarities to some echinoderms than to any other group of invertebrates.
• God caused a global geological catastrophe.	• Most individual rock formations formed quite rapidly and catastrophically.
• God did not cause a global geological catastrophe.	• Most individual rock formations formed slowly, over long ages of time. • The Coconino Sandstone was deposited underwater. • The Coconino Sandstone was deposited in a desert

which would potentially falsify the hypothesis "life was not created by God"? Be careful with your logic as you try to devise a test. A test, for example, which describes how a creator would design organisms, and then shows that organisms are not designed that way, is not valid. How would we know how a creator would or would not design life? The test must be more objective and independent of our opinions.

The concepts "God created life" and "God did not create life" are equally untestable. Science should either: 1) devise a valid experimental test for one or both of these hypotheses, or 2) not try to say that one is scientific and the other is not.

Even though both theistic and naturalistic paradigms include concepts that cannot be tested by science, it is possible to define hypotheses which are descriptions of results that should be discoverable in nature, if one of these nontestable hypotheses were true. The first requirement for making testable hypotheses is to leave out any consideration of whether a divine being or Designer was or was not involved. What is left are questions about objective things that may be found in the rocks or in living organisms. For example, if at least the basic groups of life forms were created, series of evolutionary intermediates between these groups are unlikely to be found, but if these groups were all the result of evolution it seems that a reasonable number of intermediate series would be found. If you are familiar with the evidence regarding this issue you already know that there is good news and bad news for both of these hypotheses. Someone who is looking for an easy falsification of either of the two basic hypotheses will be disappointed. The evidence is complex and our understanding of it is very incomplete; but in principle, science should be able ultimately to test between these two descriptive hypotheses.

I propose that scientifically useful (testable) theories like some of those listed in Table 1 can originate from religious concepts. We cannot directly test whether God involved Himself in earth history, but if He did involve Himself in ways described in the Bible (creation and world-wide geological catastrophe), these events should have left some evidence in the natural world. For example the evidence would include only limited evidence for evolutionary intermediates, but pervasive evidence for catastrophic geologic action. Moreover, the possible existence of such evidence can be investigated scientifically.

THE SUPERNATURAL AND THE LAWS OF NATURE

There is an important difference between saying: (a) "perhaps miracles have happened, but science cannot tell us if they have or not"; and saying: (b) "science denies that any miracles have ever happened, and will not accept any hypotheses that imply that miracles have happened." Consider for example the hypothesis "many phyla of organisms appeared on Earth suddenly, independent of each other." The response "this may have happened but science can't test this hypothesis" is quite different from "science can't consider this hypothesis because it implies a miraculous origin of life forms." In practice, science

generally takes the second position, and will not allow for miracles even when they appear to be required by the nature of the evidence. This helps to explain the comment by the prominent scientist quoted on p 9 who stated that even if creation were correct, to be a scientist he would have to deny it. Evidently he sincerely believes that it is necessary to accept the naturalistic definition of science in order to be a good scientist. Is that the way it should be, or has the pendulum swung too far, and gone from one extreme (medieval pervasive supernaturalism) to another extreme (strict naturalism)? I respect the right of others to believe that it is necessary to accept this type of naturalism to be a scientist, but I will try to persuade you that strict naturalism is not the only paradigm that can lead to effective science.

Are miracles really capricious magic, or is there another way to understand the supernatural? Imagine that God wrote down on microfiche all laws that govern the universe. In the year 1500 AD, for example, scientists knew a small percentage of these laws (Figure 2). Time moved on and we learned more of them, until by the late 1990s we knew a larger proportion of the laws, but there are still many that we have not

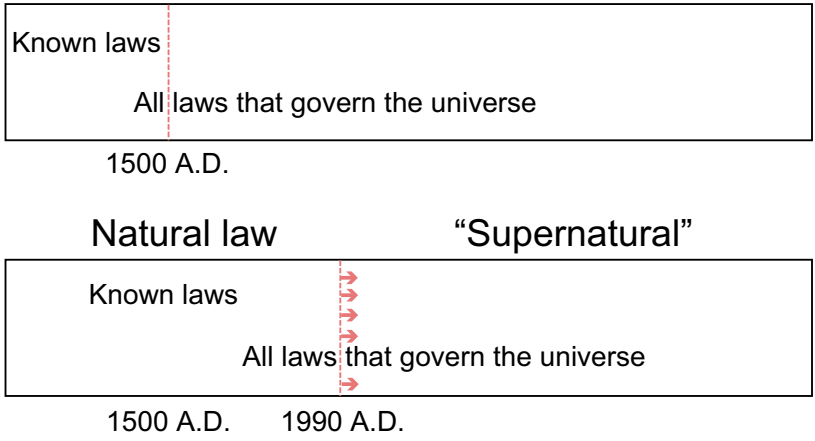

Figure 2. Relationship between natural law and phenomena that we refer to as supernatural. The rectangle represents all of the physical laws that govern the universe, divided into those laws that are known and those that are unknown to humans at a given time. Those that we understand, we call natural laws. See text for further explanation.

discovered. Imagine that someone had invented a time machine that would allow us to interject a 16th century person into the 20th century. We take him into a supermarket, and the door opens by itself as we approach. We get into a car and turn a switch and the strange carriage roars and moves down the road. We then go home and flip a little lever on the wall and the lights come on. About that time the fellow might flee in terror at these "supernatural" manifestations. Why would he think of it that way? The simple difference between his thinking and ours is that he is not familiar with the laws governing the operation of cars, electricity, etc., or with the sources of energy that make our gadgets work. He thinks of these as supernatural, but in reality he just does not understand them.

Another aspect of this same issue can be explained with an example. If I hold a book in the air and drop it, the law of gravity specifies that it will fall to the floor. We can drop it a million times and the same action always occurs. However, since I am a mobile, reasoning being, I can decide to stick out my hand under the falling book, so that it does not fall to the floor. I have interjected an outside force into the system and changed the course of events, but I have not broken any laws. God could decide to interject an outside force into Earth's balanced geologic systems and change the course of events to bring on a catastrophe, without breaking any laws of the universe.

The portion of the laws of the universe that we understand we call natural law. The things that God can do that we do not understand, we call supernatural. To us they are indeed supernatural, since we do not understand them, and/or because we have no access to the source of power that God uses. To God all the laws of the universe are a unified whole. They do not limit Him, because He designed them to control the operation of the entire universe according to His plan. If this is true, someday He could explain to us how some of the laws that are currently beyond our understanding were involved in the performance of what we call miracles, such as instantly creating life or turning water to wine. Then we may say "now I see how You did it." We will still not have the power to do many things that God can do, but we will see that they are not magic or capricious acts, but are part of the law-bound whole that God understands and uses to accomplish His purposes. God may make use of certain processes described in those laws only during the process of creation, and not use them at other times. This concept implies that He understands it all, but we do not; He can make use of all possibilities,

while we will never have the power to utilize some of them, even if we do eventually understand them. That is the difference between natural law and what we call supernatural.

This concept is fundamentally different from the "god of the gaps" that gave way in the face of modern science. The old "god of the gaps" existed because of the tendency to explain things that we couldn't understand (the "gaps" in our explanations) as resulting from the direct operation of God's power. When science searched out the answer to one of those gaps, God was not needed to solve that problem anymore, and consequently the more we learned, the less we needed God, or so it seemed. When William Harvey learned that the heart was a pump (a "machine" whose operation could be understood), and that the blood was not moved by the direct intervention of God, his new insight was not appreciated by some individuals, because it seemed to push God a little farther away.

In reality the logic in the "god of the gaps" concept was naive and implied that if we can understand how something works, God does not have any part in it. A further implication is that if God is involved in some process, that process does not function through nature's laws. That is no more defensible than to claim that since we understand how a computer works, there must not have been any intelligent beings involved in its origin. In contrast, I submit that God works according to the laws that He has established; that when we learn how the heart works we have not diminished God, we have just learned more about His laws and His magnificent inventions. Also, there is much about the universe and its laws that we do not know. It is unreasonable to assert that God cannot work outside the natural laws *that are known to us*, because the laws that we know are only a small part of the laws of the universe.

If this concept is sound, there is nothing unscientific about admitting the possibility of miracles. All it really requires is that we be willing to admit that there could be a Being in the universe powerful enough and knowledgeable enough to know and use all the laws that govern the universe. Even if we accept this, we understand that historical accounts of miracles are something that science cannot test, but it would not be unscientific to consider that such things could have happened. In some areas of science our research has progressed to the extent that the more we know, the more the data seem to imply that there was a Designer (Behe 1996).

BIASES FROM VARIOUS SOURCES

Could a person's religious perspective bias his or her interpretation of scientific data? It certainly can, and I could list a number of cases in which it is clear to me that this has happened. However, if we are not going to be superficial in our analysis of this problem we also have to ask another question: can a naturalistic philosophy bias a scientist's interpretation of data? I believe it certainly can. Our research will only answer questions that we are willing to ask, and naturalism allows only certain questions to be asked. Consider the difference between the following two questions:

Question 1: Which hypothesis is correct?

a. Naturalistic hypothesis A (gradualistic evolution)

b. Naturalistic hypothesis B (evolution by punctuated equilibria)

Question 2: Which hypothesis is correct?

a. Naturalistic hypothesis A (gradualistic evolution)

b. Naturalistic hypothesis B (evolution by punctuated equilibria)

c. Major life forms did not arise by a naturalistic process (the implication of this answer — creation by an intelligent Designer — cannot be part of the testable hypothesis, just as the concept of naturalism cannot be a testable part of an evolutionary hypothesis)

Naturalism only allows question number one, and thus answer 2C is ruled out of scientific consideration by strictly *a priori* considerations. Naturalism has a powerful biasing influence in science, in steering scientific thinking and deciding, in many cases, what conclusions will be reached. This is not generally understood in scientific circles.

When the discipline of geology was taking form in the 18th and 19th centuries the geologists James Hutton (1795) and Charles Lyell (1830-1833) each wrote books in which they developed a paradigm of geology that rejected the catastrophism of their day, and replaced it with uniformitarian (always slow, gradual) processes over eons of time. Lyell's book was the more influential one for over a century, and constricted geology to a strictly gradualistic uniformitarian paradigm. Historical analysis of Lyell's work has produced the conclusion that the catastrophists in Lyell's day were the more unbiased scientists. Lyell took a culturally derived theory and imposed it upon the data (Gould 1984). Gould and others are not saying this because they agree with the biblical views of Lyell's

colleagues; but it is apparent that those colleagues were more careful observers than Lyell, and they did not let their religious views twist their interpretation of data.

Various authors have stated that Lyell's strictly gradualistic version of uniformitarianism is not needed, or even has been bad for geology, because it has prevented geologists from considering any hypotheses that involved catastrophic interpretations of the data (Gould 1965, Krynine 1956, Valentine 1966). These authors are also not recommending a return to a Bible-based catastrophism. They are simply recognizing the evidence that many sedimentary deposits were catastrophic in nature. This recognition has brought the discipline of geology to accept the view called neocatastrophism, a naturalistic paradigm that explains the geologic record as developing over millions of years of evolutionary time, but with many catastrophic events that left their mark on the rocks (e.g., Ager 1981, Albritton 1989, Berggren & Van Couvering 1984, Huggett 1990). For a long time, Lyell's paradigm prevented geologists from recognizing the evidence for these catastrophic processes. Now that Lyell's bias has been recognized and abandoned, the philosophy of naturalism does not prevent recognition of catastrophic processes.

CONTROLLING BIAS IN SCIENTIFIC RESEARCH

The problems that Lyell's gradualism has caused in geology suggest that religion is not the only factor which has the potential to bias one's interpretation of data. Such bias is not an informed intervention problem; it is a human problem that every one of us must be aware of and seek to overcome. Science has a method for correcting the effect of bias that can be effective for interventionists as well as others (Table 2).

Table 2

The scientific method of bias control includes the following components:

1. Use good research design and careful data collection
2. Discuss specific results with scientific colleagues and present papers at scientific meetings
3. Submit papers for publication in refereed scientific journals (these papers are reviewed by several recognized experts in that field before publication).

This method is really the peer review system that helps to maintain quality in science; it is the critical discussion in Popper's (1963) scientific method. The peer review system cannot ultimately deal with philosophical questions like informed intervention, but any time we can use this philosophy (or any other) to help us define a hypothesis and collect data from rocks, fossils, or living organisms to test that hypothesis, the research data and their interpretation can be subjected to the process outlined above.

Bias is best controlled by critical interaction between scientists with varying views. Peer review did not soften Lyell's rigid geological gradualism for over a century. Why? Peer review could have functioned better if scientists with different views had continued to dialogue; if the catastrophists had not ceased to be influential. As it was, Lyell's gradualistic uniformitarianism was the only paradigm in use, with the result, until recent decades when accumulating data forced a review of Lyell's version of uniformitarianism, that the peer review system never addressed certain basic foundational questions about catastrophism.

I believe that science will benefit if it encourages active research by both scientists with a naturalistic orientation and those who accept the possibility of intervention. Both are searching for truth, and neither has anything to fear from the other if each is (1) actively engaged in quality research, (2) honest with the data, and (3) working not in isolation but as an active part of a scientific community in which there is active participation in professional meetings and peer-reviewed publication. There is no quality control quite like knowing that when a paper on our latest work is presented, there will be others, including some who disagree with us, who will be ready to point out the mistakes that we have overlooked! Also, scientists in each of these two groups are likely to recognize some types of data that the other might overlook.

IS THERE A VIABLE ALTERNATIVE TO NATURALISM?

Scientists who embrace interventionism need to be careful about criticizing scientists who make the naturalistic assumption, because there are reasons why they would want to take this approach. Science has been very successful since the adoption of naturalism, but before we deduce that this success demonstrates the truth of the naturalistic assumption, we need to look at the issues in more detail. The foundations of modern science were established by scientists who believed they were studying God's works. This belief did not prevent them from making

significant pioneering discoveries. The development of modern scientific thinking after those early pioneers involved the adoption of several specific concepts:

1. Living things and physical phenomena are like machines; they are mechanisms that can be studied and understood.
2. On a day-to-day basis, natural processes are not dependent on the capricious whims of the spirits, or the operation of magic.
3. The processes of nature follow predictable laws. By experiment and observation, we can learn what these laws are.
4. Scientific hypotheses must be testable using only criteria accessible to our five senses.
5. Change has occurred in organisms and in the physical universe — neither are static. New species of animals and plants have arisen, and geologic structures change with time.
6. Science will not consider the possibility of any intervention in the history or functioning of the universe by any higher power (naturalism).

Are items one to six equally essential for the success of science? The first concept is an assumption that is crucial for science, the second and third items are assumptions that expand on the first, and the fourth item is an operational assumption. I argue that these four concepts constitute the breakthrough that launched science on the road to its modern success. The fifth was an empirical observation and the recognition of this concept was also an important insight that opened up large vistas for research.

Some might say that naturalism follows inevitably if the first four concepts are true, but this is not necessarily correct logic. My car operates according to natural laws, and I find it interesting to study the natural processes that make it travel down the road. It is not necessary to assume a naturalistic origin for the car, in order to successfully understand its operation. The question of design, or informed intervention in the car's history only becomes an issue if I delve into the question of the car's origin. If I do, I will need to ask myself if I am willing to consider the possibility that in the origin of the car the laws of nature had some assistance from an intelligent designer. That may sound like a silly question, but it would not be trivial if we had no record of the origin of cars or similar machines. Of course analogies like this one have limits, and the car analogy breaks down because cars neither reproduce

nor have a mechanism to evolve. It does still help to illustrate that as long as we accept the first four concepts, most of what science does would not be affected by whether or not we accept the sixth concept — naturalism. Only when we study the beginnings of life, or the history of life and the universe, does it become necessary for us to decide what to do with the sixth concept — naturalism.

The scientific paradigm that includes naturalism has been successful, but is it the only potentially successful paradigm? We will now compare naturalism with an alternative, which I will call partial naturalism (generally interchangeable with the term interventionism).

Naturalistic science will only accept hypotheses that are based on the uninterrupted operation of natural laws, as understood by science today, as the sole explanation of biological or geologic events and processes. But one clarification needs to be made at this point. Even naturalistic science does not *properly* deny that God exists or that divine intervention could have happened. It just doesn't use the scientific process to study such things. Science can only investigate natural processes, and that is why hypotheses that require or imply the existence of any type of divine intervention in earth history at any time are not acceptable to science. However, naturalism is often consciously or unconsciously interpreted to include claims such as "divine intervention is not true" or is "unscientific." In any case the result is a strong bias against interventionist concepts.

Partial naturalism assumes that on a day-to-day basis the processes of nature do follow natural laws. Living things and physical processes are like "machines" in the sense that we can figure out how they work, and what laws describe their structure and function. An interventionist scientist who subscribes to this paradigm can work and think like a naturalistic scientist, with one exception: he does not *a priori* rule out the possibility that an intelligent superior being has, on rare occasions, intervened in biological or geologic history, including the origin of life forms. It is also acknowledged that such interventions could have involved the use of laws of nature that are beyond the limits of current human knowledge.

Thaxton et al. (1984) have distinguished (a) operation science (study of recurring phenomena in the universe) from (b) origins science, concluding that intelligent intervention may have been involved in origins but should never be invoked in operation science. Science cannot test or define the nature of these possible interventions (that is in the realm

of philosophy, not science), but science can recognize evidence that may point to the existence of "discontinuities" or unique events in history, and can examine their plausibility. The philosophy presented here is based on the conviction that if such discontinuities did occur, it is better to recognize their existence than to blindly ignore them.

There is a story of a man who was on his knees under a street light searching for something. A friend came by and asked what he was doing. He answered that he was looking for his keys. The friend helped search for some time, and then asked "are you sure you lost them here?" He answered "no, but the light is better here." Science can indeed see better when studying observable natural processes, but is that sufficient reason for denying that events of a different order could have occurred?

A comparison of the tenets of the two philosophies will further clarify the relationships between naturalism and interventionism. My understanding of informed interventionism can be partly defined with six concepts or assumptions paralleling those listed above. The first five are actually identical to those above. However, the sixth states that:

> 6. *There may have been, at certain times in history, informed intervention in geologic and biological history, especially in connection with origins. Hypotheses will not be shunned just because they imply the existence of such interventions.*

This highlights the crucial difference between the thinking of a naturalistic scientist and an interventionist: the latter's unwillingness to set up definitions that eject the Designer out of the universe without a fair trial. In any attempt to draw out the potential similarities between informed interventionists and others, it is best to be candid about that difference. If a person is not willing to accept the interventionist version of assumption 6, they will no doubt reject much of the approach taken in the rest of this article. The interventionist assumption 6 does not specify what sort of intervention occurred, it only leaves open the door to ask seriously the second question in this example and a similar one given above:

Question 1: Which hypothesis is correct?

a. Lyellian uniformitarianism, especially geologic gradualism
b. Neocatastrophism: catastrophic events in a naturalistic framework

Question 2: Which hypothesis is correct?

a. Lyellian uniformitarianism, especially geologic gradualism

b. Neocatastrophism: catastrophic events in a naturalistic framework

c. Catastrophism involving a global geologic catastrophe a relatively short time ago that produced a significant portion of the geologic column (with its implication of informed intervention in earth history).

A commitment to naturalism, on the other hand, does not allow question 2 to be asked because option 2c implies either (a), an interventionist origin of life forms, or (b), that there has not been enough time for an evolutionary origin of the life forms preserved in the geologic column.

EVALUATING THE TWO PARADIGMS

As individuals within each of these paradigms (naturalism and interventionism) evaluate the other paradigm, the tendency is to do exactly what Kuhn (1970, p 148) says will happen in such a situation. The two paradigms have differences in the rules that they follow (concept number 6, above), and as a result the practitioners of each approach end up talking past each other. The rules for doing science within naturalism (the six concepts above; naturalistic version) declare that partial naturalism/interventionism is, by definition (rule number 6), unscientific. In contrast, the interventionist considers this rule to be merely an untested hypothesis that could never be demonstrated by scientific data, and in fact has the potential to introduce serious biases into science. Lyell's geological gradualism restricted the range of hypotheses that could be considered, to the detriment of geology. Is it possible that naturalism has the same detrimental affect?

If the two groups sincerely wish to understand each other's thinking, each paradigm must be judged within its own rules. Followers of each paradigm must learn what it is like to think as those in the other paradigm think, without being judgmental (Thaxton et al. 1984, p 212). Only then are we prepared to make a fair evaluation of the internal consistency of each paradigm, and its success in dealing with the evidence.

In some cases informed interventionism is judged more by naturalism's rules than by the data. For example, the criticism has been made that rivers could not carve erosional features like the Grand

Canyon in a few thousand years. Of course this criticism ignores the fact that the theory which puts all of this activity within a few thousand years does not rely on present-day rivers to do the erosion, but proposes that at one time there was much more catastrophic water flow. The same also works in reverse. If interventionists want to understand the paradigm of naturalistic evolution and be prepared to critique it meaningfully, they must evaluate it by its own rules before trying to compare it with the interventionist paradigm.

If we admit the possibility of divine intervention in history, it may seem to imply that earth history will be non-understandable and capricious — not amenable to scientific investigation. This is where it is important to evaluate the paradigm's internal consistency, using its own rules. It will not be fair to evaluate this possibility using only the rules of naturalistic science. The fact is that if interventionism builds on the conviction that the Bible is a reliable communication from the Designer, it has a consistent and meaningful answer to this question. The God who intervened in history has taken the trouble to tell us about unusual events which might confuse us in our study of history if we did not know about them.

Imagine a large dam built across a canyon, backing up a lake several times larger than Lake Powell. One day the dam gives way, and the enormous rush of water erodes away the remaining traces of the dam. As the water cascades through the valleys downstream, it also erodes them into canyons many times larger than their original size. With time all human memory of the dam and its destruction is lost. One ancient book tells the story, but there is argument over the book's authenticity.

A geologist studying the canyons along the river rejects the validity of the old book and concludes that there is no natural process that could produce a flood so massive that it could account for the formation of the canyons in a relatively short time. He measures the flow of the river and the amount of sediment that it is carrying away, and calculates how long it took for the present river to carve the canyons. In time additional data point to catastrophic processes in the canyons, but he concludes that the indicated catastrophes were isolated floods with long time periods between them.

Another geologist is willing to seriously consider that the book may be reliable, and he decides that if it is correct, the insights in the book will help to keep him from misinterpreting the data. Without the book and its story of such a unique event, so different from even the natural catastrophes that are part of our modern analogues, it may be difficult

or impossible for a scientist to have hope of even being able to think of the correct hypothesis for the origin of the canyons. Even more serious, he would not be aware of the problem.

If the book is correct it provides a logically consistent working hypothesis: the flood was the consequence of an unusual event, which someone told us about, and this knowledge gives us a trustworthy beginning point for developing specific hypotheses about the erosion processes.

The central issue is our willingness to seriously consider that the book might give a correct account. If there are those who think that it does, and they conduct themselves as careful researchers, I suggest that science will be benefited more if it maintains a friendly dialogue with these scientists, rather than defining them out of the dialogue.

Interventionism can take many forms. The version presented in this essay concludes that the "old book" is a reality: the Designer has communicated to us, and there is evidence that the communication is reliable and describes the actual history of life on Earth. This communication is brief and leaves many unanswered questions, but if it is a reliable account, the most productive approach will be to take seriously the concepts it presents and see what insights they can give us in our research. Statements from the book cannot be used as evidence in science; but if those statements are true, it should be possible to use some of them as a basis for defining hypotheses that lead to productive field research. Several very general hypotheses that follow from this approach are listed in Table 3A, contrasted with parallel hypotheses based on a naturalistic evolutionary paradigm (Table 3B). Of course it must be remembered that the "old book" also contains much material that cannot be addressed from a scientific perspective.

RESEARCH UNDER THE PHILOSOPHY OF INTERVENTIONISM

My experience indicates to me that interventionism, as defined above, is an effective framework for doing science. Below are several specific examples of research that has been done under this interventionist philosophy, with resulting publications in peer-reviewed scientific journals.

1. Yellowstone Fossil Forests

In and adjacent to Yellowstone National Park, volcanic deposits contain a series of fossil forests, one above another, containing upright stumps that appear to be in their original position of growth. If this

Table 3A

Hypotheses derived from Christian interventionism:

1. Independent, nonevolutionary origin of at least the major groups of organisms. The limits of these groups will need to be determined from analysis of evidence.
2. Life has existed on Earth for a short time, measured in thousands of years, and the rocks containing at least the Phanerozoic fossil record were formed during that time.
3. There was a very high level of catastrophism in the formation of a significant portion of the Phanerozoic record.

Table 3B

Hypotheses derived from a naturalistic evolutionary paradigm:

1. All life forms trace back to the natural origins of life from non-living material.
2. Life has been on Earth for many millions of years, and the geologic record on Earth formed over this long time period.

series of forests, containing some very large trees, grew in their current position, one forest after another, a very long time would be required for its accumulation. Interventionists began studying these forests to determine if there was an equally valid, alternative interpretation. This research has led to the development of the hypothesis that the fossil trees did not grow *in situ* (where they now are), but were transported to that location together with the sediments. Several lines of research, published in professional journals, now lend support to this hypothesis (Chadwick & Yamamoto 1984; Coffin 1976, 1983a, 1983b, 1987).

2. Coconino Sandstone Trackway Research

The Coconino Sandstone is generally considered to be formed from a series of desert dunes. The only fossils it contains are trackways of either amphibians or reptiles. When I began a study of the fossil vertebrate trackways in this formation I had doubts about the desert dune origin of the tracks, initially for philosophical reasons, and set out to evaluate alternative hypotheses for formation of the tracks. So far the data from study of the tracks support the hypothesis that the fossil

tracks were made underwater (Brand 1979, 1992; Brand & Tang 1991). Whether future research will continue to support this hypothesis remains to be seen.

3. The history and status of white-footed mice (genus *Peromyscus*) on several islands in the Gulf of California

Alternative hypotheses for the status of these mice were that (1) the island mice were a separate species that had arisen from related mice on the mainland, *Peromyscus eremicus*, or (2) the island mice were still the same species as the mainland mice. In this case interventionist theory does not favor, *a priori*, one over the other. The evidence supported the conclusion that the island mice had become a separate species, apparently in response to isolation on the islands (Brand & Ryckman 1969). This and a number of similar studies demonstrate that an interventionist philosophy can be an effective stimulus for research on evolutionary processes without assuming that major groups of organisms arose by the process of evolution.

4. Precambrian Pollen in the Grand Canyon

Some interventionists have contended that Precambrian rocks in the Grand Canyon contain fossilized Angiosperm (flowering plant) pollen, and that this is evidence against evolution (Angiosperm plants presumably did not evolve until long after the Precambrian). A claim as significant as this should be independently verified to be sure of its authenticity. Another scientist repeated the research, and his data indicated that these rocks do not contain fossil Angiosperm pollen. The original claim apparently resulted from contamination of the samples by modern pollen (Chadwick 1981).

5. Human Tracks in Cretaceous Rocks

It has been widely claimed by some interventionists that Cretaceous limestone by the Paluxy River in Texas contains fossil human tracks in association with dinosaur tracks. As with the Precambrian pollen, such a significant claim should not be accepted without extensive careful study. The more significant the implications of the supposed evidence, the more rigorously it should be examined before proclaiming it as evidence for or against intervention or evolution. A restudy of the Paluxy River tracks convinced a number of us that they are not human (Neufeld 1975).

6. Other fields

In the medical sciences and in areas of biology, chemistry, and physics that do not deal with evolution or history, a number of interventionists are doing high-quality scientific research. Their interventionist philosophy does not in any way hinder them from effectively using the scientific process in their study of the workings of the natural world.

One danger that we must avoid at all cost is the very human tendency to think that because we believe that the Bible contains special insights, whatever ideas we develop based on this book are automatically right. George McCready Price (1906, 1923) provided an example of this problem. Even though the Bible says nothing about the ice age or the "out of order fossils," Price could not accept the possibility that his way of explaining the evidence pertaining to these might be wrong.

Research under the paradigm of interventionism (like other research) does not automatically lead to correct conclusions, but it begins a search in a particular direction. After the search is begun, several different turns may be necessary before the theory satisfactorily explains the evidence and has predictive ability. Some examples follow.

a. Yellowstone Fossil Forests

Initial interventionist hypotheses were that the fossil trees were actually on the surface of a slope, and did not go back into the hills in a vertical series of layers, or that there really were not many layers of forests. Research falsified these hypotheses, but led to a productive scientific hypothesis — that the fossils were transported with the sediments.

b. Order of Fossils in the Rocks

George McCready Price began with the hypothesis (although he did not necessarily see it as only a hypothesis) that there is not a predictable sequence of organisms in the fossil record, but that the organisms were buried in a random sequence during the flood. That hypothesis has been falsified, but the research involved in falsifying it led to another hypothesis — ecological zonation (Clark 1946), which still needs much refinement before it will adequately explain the fossil record. Whether it will stand in modified form or be replaced by a different hypothesis remains to be seen.

c. Coconino Sandstone Trackway Research

My first hypothesis was that the vertebrate trackways in the Coconino Sandstone were formed in some type of wet sand environment (but not underwater), but the data did not support this hypothesis. Further study suggested that the fossil tracks were most likely made while the animals were completely underwater, and so far that hypothesis has strong support from continued study of the tracks.

Errors in the initial theory or assumptions do not, in the long run, prevent truth from emerging, although beginning with the correct assumptions speeds the process. If catastrophist geologists had continued, after Lyell's time, to successfully use their paradigm in research, their work would have provided an influence to counterbalance Lyell's rigid gradualism, and the turn to catastrophist interpretations could have occurred sooner.

A NEED FOR CAUTION

At this point we need to look at the other side of the coin. Even if catastrophist geologists use their theory effectively and make discoveries that others have overlooked, there will be limits to the scientific conclusions that can be drawn with this approach. Science cannot demonstrate whether God was or was not involved in influencing our geologic history. Even if research eventually demonstrates that the best explanation for the geologic column is rapid sedimentation of a major portion of the column in one short spurt of geologic activity, this would only make it reasonable to believe the flood story if our confidence in Scripture leads us to do so. It would not *prove*, scientifically, that God caused a flood.

WHY BOTHER?

We still must pursue the question: why bother to try using this novel approach? Maybe interventionism can be a basis for doing scientific research, but is there really a need for that paradigm? Geology did correct Lyell's mistake, apparently without any help from outside of naturalism; so why is informed intervention needed? There are many bright and successful scientists who are convinced that the theory of the evolution of life forms adequately explains the evidence, and there is no need for the informed intervention hypothesis. I can understand the rationale for their attitude, and I will defend their right to disagree with me. I also suggest that there are dimensions to these issues that

often are overlooked, and that there are good reasons for taking seriously the possibility of informed intervention. It is not presented here because there is proof for it, or because it can currently answer all the questions; but because of a conviction that it has something important to offer for science as well as for religion. A clear discussion of the issues requires that we differentiate between several separate questions that are a part of the evaluation of interventionism vs. naturalism.

The progress of the last two centuries tells us that naturalism has resulted in scientific progress. Whether or not we agree with the tenets of naturalism, it is unreasonable to say that naturalism is not an effective paradigm. For reasons given in this article, I argue that interventionism can also result in effective science. The demonstration of that potential is just beginning, but interventionism can produce good science. Many of the specific questions that can be addressed with testable hypotheses are essentially the same under the two paradigms, but some will differ, as illustrated by the examples in Table 4.

Can the concepts of naturalism or interventionism be tested? The answer in both cases is no. Both naturalism and interventionism are based on non-testable assumptions, and the decision between them is based on a philosophical choice. Do either naturalistic evolution or informed intervention provide a sufficiently convincing explanation for the evidence? The answer to this question would take much more space than is available in this article, but for now I will suggest that at this time naturalism has better answers for some data, and interventionism does better at interpreting other data.

Some will no doubt say that naturalism is the clear winner in effectively interpreting the data. There are reasons for considering that answer to be premature. Ultimately, with much more data available the evidence should point more clearly to one of these paradigms as being much more successful at explaining the evidence. The adherents of each paradigm will have their own prediction as to which way the data will ultimately point. Which paradigm has more promise for effectively guiding scientific research in the future? The answer to this question is largely based on philosophy, on a prediction determined by what we each believe is the true history of life on Earth.

At this point we can return to a statement made earlier, that science should either devise an experimental test for one or both of the concepts "God created life" and "God did not create life," or not try to say that one approach is scientific and the other is not. Is that analysis fair?

Table 4. Comparison of research questions that can be addressed with testable hypotheses under the two paradigms.

Research questions that are equally important and will be addressed by the same types of data and research strategies in both paradigms:

- What physiological, anatomical, behavioral, or other mechanisms make each type of living organism well adapted to its environment?
- What are the genetic processes that control the changes in plants and animals?
- What have been the phylogenetic pathways of change in living things? How have these changes adapted the organisms to their changing environments?
- How and when were the fossils buried?
- What were the geologic processes that produced the geologic column and the geologic structure of Earth?

Research questions that will differ in the two paradigms:

Naturalism	Interventionism
• By what processes could life evolve from non-living matter?	• Does not ask that question, but predicts that life cannot arise without informed intervention and abiogenesis research will ultimately fail.
• Does not ask these questions, but predicts that such research will not be successful, because all life forms *have* arisen by evolution.	• How much evolution has occurred? What have been the limits of evolutionary change? Or are there aspects of the biosphere that are logically incompatible with purely materialistic explanation?

From what I have read and heard of the arguments between these two paradigms, I have to say that it is a fair analysis. Attempts by some creationists to make naturalistic scientists look foolish are unfortunate and unrealistic. Those scientists are doing productive science. However, it is also true that if proponents of naturalism wish to say that interventionism cannot be science, they need to devise credible scientific

tests with the potential to falsify one or both of the hypotheses: "God created life" and "God did not create life."

It could be argued that naturalism, properly defined, does not make either of the statements in these hypotheses. It only recognizes that science cannot address either hypothesis and only asks how life could have originated *if* it arose by purely mechanical means. If it was clear that most scientists understand naturalism this way, and that most of them are comfortable with the thought that it is also intellectually credible to approach science from within a non-naturalistic philosophy, then this essay would not be necessary. However, in practice naturalism does not seem to be generally interpreted that way. It is commonly considered intellectually unacceptable to consider seriously the hypothesis "God created life." But in the absence of experimental tests for these and similar hypotheses, the attempt to make interventionism, as defined here, outside of the realm of science is based strictly on an arbitrary, *a priori* definition.

To the question "why bother?" my answer is that interventionists are not asking anyone to bother trying this approach if they do not see a reason to, but *some of us actually believe that interventionist science will ultimately be more successful, because we believe that its basic tenets are closer to reality than is naturalism*. At present this belief is based on a philosophical choice, and could be criticized for being a religious choice; and so it is. But the only religion worth having is a religion based on truth. If we believe our religion is truth, and that it offers insights into earth history, we would be missing something important if we do not use it for generating testable scientific hypotheses.

As Thomas Kuhn (1970) pointed out, when a new paradigm is suggested there will at first be only a few persons who think that it is worthwhile. The paradigm's chance of success depends on those few people demonstrating that they can do effective research under it. I propose that there are many similarities between Kuhn's general concept of scientific revolutions and specific application to the naturalism/interventionism debate. The naturalistic paradigm has successfully guided science for a long time. The much newer paradigm based on informed intervention and catastrophist geology is being applied as a guide in selected cases of field and laboratory research. There is evidence that in these cases it is successful and is beginning to be developed as a competing paradigm.

Someone may respond that actually there was a revolution back in Darwin's day, when creationism was rejected. I suggest a different point of view: that the theories of evolution and uniformitarian geology developed in fields which up to that time lacked any coherent theories, and were in a preparadigm state. The first cohesive paradigms in these fields developed in an intellectual atmosphere strongly favoring naturalism. Consequently they were purely naturalistic. We now can look carefully at the data that have accumulated, see the strengths and weaknesses in the established paradigms, and propose competing paradigms. Research done under this new interventionist paradigm is beginning to have an influence on the body of scientific evidence available in certain specific areas where such research has been concentrated.

This discussion is not meant to imply that the scientific community is on the verge of a paradigm shift to interventionism. The relationship between the two origins paradigms has some interesting similarities to other paradigm competitions, but there are also important differences. The shift to plate tectonics (the theory that explains drifting continents), for example, did not require anyone to reevaluate the scientific method. Plate tectonics and the previous paradigm were both compatible with a naturalistic, evolutionary explanation of earth history, and consequently there was no strong barrier to acceptance of the plate tectonics concept after a few key discoveries threw the weight of evidence in its favor.

In contrast, interventionism redefines the limits of the scientific endeavor, and raises fundamental questions about the meaning of human life and our relationship to a higher power. Also, since the evidence needed to resolve the intervention/naturalistic-evolution debate is orders of magnitude more complex than in other recent paradigm competitions, it is unrealistic to think that a few key discoveries will win over the scientific community to an interventionist position. A peaceful coexistence between the two philosophies is a more practical goal.

WHAT SHOULD INTERVENTIONISTS BE DOING?

In published articles on the discussion over creationism a key point that is often brought up is that creationists, no matter what they may say, are not scientists — they are not doing research. Eldredge (1982) states that no creationist "has contributed a single article to any reputable scientific journal." Actually a number of interventionists are active in research, but this is not widely known. In an atmosphere of such un-

friendly debate between the two views, interventionists who are scientists will not often make their philosophical views known.

I believe the approach that is beneficial in the long run is for interventionists to conduct themselves as genuine scientists and get actively involved in research. It is important to try to develop an alternative paradigm, a successful alternative way of interpreting the data, rather than only poking holes in someone else's theory. If interventionist efforts center around disproving the prevailing evolutionary paradigm, the response will be: what do you have to offer that is better (i.e., a more successful guide for scientific research)? Interventionists should work on developing an alternative paradigm, rather than focus only on efforts to disprove evolution.

Ideally, a person's philosophy shouldn't matter as long as he or she does good science. That is the ideal, but there is a common perception that interventionists, by definition, cannot be objective scientists. This perception can only change as interventionists diligently pursue careful, quality research. On the other side of the coin many interventionists accuse "those evolutionists" of lacking any objectivity (or worse). Why do we do this to each other? We don't have to agree on everything to value each other's work. The ultimate tests of any scientist are their honesty in dealing with the data and quality of research, not personal philosophy. For the scientific community simply to judge a person on his or her honesty and effectiveness in research should be enough. This would eliminate many battles over philosophical issues.

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ANNOTATIONS FROM THE LITERATURE

ANTHROPOLOGY: ORIGIN OF MAN

Swisher CC, Rink WJ, Anton SC, Schwarcz HP, Curtis GH, Suprijo A, Widiasmoro. 1996. Latest *Homo erectus* of Java: potential contemporaneity with *Homo sapiens* in Southeast Asia. Science 274:1870-1874.

Summary: Hominid fossils were first discovered in Java in the late 1880s. They have been given the name *Homo erectus*, more popularly known as "Java Man." Conventional dates for "Java Man" are about 500,000 years, with other "erectines" dating as far back as about 2 million years. The *Homo erectus* group is frequently interpreted as a direct ancestor of modern humans. Fossil cattle teeth from the same deposits ranged in dates from 27,000 to 53,000 years by electron spin resonance and uranium-series dating. This date overlaps with fossils of modern *Homo sapiens*, raising the possibility that the two types of hominids might have co-existed.

Comment: The implication that "erectines" overlapped with humans of modern appearance is highly interesting. The exact relationships of "erectines" and modern humans are of great interest, and it is to be hoped that further studies will clarify this point. Fossil neanderthals have also been reported to overlap with modern humans. Creationists should be aware, however, that evolutionary theory no longer predicts that an ancestral species will necessarily disappear when its descendant appears. Thus it is consistent with evolutionary theory for *Homo erectus* to be the ancestor of *Homo sapiens*, yet the two species be found living at the same time.

CATASTROPHISM

Erwin DH. 1996. The mother of mass extinctions. Scientific American 275(1):72-78.

Summary: The largest mass extinction in the geologic record is at the top of the Permian. An estimated 90% or more of the fossil species found in Upper Permian rocks are not found in higher strata. Groups that disappeared include: two-thirds of the families of reptiles and

amphibians; nearly one-third of the orders of insects; and nearly half the families of marine invertebrates, including the last of the trilobites. Marine fossils from Paleozoic rocks are predominantly immobile types, such as brachiopods, crinoids, and rugose corals. Mesozoic rocks contain more mobile types, such as crabs, snails and fish. The cause of this mass disappearance is not known, but may be related to extensive volcanism in Siberia, or to changes in sea level. There is no evidence for a large end-Permian extraterrestrial impact.

Comment: Two features of this mass disappearance are of particular interest. First, the change in ecological types from largely immobile Paleozoic types to more mobile Mesozoic types may be an important signal of the processes responsible for catastrophic deposition of the geologic column. Second, the apparent relationships among flood basalts, sea-level changes and mass disappearances may suggest fruitful areas of investigation for catastrophists. In a catastrophic model, the causes of mass disappearances need not necessarily be restricted to the immediate stratigraphic level in question, but may be part of a more extensive geologic process.

EFFECT OF MUTATIONS

Baker RJ, Van Den Bussche RA, Wright AJ, Wiggins LE, Hamilton MJ, Reat EP, Smith MH, Lomakin MD, Chesser RK. 1996. High levels of genetic change in rodents of Chernobyl. Nature 380:707-708.

Summary: The nuclear accident at Chernobyl released radiation into the surrounding vicinity. The genetic effects of this radiation on the mitochondrial cytochrome b gene of mice in the area were studied. Nine Chernobyl mice were compared with 10 mice from outside the contaminated area. The Chernobyl mice had more than ten times as many nucleotide differences, implying a mutation rate at least ten times greater than in the non-Chernobyl mice. Each Chernobyl mouse had a unique gene sequence. Despite the high mutation rate, the mice appeared normal morphologically, and continue to thrive and reproduce in the area around Chernobyl. It appears that the genome of these rodents is remarkably resilient to mutational changes.

Comment: Mammals may be more tolerant both to radiation and to high mutation rate than has been thought. Nevertheless, the danger from radioactive wastes should not be minimized.

EXOTIC STONES

Bennett MR, Doyle P, Mather AE. 1996. Dropstones: their origin and significance. Palaeogeography, Palaeoclimatology, Palaeoecology 121:331-339.

Summary: Fine-grained sediments sometimes contain rocks that are unexpectedly large or of a different composition. These are called dropstones, and are typically interpreted as the result of ice rafting and inferred to be evidence of past glaciation. However, dropstones are sometimes found in geologic settings that do not seem compatible with glaciation. Another explanation is needed to account for some dropstones. Three other explanations are available. Stones may be transported in the crops or stomachs of vertebrates, or in the roots of rafting plants. Water may transport stones, either by flotation or through the motion of turbidites. A third alternative is that stones may have moved as projectiles, generally from volcanic sources, but possibly from extraterrestrial impacts, or even due to human rock-throwing. Thus, inferences of glaciation based on the presence of dropstones may need to be re-evaluated.

Comment: Several claims of pre-Pleistocene glaciation have been made, including the Permo-Carboniferous glaciation of the southern hemisphere. Climatic indicators sometimes suggest warm-climate fossils when glaciation was supposedly occurring. Other explanations for striated rocks, dropstones and tillites are known, and all claims for pre-Pleistocene glaciation should be evaluated critically.

GENOME OF YEAST

Dujon B. 1996. The yeast genome project: what did we learn? Trends in Genetics 12:263-270.

Summary: The genome of the baker's yeast, *Saccharomyces cerevisiae*, has now been completely sequenced. This is the first complete sequence for a eukaryotic organism, and permits comparison with the genomes of previously sequenced eubacteria and archaea. The yeast genome contains something over 12 million nucleotide pairs, with an estimated 6000 genes. Probably the biggest surprise of the sequencing project is the large number of "orphan genes" for which no function is known, either in yeast or in any other organism. About 2000 genes appear to fit this description at present, and it appears

likely that a significant number will remain even after further analysis and comparison. This point may be the most interesting one gained from the yeast genome sequencing project.

Comment: Genome sequencing studies so far show large numbers of genes unique to each species. If this pattern continues, it may weaken confidence in the evolutionary conjecture that gene duplication and divergence can account for the increase in the number of genes and gene functions needed to account for evolution of organisms of increasing complexity.

MASS MOVEMENT

Beutner EC, Craven AE. 1996. Volcanic fluidization and the Heart Mountain detachment, Wyoming. Geology 24:595-598.

Summary: A block of sedimentary rock some 1500 km^2 broke away from a location near the eastern border of Yellowstone National Park and slid southeast across the surface for a distance of at least 30 km, and possibly more than 50 km. The block includes Ordovician to Eocene rocks, moving during a time of volcanic activity in the Absaroka ranges. Estimates for the time involved for the movement range from a million years to perhaps less than an hour. The problem has been to explain why the block moved at all. A highly unusual microbreccia on the sliding surface has features that appear to indicate the material was fluidized, apparently by volcanic gases injected onto a bedding plane. The combination of formation of a breakaway fault and reduction of friction by the fluidized material allowed the block to slide down a 1-2 degree slope. More study is needed to determine the amount of time involved, but it could not have been very long.

Comment: The Heart Mountain detachment must have involved conditions unlike anything observed in the modern world.

Brack P, Mundil R, Oberli F, Meier M, Rieber H. 1996. Biostratigraphic and radiometric age data question the Milankovitch characteristics of the Latemar cycles (Southern Alps, Italy). Geology 24:371-375.

Summary: Finely laminated sediments are found in numerous places, including the Italian Alps. Such sequences may show patterns of repeating variation of lamina thickness. One such sequence involves hundreds of carbonate cycles in the Middle Triassic Latemar platform. These have been explained as due to the Milankovitch cycle of

20,000 years. At least 598 cycles are reported, implying a total time of about 12 million years. However, a combination of index fossils and radiometric dating indicates a maximum age of 4.7 million years for the deposits, and probably less than 4 million years. This suggests that the patterns in the laminae may not be a result of the Milankovitch cycle. The authors suggest that ancient carbonates may not supply sufficient data for unambiguous identification of Milankovitch cycles.

Comment: Possible rejection of Milankovitch cycles as the explanation for cyclic patterns of variation in laminated sediments should stimulate efforts to find better ways of explaining the origin of thin laminae in sediments. It seems remarkable that a lake should maintain relatively constant conditions of deposition over periods in excess of 100,000 years, much more so for the longer periods often suggested by the Milankovitch cycle interpretation.

ORIGIN OF THE EYE

Loosli F, Kmita-Cuniss M, Gehring WJ. 1996. Isolation of a Pax-6 homolog from the ribbonworm *Lineus sanguineus*. Proceedings of the National Academy of Sciences (USA) 93:2658-2663.

Summary: The Pax-6 gene is a master control gene for eye formation. It has been found in humans, birds, fish, insects, roundworms, mollusks, echinoderms, and others. Here it is reported from another phylum, the ribbon worms. The wide diversity of organisms in which these genes are found is interpreted to mean that the Pax-6 gene was present before the evolutionary separation of the various phyla in which it is found.

Comment: This result confirms a pattern that is becoming increasingly clear — the homeobox genes that control development are remarkably similar in organisms that are remarkably dissimilar. The evolutionary explanation for the similarity is simply common ancestry, but how does one explain the differences in eye structure? How can the same master gene produce eyes as different as the vertebrate eye and the insect eye? A further enigma is how to explain the evolutionary inference that the gene for producing eyes apparently evolved before there were any animals with eyes. Perhaps there is a better interpretation — that similar genetic patterns reflect a common Designer, with unique gene interactions in each separately created lineage.

ORIGIN OF LIFE

Lazcano A, Miller SL. 1996. The origin and early evolution of life: prebiotic chemistry, the pre-RNA world, and time. Cell 85:793-798.

Summary: Several lines of evidence indicate that life must have originated in a relatively short time, certainly less than 10 million years. This figure is necessary because the entire ocean passes through hydrothermal vents every 10 million years. Temperatures at hydrothermal vents are about 350º C. At this temperature, organic compounds are destroyed. The primordial atmosphere was probably rich in carbon dioxide, implying the absence of the reducing conditions needed for abiotic synthesis of organic compounds, probably requiring an autotrophic beginning. Ribose decomposes rapidly, with a half-life of only 44 years at 0º C, and only 73 minutes at 100º C. Adenine has a half-life of 204 days at 100º C. The minimum cellular genome is estimated at about 562,000 nucleotide pairs, close to the 580,000 nucleotide pairs of *Mycoplasma genitalium*. The limited time for the complex metabolic processes of life to arise contrasts with the conservation of these processes since the origin of life.

Comment: It is probably logically impossible to disprove the naturalistic origin of life, but this hypothesis has failed so many experimental tests and theoretical considerations that it seems an appropriate conclusion would be to abandon the hypothesis and search for alternatives.

PALEONTOLOGY: *ARCHAEOPTERYX*

Elzanowski A, Wellnhofer P. 1996. Cranial morphology of *Archaeopteryx*: evidence from the seventh skeleton. Journal of Vertebrate Paleontology 16:81-94.

Summary: *Archaeopteryx* is a fossil that possesses characteristics of both birds and reptiles. Its skull was rather poorly preserved in previous specimens, but parts of it are better preserved in the recently discovered seventh specimen. This specimen apparently was buried rapidly, before the brain could disintegrate. The skull shows some distinctly avian features, and some that appear to be uniquely shared with theropod dinosaurs. The authors conclude that *Archaeopteryx* was a bird rather than a feathered dinosaur.

Comment: The status of *Archaeopteryx* has been controversial. Creationists generally regard it as an extinct type of bird. Additional information on the structure of *Archaeopteryx* is always of interest.

PALEONTOLOGY OF CHORDATES

Shu D-G, Morris SC, Zhang X-L. 1996. A *Pikaia*-like chordate from the Lower Cambrian of China. Nature 384:157-158.

Summary: The Chengjiang fossil locality of China has become famous for the exceptional quality of preservation of its Lower Cambrian soft-bodied animals. Among these is a cephalochordate that appears similar to *Pikaia* from the Middle Cambrian Burgess Shale of Canada. The new fossil is named *Cathaymyrus*. Another Chengjiang fossil, *Yunnanozoon*, was originally described as a chordate, but has been re-evaluated as a probable hemichordate.

Comment: The discovery of *Cathaymyrus* pushes back the fossil record of the phylum Chordata to the Lower Cambrian, emphasizing the breadth and restricted stratigraphical interval of the "Cambrian Explosion."

PALEONTOLOGY: ORIGIN OF TURTLES

Lee MSY. 1996. Correlated progression and the origin of turtles. Nature 379:812-815.

Summary: Turtles have one of the most distinctive body plans among all vertebrates. They appear abruptly in the fossil record, without any clear morphological intermediates. Two groups of "parareptiles" — procolophonoids and pareiasaurs — have been proposed as sister group to the turtles. Lee advocates the pareiasaurs, a group of fossils found in Permian rocks of the Old World. Some pareiasaurs have a dorsal ridge of osteoderms, which provide anchorage for muscle attachment. Other pareiasaurs, such as *Scutosaurus*, have a dorsal covering of largely separated osteoderms. In the genus *Anthodon*, the osteoderms are united to form a rigid dorsal covering. Lee proposes that these genera form a morphological series leading to turtles. The stratigraphically lowest turtles are from Upper Triassic rocks. Interestingly, other groups of partially armored reptiles are also present in Triassic rocks, the placodonts and archosauromorphs.

Comment: Of the two groups proposed as most similar to turtles, pareiasaurs appear to be better candidates than the procolophonoids. However, very large gaps in any putative morphological series remain unfilled. It is intriguing to note that several groups of partially armored reptiles are found in Permian and/or Triassic rocks: pareiasaurs; placodonts; archosauromorphs; and turtles. It would be interesting to explore the question of whether this might reflect an ecological or taphonomic process.

PALEONTOLOGY: STROMATOLITES

Grotzinger JP. Rothman DH. 1996. An abiotic model for stromatolite morphogenesis. Nature 383:423-425.

Summary: Stromatolites are structures thought to be produced a layer at a time by the activities of cyanobacteria. This mode of growth has been observed in modern stromatolites, but fossil stromatolites rarely have fossilized bacteria, and it is not certain that this is the only method for their formation. In this study, Precambrian stromatolites from northwestern Canada were examined. Both microscopic textures and fractal patterns of growth geometry were interpreted as being produced abiotically. It seems that many types of stromatolites may be explained as the result of purely physical processes.

Comment: Precambrian stromatolites are often interpreted as evidence of living organisms during Precambrian deposition. This article shows the dangers of making such assumptions without additional evidence of microorganisms within the stromatolite.

PSEUDOGENES

Petrov DA, Lozovskaya ER, Hard DL. 1996. High intrinsic rate of DNA loss in *Drosophila*. Nature 384:346-349.

Summary: Pseudogenes are gene sequences that resemble ordinary genes, but which have apparent defects that would be expected to prevent them from functioning. Processed pseudogenes are virtually absent from *Drosophila*, but are common in mammals. The authors propose that the reason for this is that deletions are more common and larger in *Drosophila* than in mammals. The result is that *Drosophila* pseudogenes are expected to be eliminated relatively rapidly, while mammal pseudogenes might remain in the genome almost indefinitely.

Comment: Pseudogenes are considered to be functionless, yet their persistence and high frequency in mammals seems strange. An alternative explanation for this is that at least some pseudogenes in mammals are not functionless, but may play a role in gene regulation. Some conjectures as to what functions they might have could include participating in gene switching by providing alternative binding sites for regulatory factors; producing short transcripts that somehow participate in gene regulation; or providing sequence information that could be modified by such activities as gene conversion or RNA editing.

LITERATURE REVIEWS

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BLACK BOXES AND DESIGNERS

David Ekkens
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DARWIN'S BLACK BOX: THE BIOCHEMICAL CHALLENGE TO EVOLUTION. Michael J. Behe. 1996. NY: The Free Press. 307 p. Cloth, $25.50.

Of all the books that have been written recently dealing with the creation/evolution debate, this book surely ranks at or near the top. As one college teacher put it, "*Darwin's Black Box* really strengthened my faith."

Even though the author, Michael J. Behe, is Associate Professor of Biochemistry at Lehigh University (Pennsylvania), he has a style of writing that makes interesting reading for anyone, chemist or non-chemist. His illustrations range from baking a cake, to a swim in the pool, to woodchucks crossing a thousand-lane freeway at rush hour. He does include short sections of technical biochemistry in nearly every chapter, but a non-chemist can skip those sections and still get the major message of the book.

The book's main theme is an examination of problems associated with applying Charles Darwin's theory of natural selection to cell evolution. Behe wants to know if several small changes in a cell's chemicals could produce the chemical machines that cells use to live.

Part I: The Box is Opened

In this first section, Behe describes why molecular details are important. How life works at the molecular level was never explained by Darwin because the science of biochemistry was nonexistent in Darwin's day. Therefore the cell was a black box for Darwin — he

really couldn't look into it to see how it worked or how it could have evolved. Now, says Behe, our knowledge of biochemistry is advanced to the extent that we can look into the black box and see if Darwinian theory can explain the evolution of cell components.

As Behe states:

> *Anatomy is, quite simply, irrelevant to the question of whether evolution could take place on the molecular level. So is the fossil record. It no longer matters whether there are huge gaps in the fossil record.... The fossil record has nothing to tell us about whether the interactions of* [several chemicals involved in vision] *could have developed step-by-step.... Until recently ... evolutionary biologists could be unconcerned with the molecular details of life because so little was known about them. Now the black box of the cell has been opened, and the infinitesimal world that stands revealed must be explained* (p 22).

To demonstrate how upset some people are with neo-Darwinism, Behe quotes from several scientists. He quotes a scientist named Lynn Margulis: "'Neo-Darwinism, which insists on (the slow accrual of mutations), is in a complete funk"' (p 26). Behe quotes two other scientists (Orr and Coyne) as saying: "'We conclude — unexpectedly — that there is little evidence for the neo-Darwinian view: its theoretical foundations and the experimental evidence supporting it are weak'" (p 29).

But how can we test Darwinian theory and be able to accept or reject it? Behe quotes the so-called "criterion of failure" from Charles Darwin's book *The Origin of Species*, published in 1872:

> *'If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down'* (p 39).

Behe then asks what kind of system could there be that "could not possibly have been formed by 'numerous, successive, slight modifications.'" The answer he gives is an irreducibly complex system:

> *... a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning* (p 39).

When we look at a large system (an eye, for example), its complexity makes it practically impossible to think about all the molecules at the same time and to guess how complicated structure could have evolved from a simpler structure. But if we look at smaller structures, all necessary chemicals (and each of their functions) are known. Therefore we should be able to see if the irreducibly complex system could have evolved from some other functioning system. (Remember, natural selection only works on functioning systems. The precursor to the system must function and each intermediate stage must function — otherwise it will be eliminated. The other side of the coin labeled "survival of the fittest" is labeled "death of the unfit.")

Part II: Examining the Contents of the Box

This is the "meat and potatoes" section of the book. Behe examines several irreducibly complex systems: the cilium, the blood-clotting system, protein production and transport in a cell, cellular defense mechanisms (immunity), and production by a cell of AMP. Each of these systems consists of several interacting chemicals.

Behe's conclusion from studying each of these is that the probability of any of them evolving by Darwinian successive changes is infinitesimally small:

> *In summary, as biochemists have begun to examine apparently simple structures like cilia and flagella, they have discovered staggering complexity, with dozens or even hundreds of precisely tailored parts.... As the number of required parts increases, the difficulty of gradually putting the system together skyrockets, and the likelihood of indirect scenarios plummets* (p 73).

At the end of each of the chapters in Part II, Behe describes how he searched the professional literature to see if any good explanations have been published of how molecular evolution occurred. Each of these searches ended in failure: the conclusion is that no one knows. And yet, we are told that nothing makes sense in biology except in the light of evolution.

Part III: What Does the Box Tell Us?

In this concluding section, Behe examines in more detail what has been published in the professional literature concerning molecular evo-

lution. The *Journal of Molecular Evolution*, established in 1971, is devoted exclusively to answering how life at the molecular level came to be. Approximately 1000 papers have been published in JME over the last decade. Each of these papers falls into one of three classes. About 10% of them deal with origin-of-life research. Classical evolutionists believe that life originated by spontaneous generation. The first research of this type (done by Stanley Miller in 1954) electrified the world when amino acids were produced. People assumed that life would soon be made in the test tube. But listen to the conclusions quoted by Behe from Klaus Dose, one of the researchers in the field:

> *'More than 30 years of experimentation on the origin of life in the fields of chemical and molecular evolution have led to a better perception of the immensity of the problem of the origin of life on Earth rather than to its solution. At present all discussions on principal theories and experiments in the field either end in stalemate or in a confession of ignorance'* (p 168).

The second type of papers in JME (5%) deals with mathematical methods for comparing and interpreting sequence data. Although interesting, these papers assume that evolution is a gradual process; they do nothing to demonstrate it.

The third type of papers (about 80%) were sequence comparisons of nucleic acids or proteins from different organisms. "Although useful for determining possible lines of descent, ... comparing sequences cannot show how a complex biochemical system achieved its function" (p 175). The conclusion Behe reaches is that "*none* of the papers published in *JME* over the entire course of its life as a journal has ever proposed a detailed model by which a complex biochemical system might have been produced in a gradual, step-by-step Darwinian fashion" (p 176). (Behe has been criticized for not mentioning a book by Cairns-Smith, *Seven Clues to the Origin of Life*, which supposedly deals with some of the issues Behe raises.)

Behe's final chapters describe his overall conclusion: life was designed by an intelligent being. Behe discusses design and goes into a long discussion of early ideas of design. He asks why most scientists reject design and concludes that it has to do with the implications of the design idea: if one side of the elephant is labeled "intelligent design," the other side might be labeled "God." But why do scientists not want

to entertain ideas about God? Behe discusses several reasons in his final chapter.

You owe it to yourself to read this book. One word of caution: don't read this book hoping to disprove evolution, and please don't tell people that evolution has now been proven false. *Darwin's Black Box* does not prove that evolution did not or could not happen. Behe makes it clear that he is not saying anything about evolution at higher levels or about how long ago life originated. In his introductory chapter he states:

> *For the record, I have no reason to doubt that the universe is the billions of years old that physicists say it is. Further, I find the idea of common descent ... fairly convincing.... I think that evolutionary biologists have contributed enormously to our understanding of the world.... however, I do not believe [natural selection] explains molecular life* (p 5).

LITERATURE REVIEWS

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COMPROMISED BIBLICAL CREATIONISM

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CREATION COMPROMISES. Bert Thompson. 1995. Montgomery, AL: Apologetics Press. 303 p. Paper, $10.95.

The objective of this book is demonstration that compromise models such as theistic evolution, progressive creation, day-age theory, and gap theory do not conform to sound principles of either biblical exegesis or scientific evidence evaluation. The author affirms that to be logically sound and consistent, one must identify fully with either historical-grammatical exegesis of the biblical testimony concerning creation, or naturalistic evolutionary models for origins; that regardless of the motivation from which they may be proposed, any of the compromise models produce outright, or eventual, loss of essential faith in the full range of biblical testimony.

Dr. Thompson (Ph.D. in microbiology) makes a significant observation that compromise views concerning Creation Week are largely promoted by professors on Christian college campuses.

Pastors, teachers, and writers who are concerned with the maintenance of essential confidence in biblical testimony will find this book a useful resource. It is principally a collection of statements from creationist literature. The organization of these quotations, together with the author's comments, makes *Creation Compromises* a significant contribution to creationist literature.

The discussion of contradictions between the various creation compromises and the Genesis account of origins reflects the author's perspective from which the terms "heaven" and "earth" in the first two chapters of Genesis designate the entire physical universe, and the term "soul" designates an immortal entity possessed by man (see the 22-item listing under "A Million Contradictions — Not a Million Years" on

p 230-233). Nevertheless, individuals whose exegesis is confined to the definitions given in Genesis 1:8-10 and 2:7 (see NIV) will find the book to be largely useful. According to the definition of "earth" given in Genesis 1:10 (e.g., KJV, RSV, NEB, Jerusalem, NASB), the earth is only three days older than humanity, not five days older as specified by Dr. Thompson on p 177.

It is highly significant that "the writers of the Bible deal abundantly with matters of fact in science and history," while the writings of non-biblical religions "deal almost exclusively with faith/conduct matters" (p 55). The authority of the Bible with respect to faith/conduct is related to the accuracy of its testimony regarding past events. On the previous page the author asks, "Why is it that God's *unchanging* revelation in the Bible should be 'reinterpreted' to fit the *ever-changing* theories of modern scientists?" (author's emphasis). On p 55 Dr. Thompson notes that man seeks to become god, whether as a scientist or a theologian, when the straightforward testimony of the Bible is rejected.

In Chapter 10 ("Biblical Genealogies and the Age of the Earth") Dr. Thompson points out that genealogy and chronology are separate considerations. Abbreviation in a genealogy list does not invalidate a chronology that is tied to names that are listed. In Appendix II ("The Bible, Science, and the Ages of the Patriarchs"), he states that "one has to read the Bible with a large dose of imagination and a small dose of common sense" to accept some attempts to avoid the direct sense of the chronology in Genesis 5 and 11.

Creation Compromises is an excellent choice as a basis for a series of discussions by a layperson's group.

GENERAL SCIENCE NOTES

THE INTRIGUE OF THE QUESTIONS ABOUT THE BRIDGEWATER "FOSSIL FOREST" VICTORIA, AUSTRALIA

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WHAT THIS ARTICLE IS ABOUT

Fossils offer intrigue to everyone, from child to adult, and raise many questions. What is it? Where did it come from? How old is it? How did it become a fossil? and many more. Sometimes these questions have easy answers, and other times almost none of them can be answered. The Bridgewater "Fossil Forest" fossil structures fall into this latter category. Field evidence is examined in light of the current theories of the Bridgewater structures. As the data are examined almost none of the usual questions about fossils can be answered. Instead of answering questions, this study has only heightened the intrigue by offering more unanswered questions, such as their origin: transport (allochthonous) or in growth (autochthonous)?

Within the Pleistocene Bridgewater Formation on the western coast of Cape Bridgewater, Victoria, Australia, there are located several square kilometers of unique structures. Over the years these structures have been interpreted in many ways.[1,2,3] They are not only fascinating to the scientist, but also intrigue the layperson. Because of their uniqueness, protection and management of this area has come under the purview of the Department of Conservation and Natural Resources.

The basalt cliffs of Cape Bridgewater tower some 100 meters above the restless ocean. Overlying the black basalt is a reddish fossil soil horizon that has been exposed by erosion and consists of remnants of calcarenite cliffy benches. In scattered areas above these benches is exposed an additional somewhat younger red soil zone. Within these exposed fossil soils are structures resembling small upright trees, saplings, stumps and roots. The upright trees are found in the lower

horizon, while above one finds recent branch-like fossil casts, some of which contain unmistakable woody material within their core. These recent uppermost fossils are distinct from the large tree-like structures below in that they are light beige in color, are directly associated with current local vegetation, and seem to be only a surface phenomenon.

One of the earliest references that mentions the fossil "forests" of the Bridgewater Formation is that recorded by Charles Darwin. This record was drafted during his famous trip on the H.M.S. Beagle:

> *One day I accompanied Captain Fitz Roy to Bald Head; the place mentioned by so many navigators, where some imagined that they saw corals, and others that they saw petrified trees, standing in the position in which they had grown. According to our view, the beds have been formed by the wind having heaped up fine sand, composed of minute rounded particles of shells and corals, during which process branches and roots of trees, together with many land-shells, became enclosed. The whole then became consolidated by the percolation of calcareous matter; and the cylindrical cavities left by the decaying of the wood, were thus also filled up with a hard pseudo-stalactitical stone. The weather is now wearing away the softer parts, and in consequence the hard casts of the roots and branches of the trees project above the surface, and, in a singularly deceptive manner, resemble the stumps of a dead thicket.*

One of the most complete studies of the Bridgewater Formation and the fossil structures was prepared by N. Boutakoff in 1963.[4] However, Boutakoff devoted most of his efforts to the description of the geology of the Bridgewater Formation and the nearby Portland area, only briefly mentioning the fossil structures found within the Bridgewater Formation itself. In his description, Boutakoff does address the relationships of the tree-like structures and the possibility of these structures being solution pipes. As a result of his investigations he concluded that the popular name "Petrified Forest" is fully justified, even if the mechanics of formation cannot be fully described or understood.

Another excellent description of the geological setting of the Bridgewater Formation is found in the treatise "Geology of Victoria," edited by J.G. Douglas and J.A. Ferguson.[5] This treatise is devoted mostly to the geology of the area, and makes only a brief mention of the fossil tree-like structures found within the Bridgewater Formation. In this reference, the description and interpretations given by Boutakoff are

mentioned and accepted without question. The main value of the two references mentioned above is their contributions to the understanding of the geology and geomorphology of the Portland area and the Bridgewater Formation.

A short passing reference to these fossilized structures can be found in the VULCON Guidebook of the Vulcon 1995 20th Biennial Conference. On p 96 these structures are simply referred to as "solution pipes."[6]

With the exception of three or four small fossil structures located in nearby road cuts, the major exposed fossil structures are found between 38º 21' and 38º 23' south latitude. These fossil structures seem to be bounded to the north by a white outcropped limestone very similar to the major limestone outcrop located at the east side of the Bridgewater Lakes. All the major fossil exposures are located west of the Cape Bridgewater Fault.

As mentioned earlier, there are two distinct types of fossil structures: large (100 to 500 mm) diameter molds, found in the lower layers (see Figure 1), and small (10 to 80 mm) limb and root casts, found higher up (see Figure 2). The large molds, when exposed, may attain heights of 1 to 2 meters and may contain a uniform sandy/fat clay (similar to a deeply weathered tropical soil in color but not texture) infill. The limb

Figure 1. Multiple fossil structures resembling small upright trees at Cape Bridgewater. Some of these structures may reach a height of 2 m and a diameter of 400 mm.

Figure 2. Limb and root casts found within local active calcareous dunes at Cape Bridgewater. When broken open, many of these casts still contain fibrous material in the center.

and root casts which still contain the fibrous matter normally do not exceed 1 meter in length.

The large vertical molds are almost exclusively found in open barren terrain while the overlying modern limb and root casts are found in active dunes and bordering local ground cover. Informal observation immediately suggests that these limb and root casts are in near-growth density and position. On the other hand, such conclusions cannot be so easily drawn for the large molds.

Only large mold structures are found below the cliff tops along the Great South West Walk trail. Near the base of the cliffs, the bottom of these large mold structures can be seen abruptly truncating at the top of the basalt basement of Cape Bridgewater. Two or three layers of these large casts may be observed in several locations below the cliff tops. There is no communication between these multiple layers. No multiple layers of the overlying limb and root casts have been observed.

The sandy/fat clay infill of the large molds was removed from several of the molds at various locations within the main exposed area. There

was no evidence of infill stratification or mixture with detrital debris in any of the molds. The infill matrix exhibited the same soft, non-compacted consistency regardless of the location.

When exposed, the lower ends of the molds are often truncated with a rounded slightly bulbous end (see Figure 3). Root systems, when present, can almost exclusively be traced to this bulbous end. The multiple layer molds also exhibited this type of truncation.

Figure 3. Bulbous truncation common to many of the large vertical structures at Cape Bridgewater.

In one specific area several molds with double-ring structures (a mold within a mold) were noted. The inner ring is approximately 30-40 mm smaller in diameter than the outer ring.

Growth density measurements for the large mold structures were obtained by randomly selecting 3×3 meter sites within the formation

and obtaining a number count. The diameter of each mold was also measured and recorded (Table 1).

Table 1. Diameter and density measurements of the large fossil mold structures.

Square #	# Molds/m²	Avg. Diameter (mm)
1	1.89	350
2	2.44	420
3	1.22	400
4	0.67	275
5	2.22	300
6	1.78	540
7	2.78	360
8	1.89	465
9	1.33	385
10	1.78	517
Average	1.80±0.61	401±87

The data were initially examined to determine if they were consistent with either a fossilized autochthonous (in-growth position) forest hypothesis or a solution pipe hypothesis.

The solution pipe hypothesis seems to be the easiest hypothesis to evaluate. If these structures are solution pipes the following questions need to be answered:

- How can one account for such a dense concentration of pipes, over such a large area?
- If these structures are pipes, why are the pipes so close together without showing evidence of collapse or coalescence with one another?
- How can multiple layers of pipes be accounted for, especially when there is no evidence of communication between layers?
- If these structures are pipes, how can bulbous terminations be accounted for, especially those structures which seem to have roots radiating from the terminations?
- In addition to the uniform termination of the pipes, how can we account for the fact that many of these structures remained hollow? When the solutions ceased to flow, why didn't the pipes just fill up and harden?

In attempting to answer the above questions it becomes obvious that these features require an explanation other than a solution pipe hypothesis.

The most popular hypothesis is an autochthonous (in growth position) fossilized forest. This hypothesis seems to be supported by the general size, orientation, and shape of the large mold structures. The presence of roots extending from the base of some of the molds into a presumed paleosol would also tend to support the tree hypothesis. However, there are a number of other questions about this hypothesis which need to be addressed:

- If these structures represent normal trees, why are the vast majority of molds hollow?
- How can one account for the close spacing density if these structures represent a normal autochthonous forest?
- If these structures represent an autochthonous forest, how can one account for the multiple layering of these structures?

Some of these questions were also raised by Boutakoff in 1963.[7] It would seem that none of the standard hypotheses adequately address all of the data. This is especially true when the small limb and root structures are included with the large mold structures.

In order to accommodate all or nearly all of the field observations and data, this investigator is proposing a two-part model consisting of both an autochthonous and an allochthonous (transported) interpretation of the data.

The autochthonous deposit is recent. It includes the upper beige calcareous limb and root casts. Excavation of the limb casts reveals the root casts that are in direct communication with the limb casts and often contain fibrous woody matter. These beige structures have not been found within the red paleosols of the larger vertical tree-like structures and appear to be derived directly from the calcareous dune sands. The limb and root casts border similar existing ground cover and conform to local growth patterns and density. These beige cast structures are also approximately the size and shape one would expect from the fossilization of the current ground cover.

A plausible model for the formation of the limb and root casts has been outlined by Boutakoff.[8] He suggests that during initial formation, the limb or root is simply enclosed in calcareous sand, which results in

an increase of the original diameter. Secondly, the enclosed matter decays, either partially or totally, and becomes calcified. The resulting calcified structures are what is observed in the field today.

Since the surrounding cast material is similar in composition to the local migrating dunes, the following scenario can be proposed:

1. The migrating dune encroaches living ground cover, eventually inundating and killing the plants.
2. As the plant material decays, the organic acids exude into the surrounding sand and form a lithic calcareous sand cast about the limb or root.
3. After formation of the cast, wind erosion exposes the casts.

The thickness of the cast is controlled by the amount of organic acids produced during decomposition. In other words, the size of the cast is proportional to the initial size of the root or limb and the degree of decomposition.

The lower, large mold, allochthonous deposit of the model comprises the largest portion of the Bridgewater Fossil Formation and is the most difficult to understand. The allochthonous segment of the model contains only large mold casts. Evidence supporting the allochthonous position comes from the fact that there are multiple, successive layers of these structures without any evidence suggesting a fossil soil zone. Additionally, in order to accommodate the growth canopy, the growth-density for an *in-situ* forest should be much less than the measured mold structure density, unless the flora was similar to the horsetails. Furthermore, an allochthonous model for the large casts would be more compatible for structure emplacement in limestone than the autochthonous model because the limestone could also be a product of the transporting environment.

Before an acceptable depositional scenario can be proposed, the following questions need to be answered:

- If the mold structures were *in-situ*, why aren't more root systems found?
- Why are a large percentage of the mold structures hollow?
- Where did the non-stratified infill matrix originate?
- What type of flora is represented by the mold structures?
- What is the source of the surrounding limestone?
- If not allochthonous, what was the mechanism of deposition?

When all of the field data are taken into consideration it seems logical to divide these fossil structures into a modern segment and a prehistoric segment. The reasoning behind this division is two fold. First is the distinct difference in the calcilithic agents. The modern segment seems to be composed of material similar to the calcareous dunes in the locality. The prehistoric large mold structures are composed of a totally different calcilithic agent, as determined from composition and color. Second, the root and limb casts are similar to the local living flora, and seem to be directly associated with such flora. In other words, the root and limb casts seem to be a surface phenomenon only. In contrast, the large mold structures seem to have no modern-day analogue. Because of their superposition, all of the fossil structures (modern and prehistoric) had to occur after the deposition of the Iddingsite basalt flows that form Cape Bridgewater and Cape Duquesne.

Interpretation of the multiple layering of the large mold structures, coupled with the bulbous terminations and lack of roots or rhizome structures for these molds, would lend itself more readily to a transport mechanism. Transport and deposition could be directly or indirectly associated with the subsidence of the Nelson caldera, as proposed by Boutakoff.[9] However, the hollow features of these molds is problematic to a transport mechanism unless the structure of the flora itself is composed of similar-length segmented tubes.

An enigmatic feature of the prehistoric large molds is the red sandy/fat clay infill. What is the origin of this material? Why is there no evidence of stratification of this infill material within the mold structures? Why is there a distinct lack of detrital matter within this infill matrix? One of the few logical explanations for this infill material is to suggest that this material originated from a single event and a single source, and that the filling process was rapid. Because the infill is not lithified and exhibits a different mineral composition than the surrounding shell, the major fossilization mold probably occurred before infill.

Are there any flora analogues for the mold structures found in other Pleistocene deposits in the surrounding area? Before this question can be answered, one needs to know if there is any possible prehistoric flora analogues similar to these mold structures, irrespective of their position within the geologic column?

A modern day analogue can be found in the horsetails. Horsetails are in the family *Equisetaceae*, which are found within the geologic

column from the Permian to the recent.[10] Horsetails have hollow segments, closed at the upper and lower ends. The lowest of these segments has a bulbous termination from which the root mass extends. It should be noted that the average diameter of modern horsetails in the western hemisphere is on the order of 10 mm rather than 400 mm. However, ancient horsetails of flora do reach the size of these large molds.[11] The similarities of modern horsetail and the large mold structures are impressive. A study conducted on flotation characteristics of modern horsetail by H. G. Coffin[12] suggests that upright position and segment separation of *Equisetum* fossils may be associated with transport and not restricted to in-growth position. This is especially true if there is an absence of basal rhizome structures. In several sites, the large molds exhibit structural features that may be interpreted as segmentation. Segmentation can also be implied from the fact that the large mold structures, where completely exposed, seem to have equal lengths.

A review of J.G. Douglas' book "What Fossil Plant Is That"[13] and "Geology of Victoria"[14] suggests that members of the *Equisetaceae* family are not found above the Cretaceous in Victoria. This may not be a problem with a catastrophic transport mechanism. It may be that the *Equisetaceae* grew in the inland Malanganee swamps, and were simply stripped off and deposited at Cape Bridgewater. Before such a mechanism is acceptable, more research needs to be conducted in the Portland, Victoria area.

CONCLUSIONS

As one reviews the field observation data and the geological setting of the Cape Bridgewater area, a catastrophic transport/deposition hypothesis seems to currently offer a better explanation for the large molds than does an *in-situ* growth hypothesis. A transport/deposition hypothesis could account for the multiple layers of the large mold structures as well as the unique infill matrix. Additionally, a transport/deposition hypothesis would be more compatible with these large mold structures being found in the limestone cliffs directly above the Bridgewater basalt.

The beige root and limb casts are a recent phenomenon directly associated with the calcareous dune migration. The source material for these casts seems to be the local flora rather than material transported

in from a different area. These modern fossils do not require any unusual explanation such as transport or deposition.

The value of this study extends beyond the specific locality in that it supplies additional information in understanding the paleoecology and sedimentation history of the Pleistocene epoch of the southern hemisphere.

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EDITORIAL

DO WE NEED TO TURN OFF OUR BRAINS WHEN WE ENTER A CHURCH?

It has been suggested that when scientists pass by the check-in counter of a church, they might as well check in their brains along with their hats, umbrellas and overcoats. The implication is that in a church, you don't need to use your brain; there you are in the realm of faith!

Science is often equated with reason, and religion with faith. We find it convenient to talk about faith and reason as separate entities, but the dichotomy between the two soon breaks down when one considers that it takes a degree of faith to believe in science, especially some of the more speculative areas such as cosmology or evolution. Furthermore, religion, especially Christianity, has a strong appeal to reason. This appeal is the basis of a well-accepted thesis endorsed by such noted scholars as A.N. Whitehead, R.G. Collingwood, and S.L. Jaki. The thesis proposes that modern science developed in the western world because of the consistency seen especially in the God of the Bible. The Bible generally implies cause and effect, which relate to reason and science. The relation of science to a Judeo-Christian (Biblical) background is further supported by noting that the Hindu, Chinese, Mayan, Egyptian, Babylonian, and Greek cultures, all had varying degrees of incipient science, but these initial stages ended in stalemate. The probable cause was overruling philosophical concepts associated with unpredictable and capricious gods. The Bible presents only one God, who is reasonable, consistent, and usually predictable. These principles fit well with science. While we cannot be certain that this is the reason that modern science developed in the western world, the very existence and popularity of the thesis suggests that there need not be a strong dichotomy between science and biblical religion. Thus we don't need to turn our brains off when we enter a church, at least not a Christian, Muslim, or Jewish church.

Other questions further confound the separation we like to make between faith and reason. Can we ignore the faith we have in the reasoning process? How can we be sure that our reasoning

is correct, or be sure that we have enough information to draw proper conclusions? Unfortunately we don't know how much we don't know, but we have faith that we know enough to arrive at major conclusions through reasoning. Conversely, faith is often based on reason. In its most rational form, faith can be a logical extension of our reasoning process. The facts we observe serve as a basis for reasoning beyond the demonstrable, but this moves us towards the realm of faith.

In the ongoing controversy between science and the Bible, some attempt reconciliation by proposing an irresolvable dichotomy between the two. Such thinking has some basis in the dualistic philosophy, promoted by Decartes and others, that mind and matter are totally separate. Matter would be more in the scientific realm, and religion more in the realm of the mind. Such a dichotomy is reminiscent of the comment that some scientists think about God, but only on weekends. Any suggestion of such dualism runs into the challenge of the concept of truth. Truth is truth on weekends as well as during the week, and it is truth whether we are in or out of a church. Truth is reality, and if reality exists (few deny its existence), it should be consistent in all its manifestations, whether in the realms of matter or mind, or similarly in the realms of science or religion. Truth could not contradict itself or it would not be truth. Furthermore, both science and religion in varying ways and degrees seek for truth.

Attempting to separate science and religion can be a convenient way to avoid the truth challenge, but it does not bring us to truth. In the context of the Bible we must acknowledge that the truth that is sought for is manifest in both God's word and God's creation. Each should bring us to the same truth. In the context of science, truth should be consistent with the data of nature, as well as other aspects of reality, including such abstruse components as humanity's spiritual dimension. If science is looking for truth, it needs to be open to those aspects of reality, such as morality or our freedom of choice, that are beyond the cause-and-effect system of science. Reality is too complex to be isolated into the simple components of faith and reason. We cannot neatly turn off one or the other.

There is a further reason why we should not turn our minds off when we enter a church. An impressive body of scientific information has been found that supports the biblical model of origins better

than science's evolutionary model. Since there are hundreds of thousands of scientists interpreting nature in a model that excludes the Bible, and only a small number who include it, the number and the strength of the scientific findings that fit better with the Bible is rather remarkable. What would the picture be if a larger proportion of scientists were interested in seriously evaluating the biblical concept of beginnings? I would venture that we would have a very different intellectual climate of opinion regarding origins.

Much of the scientific data that supports the Bible has been discussed in various ways in previous issues of this journal. A detailed list would be quite long. The leading topics and questions relate to the following: (1) How could life originate by itself? (2) After nearly two centuries there is still no workable model for the development of biological complexity, thus seriously jeopardizing Darwin's model of natural selection. (3) The proposed billions of years for the evolution of life are totally inadequate for the improbable events proposed for evolution. (4) The rapid rates of erosion of the continents challenge their existence for the presumed billions of years. (5) The lack of erosion at assumed gaps in Earth's sedimentary layers indicates that only a short time was involved in their deposition. Other evidence also reflects the rapid deposition of these layers as expected from the biblical flood. (6) The extreme rarity of fossil intermediates between the major groups of organisms suggests that evolution from simple to complex never occurred. (7) A significant number of scientists who do not believe in the Bible are criticizing the evolutionary model. This scientific data demands answers. In my opinion, the creation model of the Bible survives critical evaluation much better than does the naturalistic evolutionary model.

The scientific findings that support the Bible indicate that we don't need to turn off our brains when we enter a church. Truth, which has to be consistent in all aspects of reality, does not fear investigation in all realms. If we are looking for truth, we need to keep our minds functioning at all times, evaluating truth and error as best we can in all realms, whether in the church or in the laboratory.

Ariel A. Roth

"LAYING DOWN THE PEN"

In the old days, when one finished a writing task it was appropriate to use the climactic cliché: "Laying down the pen." That was the end. The modern equivalent would be: Turning off the computer. However that does not seem as final to me. We turn off our computers every time we have to reboot to get out of a malfunction. Clichés aside, this is the last issue of ***Origins*** that I will be editing. Producing ***Origins*** has been stimulating, satisfying, and challenging. It is a joy to see every issue published. However, I have carried this responsibility for 23 years, and the time has come for a change. It is with a mixture of regrets, relief, and anticipation that I turn to other activities.

Origins could not exist without the help of many. I am most grateful to the authors who have provided a high quality of writing that which has permitted the journal to gain the degree of respectability which it has. These authors have not only produced original scholarly material, but they have been very patient with suggested changes as manuscripts were processed towards publication. Their dedication has facilitated the sometimes painful surgery suggested by reviewers and editors. The reviewers themselves, who are the unsung heroes of the editorial process, have been invaluable, and I want to thank them for their long hours of unselfish work. They have been the silent guardians of quality.

A few individuals have made very special contributions to ***Origins***. I especially wish to thank Bob Brown and Leonard Brand for their careful criticism of practically everything that was published. Kathy Ching has put every issue together into a rational whole, and Jim Gibson has prepared most of the scientific-literature reviews in the recent years of publication. All of these and many others have my profound gratitude. I also wish to thank the readers, particularly for their feedback, much of it more generous than we deserve.

I well remember writing the first editorial for ***Origins***. It was in 1973 on a flight to Hawaii as I was headed for Enewetak Atoll to continue my research on coral reefs. I mused about how to start a new journal, its success or failure, and especially its purpose. In that editorial I expressed my hope that ***Origins*** would help give a correct view of the Creator by the study of both His creation and His revelation. Many of the questions that have been discussed in ***Origins*** could have been purely academic, but their implications were not. This is where all those who have helped with the journal have made a contribution far and

above normal journalistic activity. They have contributed towards a correct image of the nature of the Creator and His activities. In this age of relativism, agnosticism, skepticism, and pluralism, such information is much needed. As I bid you farewell, I wish to thank all of you for your special contribution, and I want to encourage you to continue your highly meaningful activities of witnessing for the truth about our Creator. May God bless each of you.

Ariel A. Roth

ARTICLES

FOSSIL PATTERNS: A CLASSIFICATION AND EVALUATION

Jim Gibson
Geoscience Research Institute

WHAT THIS ARTICLE IS ABOUT

One of the most interesting challenges in understanding Earth history is explanation of the order in the fossil record. Identification and analysis of fossil patterns may provide one of the tools needed to reach a better understanding of the fossil record. Fossil patterns and fossil trends that extend through the fossil record imply that some processes acted throughout the production of that record. In this paper, 25 reported fossil patterns are classified into four categories: fossil diversity patterns; fossil morphological patterns; fossil ecological patterns; and depositional patterns. Possible creationist and evolutionary interpretations of these fossil patterns and trends are described. Some fossil patterns seem difficult to explain from a creationist viewpoint; others seem difficult to explain from an evolutionary viewpoint. Further research of fossil patterns and fossil trends may aid in our understanding of the processes that were responsible for producing the order in the fossil record.

Study of the fossil record has revealed much about the past. Our knowledge has been developed through the study of such features as anatomical structures, the degree of preservation, the types of fossils found together, and the nature of the surrounding sediments. With the accumulation of such data, it is natural that comparative studies would be undertaken to determine what patterns can be identified. Patterns in the fossil record may provide valuable clues to identifying processes active during production of the fossil record. This paper is intended to survey and classify the types of fossil patterns that have been reported in the literature, and to comment on their possible significance. Most of the fossil patterns reported here are from the Phanerozoic portion of the geologic column (see Figure 1), but some Precambrian patterns are included.

Stratigraphic Level		Typical Fossils
Cenozoic	Quaternary	Humans, familiar mammal species
	Neogene	Familiar mammal types
	Paleogene	Extinct mammal types
Mesozoic	Cretaceous	Dinosaurs
	Jurassic	Dinosaurs
	Triassic	Archosaurs
Paleozoic	Permian	Reptiles
	Carboniferous	
	Pennsylvanian	
	Mississippian	Coal plantsAmphibians
	Devonian	Fish
	Silurian	Marine invertebrates
	Ordovician	Marine invertebrates
	Cambrian	Marine invertebrates
	Vendian	Ediacaran fossils
Precambrian	"Pre-Vendian"	Bacteria

Figure 1. A greatly simplified outline of the biostratigraphic column.

Many general patterns in the fossil record have been reported. Fossil patterns that show a sustained directional change are here referred to as fossil trends. We may distinguish two types of fossil trends.[1] A replacement fossil trend exists when fossils with certain characteristics are replaced by fossils with different characteristics. An addition fossil trend occurs where fossils with certain characteristics are joined by fossils with different characteristics. Both types of trends are found in the fossil record. These different types of trends may have different causal explanations, so it is important to note which kind of trend is involved in any given pattern. All patterns are generalizations, and exceptions may occur.

Most fossil patterns can be placed in one of four categories. (1) Diversity patterns are those that relate to the frequencies of fossil taxa. (2) Morphological patterns are those that relate to morphological characteristics of fossil taxa. (3) Ecological patterns involve consideration of the types of habitats represented by the fossils, without concern for taxonomic group. (4) Depositional patterns are those that relate to the types of sediments in which fossils are preserved; for example, whether catastrophic burial conditions are indicated.

Hundreds of examples of fossil patterns have been reported, far greater than can be mentioned here. By grouping them in categories, it is possible to describe representative fossil patterns and attempt an evaluation of their significance (see Appendices 1-3).

MAJOR PATTERNS IN THE FOSSIL RECORD

Diversity Patterns

Repeated biotic turnover. Diversity patterns form some of the most conspicuous and significant features of the fossil record. One of the most important features of the fossil record is the separation of different types of fossils into different strata.[2] (This pattern does not show so well in the Precambrian strata.[3]) This separation of fossils into different layers is so consistent that scientists often use the fossils to assist in classifying the sediments. As an example, consider the extinct group of arthropods known as trilobites. Trilobites are found only in Paleozoic rocks. Certain types of trilobites occur only in Cambrian sediments, others occur only in Ordovician sediments, and some occur only in other layers. Likewise, dinosaurs are found only in Mesozoic rocks, with different types of dinosaurs in Triassic, Jurassic and Cretaceous layers. Biotic turnover is a replacement pattern, and contains two striking component patterns, discussed in the following two sections.

Scientists have noted how consistently the fossils are arranged in layers, and have arranged these layers in sequence, and compared them with layers from other regions. A kind of "master sequence" has been prepared. This master sequence of fossils is known as the biostratigraphic column (see Figure 1). Strata with Cenozoic fossils occur at the top of the column, with strata containing Mesozoic fossils beneath them, and rocks containing Paleozoic fossils beneath the Mesozoic strata. The *Precambrian* layers occur below the Paleozoic.

Coordinated appearances. A striking feature of the fossil record is the sudden appearance of numerous types of fossils in various locations over the Earth at about the same point in the geologic column. The most famous example occurs in the Cambrian rocks, which lie at the base of the Paleozoic rocks,[4] and is called the "Cambrian Explosion." Precambrian rocks contain relatively few fossils, most of which appear to be bacteria. There are a few strange fossil impressions below the Cambrian, known as Ediacaran fossils, that may represent multicellular organisms. But a large proportion of the major groups of invertebrates with hard skeletal parts are represented as fossils in the Cambrian strata (see Figure 2). Many phyla of soft-bodied animals are missing from the Cambrian record, but this is thought to reflect the incompleteness of the fossil record, not the absence of these phyla during deposition of Cambrian sediments. Many other examples of coordinated appearance

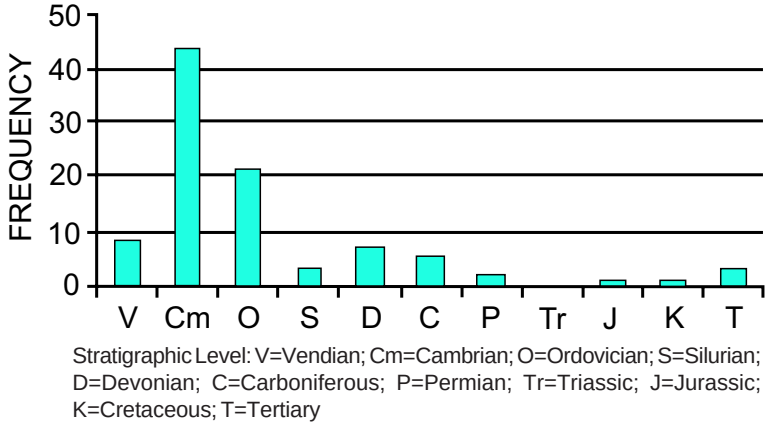
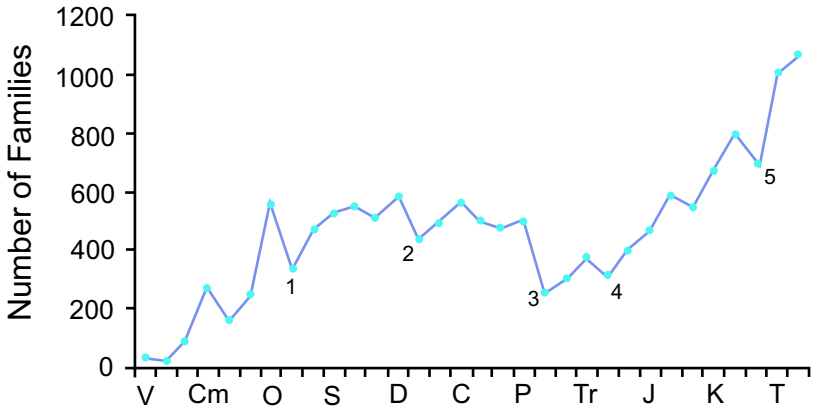


Figure 2. Frequencies of first appearances of classes of marine animal fossils. (Data from Erwin, Valentine & Sepkoski 1987; see Endnote 5.)

occur,[5] but the Cambrian Explosion is by far the most spectacular example. Coordinated appearance is an addition pattern that persists throughout the fossil record. No trend has been reported for this pattern.

Coordinated disappearances. Large numbers of fossil species may disappear from the geologic record at a specific stratigraphic level (see Figure 3). The disappearance is never complete, but there are several examples where estimates indicate that more than 50% of the species disappear at the same stratigraphic level.[6] Boundaries between stratigraphic levels are often identified on the basis of coordinated disappearances. The greatest example of this is the disappearance of nearly half of the families (see Figure 3) and an estimated 95% of all species at the top of the Paleozoic. Dinosaurs and many other groups of reptiles and marine invertebrates disappear from the record at the top of the Mesozoic. Other examples of large-scale coordinated disappearances occur at the top of the Ordovician, near the top of the Devonian, and the top of the Triassic. Coordinated disappearance is a subtraction pattern. No sustained trends in this pattern have been reported.

Increasing diversity. The number of species generally increases as one moves upward through the fossil record. The increase is highly irregular, but the overall trend is clear.[7] For example, the number of species known from Cambrian rocks is approximately 8,000, increasing to 15,000 in the Carboniferous (upper Paleozoic). Total species diversity



Stratigraphic Level: V=Vendian; Cm=Cambrian; O=Ordovician; S=Silurian; D=Devonian; C=Carboniferous; P=Permian; Tr=Triassic; J=Jurassic; K=Cretaceous; T=Tertiary. Points labeled 1-5 represent the five largest "mass extinctions"

Figure 3. Stratigraphic pattern of the number of families of marine invertebrates represented by the fossils in each stratigraphic level. (After Sepkoski 1993; see Endnote 6.)

then drops, but increases to 22,000 in Cretaceous rocks, and to 43,000 in Cenozoic rocks. Similar trends toward increased diversity are observed for genera and families (see Figure 3), but not for phyla and classes (see next section). Diversity also often increases within a taxon; for example, the number of species or genera may increase within a family or higher category. Increasing diversity is a trend involving both addition and replacement, with addition dominating. A notable exception to this pattern is the increase and then decrease in microfossil diversity in Precambrian rocks.[8]

Disparity before diversity. Disparity refers to the extent of morphological divergence among members of a group, while diversity refers to the number of taxa within a group. Remarkably, the number of fossil species (diversity) in the Cambrian is low, but the number of phyla and classes (disparity) is high, compared to the numbers in other portions of the geologic column. In general, each phylum or class of Cambrian fossils contains only a few species, while these same groups may have larger numbers of species in strata above the Cambrian. The strata above the Cambrian contain larger numbers of species and families, but

few additional phyla. Thus the Cambrian fossils are highly disparate, but the number of species (diversity) is relatively low. This pattern has been called "disparity before diversity" by Stephen Jay Gould.[9] There are other examples in the geologic column where disparity precedes diversity within certain groups,[10] but the Cambrian Explosion is the greatest example. This pattern has only a very weak directional component, and probably does not qualify as a fossil trend.

Provinciality. Provinciality refers to the distinction between fossil assemblages from different geographic regions. Provinciality is said to be high when each region has a distinctive fossil assemblage, and low when the number of distinct fossil assemblages is low. Stratigraphic patterns of provinciality generally require more data than are readily available. However, it has been reported that provinciality of terrestrial biotas tends to increase through the fossil record.[11]

Morphological Patterns

Increasing complexity. Morphological trends most closely related to the theory of common ancestry are of special significance to discussions of creation and evolution. One of the most widely reported trends is the increase in complexity, from bacteria in Precambrian rocks to humans in the Cenozoic strata. This is sometimes seen as the major theme in evolution — from simple to complex. Complexity is a difficult concept to quantify, but the number of cell types has been used as an estimator of complexity.[12] However, the cell type data supporting this trend appear correlated with the vertebrate sequence (see Figure 4), and may be an accidental by-product of that sequence. The trend toward increasing complexity is actually an addition trend, not a replacement trend. There is no evidence that living bacteria are more complex than bacteria found in Precambrian rocks.[13] The trend toward increasing complexity is correlated with the trend toward increasing diversity. Certain groups considered to be more complex, particularly groups of vertebrates and plants, progressively appear in the geologic record in a sequence that corresponds with increasing complexity.

Morphological species-stasis. Morphological stasis is the persistence of morphology through portions of the geologic column.[14] Although there is some dispute over this pattern, it appears that most paleontologists accept the predominance of morphological stasis in species, A fossil species typically looks the same at the first and last appearances.

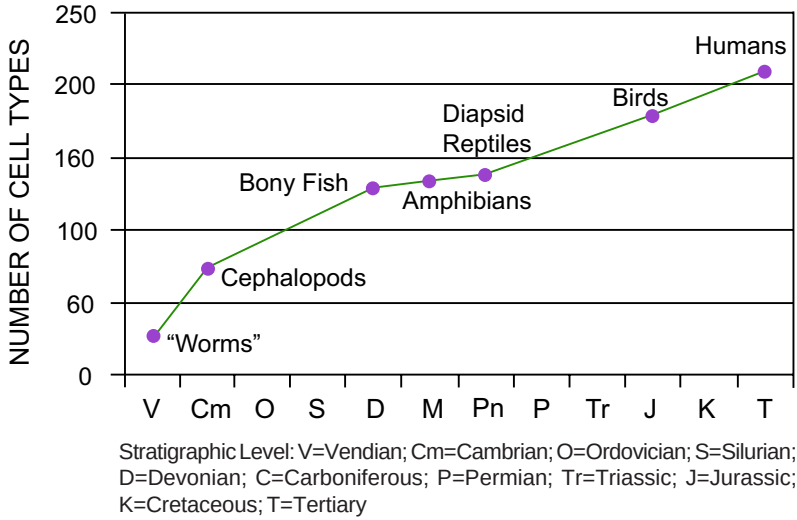


Figure 4. Stratigraphic increase in maximum number of cell types. (After Valentine 1994; see Endnote 12).

Individual specimens may show minor variations around some average, but there is generally no directionality to morphological differences within a species. Numerous examples of directional change have been proposed,[15] but these are claimed to represent a minority of cases, and some have been reinterpreted by other studies.[16] The most extreme case of stasis is probably the cyanobacteria, which appear the same in Precambrian sediments and in modern living populations.[17]

Morphological higher-taxon stasis. Morphological stasis at higher taxonomic categories[18] refers to the persistence of body plans at taxonomic categories higher than species. For example, many invertebrate body plans at phylum and class levels persist through the entire Phanerozoic. This persistence does not produce a fossil trend, but continues throughout the fossil record. Higher-taxon stasis is related to the appearance of disparity before diversity, discussed above.

Coordinated stasis. Coordinated stasis refers to the observation that groups of species in a particular geologic formation, or portion of a formation, may remain essentially unchanged through sediments that are interpreted as representing millions of years of time.[19] Fossils exhibiting coordinated stasis may occur in sediments that are bounded above and below by horizons of high biotic turnover. Currently, this pattern is contro-

versial, and more study is needed to test its significance. No direction has been reported for this pattern.

Morphological gaps among species. Fossil species are typically separated from each other by gaps in morphology.[20] This causes the abrupt appearance typical of fossil species. Of course, it should be remembered that fossil species are typically identified on the basis of morphology. It is the existence of morphological gaps that permits different fossil species to be distinguished. Two fossil species that grade into one another might be recognized as a single species with greater than average variability. Fossil species with higher than average variability are known, but this situation can also be found in some living species. In general terms, it appears that individual variation within fossil species is usually of the same magnitude as it is within living species. This pattern persists throughout the fossil record, without any directional tendency.

Morphological gaps form a nested hierarchical pattern. Morphologies of fossils generally can be arranged to form a hierarchically nested pattern, forming the basis of the present system of taxonomic categories. A group of species separated by small morphological gaps comprises a genus. Genera are separated by larger morphological gaps. The gaps are of increasing size as one considers higher taxonomic categories such as families, orders and classes.[21] New fossil discoveries sometimes reduce the size of the gaps, especially at lower taxonomic levels,[22] but the gaps at higher taxonomic levels are strikingly distinct. This pattern does not seem to result in any directional trend through the fossil record. Occasional exceptions to this pattern occur in the form of "morphological mosaics" — species with a mixture of characteristics from two or more otherwise morphologically distinct groups. Such species may indicate the artificial nature of our taxonomic system.

Changes in body size. Body size often shows a directional trend for species within a group.[23] Trends toward increasing size are better known, but trends toward decreasing size are also reported. Most trends among tetrapods (amphibians, reptiles, birds and mammals) involve size.[24] Trends in body size may be addition trends or replacement trends. Trends in body size are stratigraphically limited — they typically extend through only one or a few stratigraphic divisions.

Morphological series. Fossil species can often be arranged in a morphological series in which the directionality of morphological change

is consistent with the stratigraphic sequence of the fossils.[25] The most famous example of this is the horse series, which begins with a 5-toed species (which may or may not be a horse) in the Eocene (lower Tertiary), progresses to a group of 3-toed species in the Oligocene and Miocene (middle Tertiary), and ends with living one-toed horses. This trend is accompanied by a trend toward increasing body size.[26] Another morphological series is the increasing mammal-like characteristics in the synapsid reptiles of the upper Paleozoic and lower Mesozoic rocks.[27] Other examples include the series from dinosaurs to birds,[28] from land mammals to whales,[29] and among groups of invertebrates.[30] Morphological series are primarily replacement trends, but also more may be some addition.

Increasing modernity. Most fossils are of extinct species, but some are more similar to living species than are others. Fossils from higher in the stratigraphic column resemble living species more than do the fossils from lower in the column.[31] For example, Cenozoic mollusks are rather similar to living species, while Mesozoic mollusks are less similar, and Paleozoic mollusks are quite different from those living today (Figure 5). This trend is seen also among the vertebrates. Paleozoic fish are mostly strange-looking fish, unlike any living today. Mesozoic fish are more similar to living fish, and Cenozoic fish look quite similar to living kinds of fish. This replacement trend is well known and applies to nearly all groups of organisms except the bacteria, which seem to have changed very little.[32]

Ubiquitous specialization. Specialization of a species means that the species has morphological structures that appear appropriate for specific habitats or ecological roles. Virtually all fossil species are specialized in some way. This is illustrated by the arthropods of the Cambrian Explosion, as pointed out by Gould.[33] Species lacking notable specialization are said to be generalized. Most species have some features that are relatively generalized, while other features may be highly specialized. This is a general pattern in the fossil record, and does not form a directional trend.

Lack of identifiable ancestors. The fossil record contains more than two hundred thousand species. Finding relationships among these species is problematic.[34] Higher taxa are often referred to as ancestral to other higher taxa, but evolutionists acknowledge that higher taxa cannot be actual ancestors of anything, since they are taxonomic constructs rather than real entities. Groups of species with successively smaller morphological differences can be identified, and genealogical relationships can

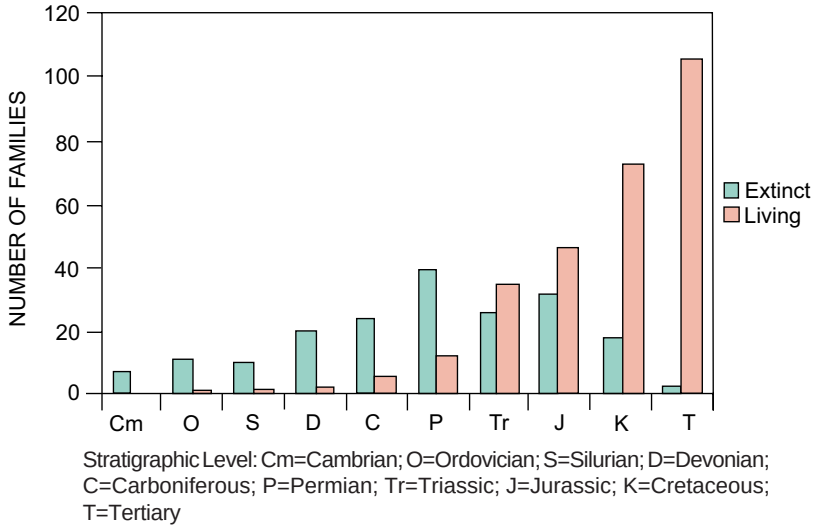


Figure 5. Comparison of numbers of extinct and living bivalve families. (Data compiled by Leonard Brand from Benton 1993; see Endnote 2).

be proposed. However, it is remarkably difficult to identify one fossil species as directly ancestral to another. The difficulty is compounded as the taxonomic category under discussion increases. One of the chief reasons for the difficulty is that nearly all species have some specialization that is thought to preclude them from the direct ancestry of any other known species. No directionality for this pattern has been reported.

ECOLOGICAL PATTERNS

Increasing habitat diversity. The number of habitats represented increases as one moves upward through the geologic column.[35] Precambrian rocks are dominated by fossils of bacteria. Cambrian rocks have only marine fossils, mostly of species that lived on hard substrates on the sea floor. Fossils of freshwater species first appear in numbers in the Silurian (mid-Paleozoic), although there are some possible freshwater species in lower deposits. Fully terrestrial species are reported from Silurian rocks, but are better represented in Devonian rocks. Mesozoic rocks contain fossils from a greater diversity of habitats, and Cenozoic rocks continue the trend toward greater diversity of habitats represented. This principle extends as well to ecology at a smaller scale. Twenty ecological guilds have been identified in the marine realm.[36] Nine of these

are present in the Cambrian, 14 are present in the Paleozoic as a whole, and 20 are present in Cenozoic fossils. This is another example of trend by addition, in this case an "ecological expansion."

Increasing terrestriality. Some trends toward increasing terrestriality in the fossil record have been reported. Fossils from the lowest Paleozoic strata are all of marine creatures that apparently lived on or close to the sea floor.[37] In the middle Paleozoic, one finds not only sea creatures, but also many fossils of species that apparently lived in swamps or perhaps along the margins of the seas or rivers. In the upper Paleozoic, one finds fully terrestrial species. Mesozoic and Cenozoic fossils include representatives from all the preceding ecological habitats. The clearest examples of this trend are given by the sequence of first appearances of groups of plants[38] and vertebrates.[39] The lowest vertebrates in the geologic column are fish, which require water. The next ecological type to appear are the amphibians, which live along water margins. Higher in the column, they are joined by the reptiles, which can live away from water. Mammals and birds are the last classes of vertebrates to appear as fossils. Increasing terrestriality is not a strong trend, because exceptions occur. The most notable exception may be the dominance of (probably) photosynthetic bacteria in the Precambrian, although there have been suggestions these could have been subsurface contaminants.[40] It is important to note that this trend is not a replacement trend, but an addition trend, because all these habitats are still occupied.

Increasing mobility. A possible trend toward increasing mobility has been reported among marine invertebrates.[41] Paleozoic fossils are said to be dominated by species living on or near the sea bottom and with limited mobility. Mesozoic and Cenozoic marine fossils tend to include more mobile types. On land, there may be a similar effect produced by trends toward increasing size, such as seems to be the case among some of the dinosaurs and mammals.[42] It is not certain how common this trend is. If the trend is valid, it would be another trend by addition.

PATTERNS IN DEPOSITIONAL ENVIRONMENTS

Storm deposits. Information about patterns in depositional environments is not as readily available as for the other patterns included in this study, but some work is being done in this area.[43] For example, storm deposits are reported to occur most frequently in Ordovician, Silurian, Devonian, Jurassic, and Cretaceous rocks (see Figure 6). Deposits in-

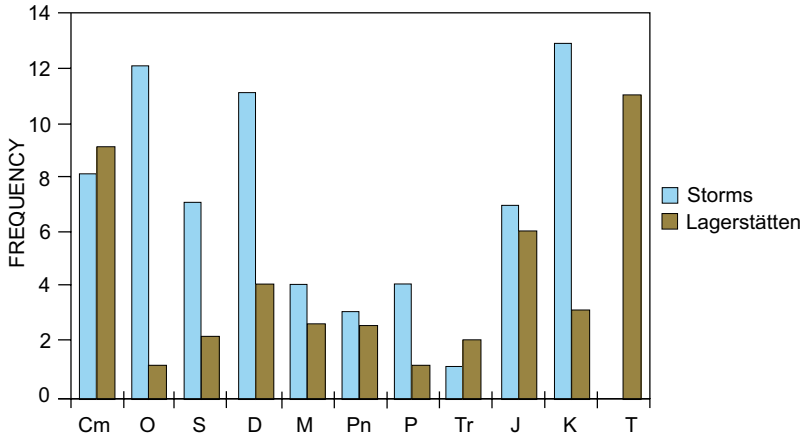


Figure 6. Stratigraphic distribution of storm deposits and lagerstätten. (Data from Marsaglia and Klein 1983, and Allison and Briggs 1993; see Endnotes 43 & 44.)

terpreted as hurricanes are most frequent in Ordovician and Devonian, while inferred winter storms are most common in Silurian and Cretaceous rocks.

Well-preserved soft-bodied faunas. Most fossils are remains of hard-bodied organisms, especially mollusks, echinoderms, arthropods, vertebrates and plants. However, some areas (called "lagerstätten") are known for the exceptional preservation of soft-bodied fauna, including worms, etc.[44] Such exceptional faunas are scattered through the geologic column, but may be overrepresented in Cambrian and Jurassic rocks (see Figure 6).

Depositional energy for first appearances. Sediments can be identified as high or low energy based on the sizes of the particles. Large particles require more energy for their transport and deposition than do small particles. Low-energy deposits, such as marine shales, are often associated with deep water deposition, while higher energy deposits, such as marine sandstones, may be interpreted as near shore deposits. It has been observed that most higher taxa of marine invertebrates have first appearances in high energy deposits, while last appearances

tend to be in low energy deposits.[45] This trend is typically called the onshore-offshore hypothesis.

Depositional environments. Certain types of sedimentary deposits show patterns or trends in frequency in the geologic column. For example, 85% of inferred lake deposits occur in Cenozoic rocks, 11% in Mesozoic rocks and only 4% in Paleozoic rocks.[46] On the other hand, limestone comprises a larger proportion of Paleozoic and Mesozoic rock, with lower proportions in Cenozoic rocks.[47]

Preservational modes. This is an area that has not received sufficient study. Some published reports indicate stratigraphic differences in modes of preservation.[48] For example, silicification is reportedly more common among Paleozoic fossils than among Mesozoic or Cenozoic fossils. More information is needed regarding this type of pattern.

A NOTE ON GEOGRAPHIC PATTERNS

Several patterns that reflect geographic variation within a stratigraphical division have been observed in the fossil record.[49] Geographic trends include diversity gradients and variation in length of stratigraphic range. Latitude is a well-known factor affecting geographical trends. Geographical patterns are beyond the scope of this paper, unless they are compared through the stratigraphic column.

PROBLEMS IN INTERPRETING FOSSIL PATTERNS AND TRENDS

It may be quite difficult to determine a cause behind a fossil trend. In fact, apparent trends may occur in random data.[50] Trends may also be "hitchhikers" that are merely the result of a trend in some other feature.[51] For example, many "trends" in morphological characters are correlated with trends in body size or ecology.[52] These cautions should be kept in mind when interpreting fossil trends.

EXPLAINING THE FEATURES OF THE FOSSIL RECORD AS THE RESULT OF EVOLUTION

Most scientists interpret the fossil record to be a record of evolutionary history.[53] They explain the segregation of fossils into various strata as the result of changes occurring over long periods of time. Different kinds of organisms lived at different times, and were fossilized as the layers were deposited in sequence. The species that occur in the lower

rocks are thought to be the evolutionary ancestors of those higher in the stratigraphic column. As one moves upward through the geologic column, one is moving closer to the present time. Thus one should expect to find that fossils in the upper strata would look familiar, because they are more closely related to living species. Fossils in the lower strata are only distantly related to living species, or from groups that no longer exist. They can be expected to look different from anything now living.

Species with strange combinations of traits may represent the kinds of transitional stages that occurred as new kinds of species evolved from older kinds. The ecological expansion seen in the geologic column reflects the fact that life began in the sea. Living organisms were not able to live on land until they had evolved the necessary structures to survive out of the water. Evolutionists believe that the evolutionary theory provides a good explanation for the main features of the fossil record, including biotic turnover, increasing modernity, morphological series, and ecological expansion.

Several features of the fossil record are at least consistent with evolutionary theory. Increasing diversity would be expected if a single common ancestor diversified and produced increasingly diverse and disparate descendents. Evolution of adaptations for terrestriality would require time, during which a trend toward increasing terrestriality might be expected. Increasing complexity and mobility might result from continuing competition and expanding ecological occupation. Body size trends might also result from increasing levels of competition.[54] Increasing competition might also drive older marine groups from onshore to offshore habitats as new onshore groups evolved. Increasing provinciality is expected as a single land mass, Pangaea, broke apart and formed separate, increasingly isolated regions.

However, there are some other considerations. The evolutionary theory does not provide such a good explanation for the "Cambrian Explosion." One would not expect evolution to produce a sudden increase in disparity, especially when one considers the great differences among the groups of Cambrian fossils. The lack of Precambrian ancestors for the Cambrian groups is another point not easily explained by evolutionary theory, although many hypotheses have been proposed.[55] Coordinated stasis, if valid, seems highly anomalous for evolutionary theory. Coordinated disappearance, commonly called "mass extinction," seems difficult to explain without a major global catastrophe. Trends in depositional

environments also seem to suggest successive links in an overall process, rather than a stochastic sequence of unrelated events.

Neither does evolution provide a very good explanation for the pattern of morphological gaps separating the different higher taxa of fossils. The standard explanation is that the fossil record is incomplete. The gaps between fossil taxa represent extinct species that really lived, but have not been discovered as fossils. These missing fossils have been called "missing links." The fossil record surely is incomplete, but does this really explain the pattern of the fossils?[56]

The sheep and the cow are fairly similar morphologically. The chances of finding more species like them would seem unlikely if the fossil record is highly incomplete. But a sheep and a monkey are much different. There should be many fossil species showing the evolutionary stages between a sheep and a monkey. But the opposite is true. There are many kinds of fossils that are similar to sheep and cattle, respectively, but fossils that are intermediate between sheep and monkeys are virtually absent. If we take the fossil record at face value, these supposed intermediate stages may never have existed. An incomplete fossil record might explain the gaps between closely similar species, but not the pattern of gaps among higher categories. Ubiquitous specialization and lack of identifiable ancestors also seem difficult for evolutionary theory to explain.

Even morphological series may be problematic for evolutionary theory. Observed morphological effects due to natural selection occur much more rapidly than changes typically seen in fossil series.[57] What kind of selective force could persist for millions of years, continuously driving morphological change in such tiny increments? Evolutionary theory does not provide a good explanation for the Cambrian explosion, coordinated stasis, the general lack of identifiable ancestors, or the systematic gaps among species and groups of species. Trends in depositional environments also seem poorly explained by evolutionary theory. There is reasonable empirical basis to look for another theory to explain the fossil record.

EXPLAINING THE FEATURES OF THE FOSSIL RECORD IN THE CONTEXT OF SCRIPTURE

Several scientists have attempted to develop creationist interpretations of the fossil record,[58] with mixed success. Many of the explan-

ations are *ad hoc*, and more work is badly needed. Nevertheless, a good start has been made, and further progress can be expected. Ideas from many sources have been incorporated into the discussion below.

Some features of the fossil record are readily explained from a creationist viewpoint. The "Cambrian Explosion" may be readily explained as the result of the burial of the sea floor in the early stages of the biblical flood.[59] The Cambrian fossils are not related to each other genealogically. Instead, they are related ecologically. They are all creatures of the sea floor. Other examples of "coordinated appearances" may result from flood encroachment on new biozones.[60] The combination of "Cambrian Explosion" and "higher-taxon stasis" would produce the pattern of "disparity before diversity."

As new communities were encountered by rising flood water, new groups of species would be added to the fossil record. The new groups of species would show only normal intra-specific variation, producing a record of "coordinated stasis." "Coordinated disappearances" would occur when a particular source area was exhausted, or due to some critical change in flood conditions.[61] The global nature of many coordinated disappearances indicates a global process. Such an "expanding flood" would naturally produce an increase in diversity through the fossil record.

The theory of special creation can also explain the morphological gaps separating the fossils into different groups. Major morphological gaps distinguish different groups that were separately created, producing "higher-taxon stasis."[62] Higher-taxon morphological stasis might reflect the inability of originally created kinds to vary naturally beyond certain limits determined by their genetic makeups. Special creation also explains the lack of identifiable ancestors in the fossil record, as well as the specialization seen in virtually all forms of life.

Morphological closely similar fossil species may represent differences that accumulated in isolated populations after the creation. Species-level morphological stasis and the noted shortage of transitional fossils at low taxonomic levels may be the result of catastrophic preservation; it is not necessary to suppose that intermediates between similar species and genera never existed, or that species are as stable as suggested by the fossil record.[63] On the other hand, interspecific morphological series might represent hydrodynamic sorting[64] or pre-Flood geographical clines such as are well-known in the present ecology.[65] In the case of species

with life-spans of a few weeks or less, a trend might reflect an actual series of speciation events.[66] These factors might also account for some of the many reported examples of trends in body size.

The ecological component in the geological column also seems consistent with creationist theories, although the details are not well understood. It could be the result of the expanding activity of the Flood. As the Flood began, sediment would be transported to the lowest elevations first. The sea floor would probably be the first to be covered, burying the organisms that lived there.[67] As the waters rose, additional groups of organisms would be added. Eventually, upland habitats would be flooded, and upland species added to the stack of fossil layers, producing the trend toward increasing terrestriality. Mobility might also be an important factor.[68] This process might also account for the sequence of first appearances of vertebrate classes, upon which the pattern of increasing complexity depends (see Figure 4).

In reality, the process of producing the fossil record was much more complex than simple ecological differences. Additional marine groups are found throughout the geologic column, which suggests the existence of continental seas at different elevations and in different geographic regions.[69] In addition, fossils from Precambrian rocks are dominated by apparently photosynthetic[70] bacteria, which must have somehow gotten into the rocks, perhaps very early in the Flood[71] or pre-Flood,[72] or as contaminants,[73] or perhaps accidentally trapped in some underground system involved in the pre-Flood water cycle.

Trends in patterns of deposition may reflect the advancing stages of the Flood. The reported possibly nonrandom distribution of storm deposits and lagerstätten may indicate a non-uniform process responsible for the fossil record. A worldwide flood might provide an explanation for this; if so, the details remain to be worked out. Depositional trends such as decreasing limestone deposition and increasing lake deposits seem plausible results of a worldwide flood. First appearances of major taxa in deposits interpreted as onshore deposits may be the result of interpreting high energy deposits as onshore. Perhaps high energy deposits are more likely than low-energy deposits to capture and preserve previously unrecorded types of fossils. The reported decrease in silicification of fossils through the Phanerozoic may indicate important changes in ocean chemistry, perhaps associated with changes in volcanic activity.

The existence of so many fossils and their spectacular preservation[74] indicate special circumstances that are rare in today's world. Evidence

for rapid burial, widespread geologic activity, and chemical activity of highly mineralized water are expected effects of a worldwide flood.

However, there are some features of the geologic column that creationists have more difficulty explaining. The consistent manner in which the fossils are segregated in the geologic column is one of those features. One would think that a worldwide flood would produce extensive mixing of various types of fossils. Perhaps the pre-Flood world was highly structured, both ecologically and taxonomically. Thus, as the Flood waters rose vertically and expanded geographically, different habitats were engulfed, and different taxonomic groups were successively deposited as fossils. This would result in noticeable differences in the kinds of fossils encountered as one compares different strata in the geologic column.

Another difficult trend to explain is the increasing similarity to modern forms as one views the fossil column from bottom to top. This fossil trend might be a result of the high degree of structure postulated for the pre-Flood world. Those habitats closest to the bottom were the first to be buried, and suffered the greatest extent of extinction. The last groups of organisms to be engulfed by the Flood would have the best chance of survival.[75] The result would be that the bottom layers would have fossils of species that are unfamiliar to us now, while the uppermost strata would have many fossils of familiar kinds of organisms.

The observed pattern also applies to terrestrial vertebrates, thought to be preserved only in the ark. It is not clear why terrestrial vertebrates show the same pattern as marine invertebrates. One suggested explanation for this[76] is that upland species were better adapted for the cooler (and probably harsher) post-Flood climates. Another suggestion[77] is that survival of the species preserved on the ark depended on the survival of species not on the ark, and those species whose food supply was destroyed could not survive.

Certain morphological series are also difficult to explain. The synapsid reptiles are an example. Increasing mammal-like traits are seen in synapsid fossils through the Permian and Triassic. A creationist might seek to discover whether there is some other associated trend, such as one relating to ecology,[78] behavior or distribution, that is responsible for the morphological series. It is significant that no series of actual ancestors and descendants can be identified among the synapsid reptile fossils — only a general trend toward increasing mammal-like

characteristics. Although creationists have pointed out the difficulties of interpreting this series as an evolutionary sequence, they have not developed a detailed alternative explanation. It has been suggested that the synapsid reptiles reflect a richer pre-Flood diversity,[79] and that the trend toward increasing mammalian characters might be a side-effect of an ecological pattern.[80]

A final difficulty is the increasing provinciality in Mesozoic and Cenozoic terrestrial faunas. One would expect increasing provinciality post-Flood, but it is not so clear why provinciality would increase in sediments thought to be deposited during the flood. Provinciality is low in the lower Mesozoic, then increases in the upper Mesozoic, with still further increases in the lower Cenozoic. This pattern could be partly an artifact of incomplete sampling of the fossil record, or perhaps it is a reflection of pre-Flood biogeographical differences, such as between the northern and southern hemispheres. It could also be taken to indicate that the Cenozoic is a record of post-Flood repopulation,[81] but there are reasons for restricting the post-Flood repopulation to the upper Cenozoic.[82] Either interpretation involves unsolved problems.

DISCUSSION

Those who have hoped fossil patterns and trends would reveal a straightforward story of Earth history have met disappointment. Some features of the fossil record seem to suggest one view, while other features seem to suggest another. Persons with differing views of Earth history can point to selected features of the fossil record to support their views.

Regardless of the viewpoint, our understanding is incomplete. The challenge to creationists is to explain fossil trends as the result of the way in which the Flood eroded and buried the biota of various habitats. The creationist viewpoint considers ecological and depositional trends to be primary. Diversity trends and morphological series are considered to be secondary consequences of the primary trends.

From this viewpoint, ecological fossil trends are interpreted to reflect the expansion of Flood activity as additional habitats and additional geographic regions were swept away. This implies segregation of habitats in a highly structured pre-Flood ecology. The observed ecological fossil trends are trends by addition, not by replacement (see Appendix 3). Since relatively dense and immobile marine invertebrates are found in

upper layers as well as in lower layers, there must have been additional source areas available for destruction at different stages in the Flood. This is why pre-Flood marine habitats are postulated to have occurred in different regions and at different elevations. This part of the explanation seems *ad hoc*, but a highly structured pre-Flood ecology seems to be an essential part of the theory.

Depositional trends are less frequently reported, but a few have been identified (see Appendix 3). The decrease in relative importance of limestone together with the increase in lake deposits can be linked to the expansion of the Flood beyond the main ocean bodies into the terrestrial environment. Habitat inferences based on depositional energy might alternatively be considered under depositional patterns. More study in this area is highly desirable. The relative geographic locations and stratigraphic positions of high energy and low energy deposits might provide helpful insights into the sequence and extent of various local or regional events during the Flood. The same could be said of patterns of storm deposits and lagerstätten. It would be interesting to determine if these patterns could be related to extraterrestrial impacts, plate arrangements, or paleocurrents. More information is also needed about possible trends in taphonomic processes.

Several diversity trends can be interpreted as the result of the expansion of Flood activity (see Appendix 1). Among these are coordinated appearances (e.g., the Cambrian Explosion), increasing diversity, disparity before diversity, and coordinated disappearances. The precise and consistent stratigraphic sorting of fossils into different strata is more problematic. A large-scale sorting mechanism is required to explain the consistency of the sorting over continent-sized geographic regions. The Flood may provide such a mechanism, but the details have yet to be worked with. The trend toward increasing provinciality also seems problematic for the Flood theory.

Morphological patterns provide a mixed bag for creationists. Most morphological patterns are consistent with creationist expectations (see Appendix 2). These include morphological stasis in fossil species, morphological gaps among species, systematic gaps among higher taxa, higher-taxon stasis, coordinated stasis, lack of ancestors, and ubiquitous morphological specialization. Many body-size trends may be expected in a flood, but further study is needed to clarify the processes involved.

Increasing complexity may be a secondary effect of increasing terrestriality among vertebrates. The most significant challenges to cre-

ationism from the fossil record are probably the increasing similarity to modern species and stratigraphic sorting of species into morphological series. These trends are the most important fossil evidence for the alternative to the Flood theory, the theory of evolution. One of the major goals of creation scientists should be to provide alternative explanations for morphological series of fossils. Some morphological series have been linked to ecological rather than evolutionary causes,[83] but much more study is needed in this area.

CONCLUSION

The fossil record is a record of destruction and death. Is it the record of undirected history, in which every species lives for a while, then becomes extinct? Does it trace an evolutionary history of common ancestry, natural selection and improvement? Or is it a record of world-wide catastrophic destruction, designed to serve as a reminder of the effects of sin? Science alone does not provide a satisfactory answer, but the Bible indicates the latter interpretation is the correct one. The details are not given, and no present theory adequately explains all the data. No one has been able to figure out how to put everything together.

However, by comparing the Bible and the fossil record, we can find meaning in the geologic column. Catastrophic activity and global patterns, perhaps the two most important predictions of the Flood theory, are clearly seen in the fossil record. The sudden, abrupt appearance of morphological disparity among marine animals in the "Cambrian Explosion" speaks of the beginning of the Flood. The terrible destructive power of the Flood is seen in the many extinct fossil groups. The lack of ancestors in the Precambrian rocks indicates the separate creation of many different groups. The presence of morphological gaps among higher taxa throughout the fossil record further illustrates this point.

Not everyone will interpret the record in this way. But those who are willing to test their ideas by the Bible can see divine purpose in the fossil record. This evidence affirms the reality of divine purpose in the present, and in the future.

ENDNOTES

1. (a) Gould SJ. 1988. Trends as changes in variance: a new slant on progress and directionality in evolution. Journal of Paleontology 62:319-329. See also: (b) Gould SJ. 1996. Full house. NY: Harmony House; (c) Ruse M. 1993. Evolution and progress. Trends in Ecology and Evolution 8:55-59; (d) Raup DM, Gould SJ. 1974. Stochastic simulation and evolution of morphology — Towards a nomothetic paleontology. Systematic Zoology 23:305-322.

2. For example, see: (a) Benton MJ. 1993. Fossil record 2. London: Chapman and Hall; also, for vertebrates, see: (b) Carroll RL. 1988. Vertebrate paleontology and evolution. NY: Freeman; for invertebrates, see: (c) Boardman RS, Cheetham AH, Rowell AJ, editors. 1987. Fossil invertebrates. Blackwell. Boston.; for plants, see: (d) Stewart WN, Rothwell GW. 1993. Paleobotany and the evolution of plants. 2nd ed. Cambridge and NY: Cambridge University Press.

3. Schopf JW. 1992. Proterozoic prokaryotes: Affinities, geologic distribution, and evolutionary trends. In: Schopf JW, Klein C, editors. The Proterozoic biosphere. Cambridge: Cambridge University Press, p 195-218.

4. An interesting account of the Cambrian Explosion is included in: (a) Gould SJ. 1989. Wonderful life. NY. W.W. Norton and Co. Other references include: (b) Conway Morris S. 1989. Burgess Shale faunas and the Cambrian Explosion. Science 246:339-346; (c) Dzik J. 1993. Early metazoan evolution and the meaning of its fossil record. Evolutionary Biology 27:339-382; (d) Signor PW. 1990. The geologic history of diversity. Annual Review of Ecology and Systematics 21:509-539; (e) Valentine JW. 1994. Late Precambrian bilaterians: grades and clades. Proceedings of the National Academy of Sciences (USA) 10:190-194; (f) Valentine JW. 1995. Why no new phyla after the Cambrian? Genome and ecospace hypotheses revisited. Palaios 10:190-194; (g) Valentine JW, Awramik SM, Signor PW, Sadler PM. 1991. The biological explosion at the Precambrian-Cambrian boundary. Evolutionary Biology 25:279-356.

5. For example, see: (a) Benton MJ. 1995. Diversification and extinction in the history of life. Science 268:5258; (b) Droser ML, Fortey RA, Xing Li. 1996. The Ordovician radiation. American Scientist 84:122-131; (c) Doyle JA. 1977. Patterns of evolution in early angiosperms. In: Hallam A, editor. Patterns of evolution. Amsterdam and NY: Elsevier Scientific Publishing Co., p 501-546; (d) Erwin DH, Valentine JW, Sepkoski JJ. 1987. A comparative study of diversification events: the Early Paleozoic versus the Mesozoic. Evolution 41:1177-1186; (e) Feduccia A. 1995. Explosive evolution in Tertiary birds and mammals. Science 267:637-638; (f) Foote M. 1992. Paleozoic record of morphological diversity in blastozoan echinoderms. Proceedings of the National Academy of Sciences (USA) 89:7325-7329; (g) Foote M. 1994. Morphological disparity in Ordovician-Devonian crinoids and the early saturation of morphological space. Paleobiology 20:320-344; (h) Foote M. 1996. On the probability of ancestors in the fossil record. Paleobiology 22:141-151; (i) Gould SJ, Gilinsky NL, German RZ. 1987. Asymmetry of lineages and the direction of evolutionary time. Science 236:1437-1441; (j) Hunt AP, Lucas SG. 1991. Synchronous first appearance of dinosaurs worldwide during the Late Triassic (Late Carnian: Tuvalian). Geological Society of American Abstracts with Program 1991:A457; (k) Miller AI, Foote M. 1996. Calibrating the Ordovician Radiation of marine life: implications for Phanerozoic diversity trends. Paleobiology 22:304-309; (l) Niklas KJ. 1994. One giant step for life. Natural History 103(6):22-25; (m) Paul CRC. 1977. Evolution of primitive echinoderms. In: Hallam, p 123-158 (see Note 5); (n) Sepkoski JJ. 1981. A factor analytic description of the Phanerozoic marine fossil record. Paleobiology 7:36-53; (o) Zang, W-I. 1995. Early Neoproterozoic sequence stratigraphy and acritarch biostratigraphy, eastern Officer Basin, South Australia. Precambrian Research 74:119-175.

6. Mass extinctions are discussed in scores of publications. Some examples include: (a) Bardet N. 1994. Extinction events among Mesozoic marine reptiles. Historical

Biology 7:313-324; (b) Benton 1995 (see Note 5); (c) Erwin DH. 1993. The great Paleozoic crisis. NY: Columbia University Press; (d) Jablonski D. 1991. Extinctions: a paleontological perspective. Science 253:754-757; (e) Long JA. 1993. Early-Middle Palaeozoic vertebrate extinctions events. In: Long JA, editor. Paleozoic vertebrate biostratigraphy and biogeography. Baltimore: Johns Hopkins Press, p 54-63; (f) McGhee GR. 1996. The Late Devonian mass extinction. NY: Columbia University Press; (g) Raup DM, Sepkoski JJ. 1982. Mass extinctions in the marine fossil record. Science 215:1501-1503; (h) Sepkoski JJ. 1993. Ten years in the library: new data confirm paleontological patterns. Paleobiology 19:43-51; (i) Sepkoski JJ. 1994. Extinction and the fossil record. Geotimes 39(3):15-17.

7. (a) Benton 1995 (see Note 5); (b) Erwin, Valentine, and Sepkoski 1987 (see Note 5); (c) Knoll AH. 1984. Patterns of extinction in the fossil record of vascular plants. In: Nitecki MH, editor. Extinction. Chicago and London: University of Chicago Press, p 21-68; (d) Raup DM. 1976. Species diversity in the Phanerozoic: a tabulation. Paleobiology 2:279-288.; (e) Rosenzweig ML. 1995. Species diversity in space and time. Cambridge: Cambridge University Press; (f) Sepkoski JJ, Sheehan PM. 1983. Diversification, faunal change, and community replacement during the Ordovician radiations. In: Tevesz MJS, McCall PL, editors. Biotic interactions in Recent and fossil benthic communities. NY and London: Plenum Press, p 673-717; (g) Signor 1985. Real and apparent trends in species richness through time. In: Valentine JW, editor. Phanerozoic diversity patterns. Princeton, NJ: Princeton University Press, p 129-150; (h) Signor 1990 (see Note 4); (i) Signor PW. 1994. Biodiversity in geological time. American Zoologist 34:23-32.

8. (a) Schopf JW. 1992. Patterns of Proterozoic microfossil diversity: an initial, tentative, analysis. In: Schopf and Klein, p 529-552 (see Note 3); (b) Walter MR, Grotzinger JP, Schopf JW. 1992. Proterozoic stromatolites. In: Schopf & Klein, p 253-260 (see Note 3).

9. See Gould 1989 (Note 4).

10. See references in Note 5.

11. (a) Cox CB. 1974. Vertebrate palaeodistributional patterns and continental drift. Journal of Biogeography 1:75-94.; (b) Hutton N. 1992. Global distribution of terrestrial and aquatic tetrapods, and its relevance to the position of continental masses. In: Chatterjee S, Hotton N, editors. New concepts in global tectonics. Lubbock, TX: Texas Tech University Press, p 267-285; (c) Shubin NH, Sues H-D. 1991. Biogeography of early Mesozoic continental tetrapods. Paleobiology 17:214-230. An irregular pattern of provinciality is implied in: (d) Wing SL, Sues H-D. 1992. Mesozoic and Early Cenozoic terrestrial ecosystems. In: Behrensmeyer AK, Damuth JD, DiMichele WA, Potts R, Sues H-D, Wing SL, editors. Terrestrial ecosystems through time. Chicago and London: University of Chicago Press, p 327-416.

12. (a) McShea DW. 1996. Metazoan complexity and evolution: is there a trend? Evolution 50:477-492; (b) Ruse 1993 (see Note 1); (c) Valentine JW. 1994. Morphological complexity increase in metazoans. Paleobiology 20:131-142.

13. Schopf 1992, p 195-218 (see Note 3).

14. (a) Brett CE, Ivany LC, Schopf KM. 1996. Coordinated stasis: an overview. Palaeogeography, Palaeoclimatology, Palaeoecology 127:1-20; (b) DiMichele WA, Hook RW. 1992. Paleozoic terrestrial ecosystems. In: Behrensmeyer AK, Damuth JD, DiMichele WA, Potts R, Sues H-D, Wing SL, editors. Terrestrial ecosystems through time. Chicago and London: University of Chicago Press, p 205-325; (c) Eldredge N. 1996. Hierarchies in macroevolution. In: Jablonski D, Erwin DH, Lipps JH, editors. Evolutionary paleobiology. Chicago and London: University of Chicago Press, p 42-61; (d) Flynn LJ, Barry JC, Morgan ME, Pilbeam D, Jacobs LL, Lindsay EH. 1995. Neogene Siwalik mammalian lineages: species longevities, rates of change, and modes of speciation. Palaeogeography, Palaeoclimatology, Palaeoecology 115:249-264;

(e) Morris PJ, Ivany LC, Schopf KM, Brett CE. 1995. The challenge of paleoecological stasis: reassessing sources of evolutionary stability. Proceedings of the National Academy of Sciences (USA) 92:11269-11273; (f) Tang CM, Bottjer DJ. 1996. Long-term faunal stasis without evolutionary coordination: Jurassic benthic marine paleocommunities, Western Interior, United States. Geology 24:815-818. See also references in Note 15.

15. (a) Cuffy RJ. 1984. Paleontologic evidence and organic evolution. In: Montagu A, editor. Science and creationism. Oxford and NY: Oxford University Press, p 255-281. Reprinted from Journal of the American Scientific Affiliation 24(4, December 1972); (b) Gingerich PD. 1974. Stratigraphic record of Early Eocene *Hyopsodus* and the geometry of mammalian phylogeny. Nature 248:107-109; (c) Strahler AN. 1987. Science and Earth history: the evolution/creation controversy. Buffalo, NY: Prometheus Books.

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17. Schopf 1992, p 195-218 (see Note 3).

18. (a) Wise KP. 1991. Changing stasis. Origins Research 13(1):20; (b) Battson AL. 1994. On the origin of stasis by means of natural processes. Perspectives on Science and Christian Faith 46:230-241.

19. (a) Brett, Ivany, and Schopf 1996 (see Note 14); (b) Ivany LC. 1997. Testing for coordinated stasis in the Eocene Gulf Coastal Plain. Geological Society Abstracts With Program A404-405; (c) Morris, Ivany, Schopf, & Brett 1995 (see Note 14). Many more papers on this topic are in Brett et al. 1996.

20. (a) Dommergues J-L. 1990. Ammonoids. In: McNamara KJ, editor. Evolutionary trends. Tucson: University of Arizona Press, p 162-187; (b) Eldredge & Gould 1972 (see Note 16); (c) Erwin, Valentine, & Sepkoski 1987 (see Note 5); (d) McNamara KJ. 1990. Epilogue. In: McNamara, p 347-350; (e) Williamson PG. 1981. Palaeontological documentation of speciation in Cenozoic molluscs from Turkana Basin. Nature 293:437-443; (f) see also references in Note 11. An opposing view is given in: (g) Gingerich 1974 (see Note 15).

21. This point is argued on p 191-194 of: (a) Denton M. 1986. Evolution: a theory in crisis. Bethesda, MD: Adler and Adler; see also (b) Carroll RL. 1992. The primary radiation of terrestrial vertebrates. Annual Review of Earth and Planetary Sciences 20:45-84.

22. A long list of claims, many of which have been re-interpreted, is given in: Cuffy 1984 (see Note 15). For other references see Notes 24-27.

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McNamara, p 75-118 (see Note 20); (g) McNamara KJ. 1990. Echinoids. In: McNamara, p 205-231 (see Note 20); (h) Mendelson CV, Schopf JW. 1992. Proterozoic and Early Cambrian Acritarchs. In: Schopf and Klein, p 219-232 (see Note 3); (i) Morgan ME, Barry JC. 1991. Trends in body size among Middle and Late Miocene herbivores from the Siwaliks of northern Pakistan. Journal of Vertebrate Paleontology 11(Suppl):48A, abstract 149.

24. Benton MJ. 1990. Reptiles. In: McNamara, p 279-300 (see Note 20).

25. (a) Clyde WC, Fisher DC. 1997. Comparing the fit of stratigraphic and morphologic data in phylogenetic analysis. Paleobiology 23:1-19; (b) Hitchin R, Benton MJ. 1997. Congruence between parsimony and stratigraphy: comparisons of three indices. Paleobiology 23:20-32; (c) Huelsenbeck JP. 1994. Comparing the stratigraphic record to estimates of phylogeny. Paleobiology 20:470-483; (d) Norell MA, Novacek MJ. 1992. The fossil record and evolution: comparing cladistic and paleontologic evidence for vertebrate history. Science 255:1690-1693; (e) Norell MA, Novacek MJ. 1992. Congruence between superpositional and phylogenetic patterns: comparing cladistic patterns with fossil records. Cladistics 8:319-337; (f) Padian K, Lindberg DR, Polly PD. 1994. Cladistics and the fossil record: the uses of history. Annual Review of Earth and Planetary Sciences 22:63-91; (g) Prado JL, Alberdi MT 1996. A cladistic analysis of the horses of the tribe Equini. Palaeontology 39:663-680; (h) Weishampel DB. 1996. Fossils, phylogeny, and discovery: a cladistic study of the history of tree topologies and ghost lineage durations. Journal of Vertebrate Paleontology 16:191-197. Lack of stratigraphic agreement is reported in: (i) Antsey RL. 1990. Bryozoans. In McNamara, p 232-252 (see Note 20).

26. (a) Gould SJ. 1990. Speciation and sorting as the source of evolutionary trends or 'things are seldom what they seem.' In: McNamara, p 3-27 (see Note 20); (b) MacFadden BJ. 1992. Fossil horses. Cambridge and NY: Cambridge University Press.

27. (a) Fraser NC, Sues H-D, editors. 1994. In the shadow of the dinosaurs. Cambridge and NY: Cambridge University Press. See especially Chapter 6 (by Zhexi Luo) and Chapter 20 (by S.G. Lucas & A.P. Hunt); (b) Hotton N, MacLean PD, Roth JJ, Roth EC, editors. 1986. The ecology and biology of mammal-like reptiles. Washington DC and London: Smithsonian Institution Press; (c) Kemp TS. 1982. Mammal-like reptiles and the origin of mammals. London and NY: Academic Press.

28. (a) Fastovsky DE, Weishampel DB. 1996. The evolution and extinction of the dinosaurs. Cambridge and NY: Cambridge University Press; (b) Gatesy SM, Dial KP. 1996. Locomotor modules and the evolution of avian flight. Evolution 50:331-340. For minority view, see: (c) Feduccia A. 1996. The origin and evolution of birds. New Haven and London: Yale University Press; (d) Martin LD. 1991. Mesozoic birds and the origin of birds. In: Schultze H-P, Trueb L, editors. Origins of the higher groups of tetrapods. Ithaca and London: Comstock Publishing, p 485-540.

29. (a) Gingerich PD, Raza SM, Arif M, Anwar M, Zhou X. 1994. New whale from the Eocene of Pakistan and the origin of cetacean swimming. Nature 368:844-847; (b) Thewissen JGM, Hussain ST, Arif M. 1994. Fossil evidence for the origin of aquatic locomotion in archaeocete whales. Science 263:210-212.

30. (a) Landman NH. 1988. Heterochrony in ammonites. In: McKinney ML, editor. Heterochrony in evolution: a multidisciplinary approach. NY: Plenum, p 159-182; (b) Lidgard S, Jackson JBC. 1989. Growth in encrusting cheilostome bryozoans: I. Evolutionary trends. Paleobiology 15:255-282; (c) McNamara 1990 (see Note 20); (d) Wagner PJ. 1996. Contrasting the underlying patterns of active trends in morphologic evolution. Evolution 50:990-1007.

31. This point can be confirmed by analyzing the data in: (a) Benton 1993 (see Note 2). See also: (b) Horowitz AS, Pachut JF. 1994. Lyellian bryozoan percentages and the fossil record of the Recent bryozoan fauna. Palaios 9:500-505.

32. Schopf 1992 (see Note 3).

33. Gould makes this point in the book, Wonderful Life (see Note 4).

34. Cladistics does not provide a method of identifying ancestors. Two attempts to do so are: (a) Alroy J. 1995. Continuous track analysis: a new phylogenetic and biogeographic method. Systematic Biology 44:152-178; (b) Paul CRC. 1992. The recognition of ancestors. Historical Biology 6:239-250. A possible ancestor of dogs is identified in: (c) Tedford RH, Taylor BE, Wang X. More problematic examples are: (d) Heinrich RE, Rose KD. 1995. Partial skeleton of the primitive carnivoran *Miacis petilus* from the Early Eocene of Wyoming. Journal of Mammalogy 76:148-162; (e) Rose KD. 1982. Skeleton of *Diacodexis*, oldest known artiodactyl. Science 216:621-623; (f) Rose KD. 1987. Climbing adaptations in the Early Eocene mammal *Chriacus* and the origin of artiodactyla. Science 236:314-316; (g) Rose KD. 1996. On the origin of the order Artiodactyla. Proceedings of the National Academy of Sciences (USA) 93:1705-1709.

35. (a) Benton MJ. 1996. On the nonprevalence of competitive replacement in the evolution of tetrapods. In: Jablonski, Erwin, & Lipps, p 185-210 (see Note 14); (b) Droser ML, Bottjer DJ, Sheehan PM. 1997. Evaluating the ecological architecture of major events in the Phanerozoic history of marine invertebrate life. Geology 25:167-170; (c) Sepkoski & Sheehan 1983 (see Note 7); (d) Sepkoski JJ, Miller AI. 1985. Evolutionary faunas and the distribution of Paleozoic marine communities in space and time. In: Valentine, p 153-190, (see Note 7); (e) Thayer CW. 1983. Sediment-mediated biological disturbance and the evolution of marine benthos. In: Tevesz & McCall, p 479-625 (see Note 7); (f) Vermeij GJ. 1987. Evolution and escalation. Princeton, NJ: Princeton University Press; (g) Wing & Sues 1992 (see Note 11).

36. (a) Bambach RK. 1983. Ecospace utilization and guilds in marine communities through the Phanerozoic. In: Tevesz & McCall, p 719-746 (see Note 7); (b) Bambach RK. 1985. Classes and adaptive variety: the ecology of diversification in marine faunas through the Phanerozoic. In: Valentine, p 191-253 (see Note 7); (c) Bambach RK, Bennington JB. 1996. Do communities evolve? A major question in evolutionary paleoecology. In: Jablonski, Erwin, & Lipps, p 123-160 (see Note 14); (d) Sepkoski JJ. 1996. Competition in macroevolution: the double wedge revisited. In: Jablonski, Erwin, & Lipps, p 211-255 (see Note 14).

37. (a) Conway Morris S, Whittington HB. 1979. The animals of the Burgess Shale. Scientific American 241(1):122-133; (b) Erwin 1993 (see Note 6).

38. (a) DiMichele WA, Aronson RB. 1992. The Pennsylvanian-Permian vegetational transition: a terrestrial analogue to the onshore-offshore hypothesis. Evolution 46:807-824; (b) DiMichele and Hook 1992 (see Note 14); (c) Niklas KJ, Tiffney BH, Knoll AH. 1985. Patterns in vascular land plant diversification: an analysis at the species level. In: Valentine, p 97-128 (see Note 7).

39. The only vertebrate fossils of the lower Paleozoic are aquatic forms. They are joined by semi-aquatic and lowland forms in the mid- and upper Paleozoic, with an increase in terrestrial forms through the rest of the geologic column. E.g., see: (a) DiMichele & Hook 1992 (see Note 14); (b) Olson EC. 1966. Community evolution and the origin of mammals. Ecology 47:291-302. For a different viewpoint, see: (c) Padian K, Clemens WA. 1985. Terrestrial vertebrate diversity: episodes and insights. In: Valentine, p 41-96 (see Note 7).

40. Roth AA. 1992. Life in the deep rocks and the deep fossil record. Origins 19:93-104.

41. (a) Erwin 1993 (see Note 6); (b) Thayer 1983 (see Note 35); (c) Vermeij 1987 (see Note 35).

42. (a) Cowen R. 1996. Locomotion and respiration in aquatic air-breathing vertebrates. In: Jablonski, Erwin, & Lipps, p 337-353 (see Note 14); (b) Janis CM, Damuth J. 1990. Mammals. In: McNamara, p 301-345 (see Note 20); (c) Stucky RK. 1989. Evolution of land mammal diversity in North America during the Cenozoic. Current Mammalogy 2:375-432.

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45. (a) DiMichele and Aronson 1992 (see Note 38); (b) Bottjer DJ, Jablonski D. 1988. Paleoenvironmental patterns in the evolution of post-Paleozoic benthic marine invertebrates. Palaios 3:540-560; (c) Jablonski D, Sepkoski JJ, Bottjer DJ, Sheehan PM. 1983. Onshore-offshore patterns in the evolution of Phanerozoic shelf communities. Science 222:1123-1125; (d) Jablonski D, Bottjer DJ. 1991. Environmental patterns in the origins of higher taxa: the post-Paleozoic fossil record. Science 252:1831-1833; (e) Miller AI. 1988. Spatio-temporal transitions in Paleozoic bivalvia: an analysis of North American fossil assemblages. Historical Biology 1:251-273; (f) Sepkoski JJ. 1991. A model of onshore-offshore change in faunal diversity. Paleobiology 17:58-77.

46. Behrensmeyer AK, Hook RW. 1992. Paleoenvironmental contexts and taphonomic modes. In: Behrensmeyer, Damuth, DiMichele, Potts, Sues, & Wing, p 15-136 (see Note 11).

47. Ronov AB. 1982. The Earth's sedimentary shell (quantitative patterns of its structure, compositions, and evolution). International Geology Review 24:1365-1388.

48. (a) Behrensmeyer & Hook 1992 (see Note 46); (b) Greenstein B. 1992. Taphonomic bias and the evolutionary history of the family Cidaridae (Echinodermata: Echinoidea). Paleobiology 18:50-79; (c) Kidder DL, Schubert JK, Erwin DH. 1997. Secular patterns of invertebrate skeletal silicification. Geological Society of America Abstracts With Program A265; (d) Kidwell SM, Brenchley PJ. 1996. Evolution of the fossil record: thickness trends in marine skeletal accumulations and their implications. In: Jablonski, Erwin, & Lipps, p 290-336 (see Note 14).

49. (a) Ausich WI, Bottjer DJ. 1985. Phanerozoic tiering in suspension-feeding communities on soft substrata: implications for diversity. In: Valentine, p 255-274 (see Note 7); (b) Durazzi JT, Stehli FG. 1972. Average generic age, the planetary temperature gradient, and pole location. Systematic Zoology 21:384-389; (c) Flessa KW, Jablonksi D. 1996. The geography of evolutionary turnover: a global analysis of extant bivalves. In: Jablonski, Erwin, & Lipps, p 376-397 (see Note 14); (d) Koch PL. 1986. Clinal geographic variation in mammals: implications for the study of chronoclines. Paleobiology 12:269-281; (e) Long JA. 1993. Early-Middle Palaeozoic vertebrate extinction events. In: Long, p 54-63 (see Note 6); (f) Raup DM, Stanley SM. 1978. Principles of paleontology. 2nd edition. San Francisco: Freeman, Chapter 11, Evolution and the fossil record; (g) Rosenzweig ML. 1995 (see Note 7); Signor 1990 (see Note 4); Signor 1994 (see Note 7); Wing and Sues 1992 (see Note 11).

50. Raup & Gould 1974 (see Note 1).

51. (a) Cheetham AH. 1987. Tempo of evolution in a Neogene bryozoan: are trends in single morphologic characters misleading? Paleobiology 13:286-296; (b) Gould 1990 (see Note 26); (c) Holland SM. 1995. The stratigraphic distribution of fossils. Paleobiology 21:92-109; (d) McKee JK. 1995. Turnover patterns and species longevity of large mammals from the Late Pliocene and Pleistocene of southern Africa: a comparison of simulated and empirical data. Journal of Theoretical Biology 172:141-147.

52. (a) Aberhan M. 1993. Faunal replacement in the Early Jurassic of northern Chile: implications for the evolution in Mesozoic benthic shelf ecosystems. Palaeogeography, Palaeoclimatology, Palaeoecology 103:155-177; (b) Behrensmeyer & Hook 1992 (see Note 46); (c) Carlson JS. 1992. Evolutionary trends in the articulate brachiopod

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53. See any standard text on historical geology or paleontology, for example: (a) Poort JM, Carlson RJ. 1997. Historical geology: interpretations and applications. 5th edition. Englewood Cliffs, NJ: Prentice-Hall; (b) Rogers JJW 1993. A history of the Earth. Cambridge: Cambridge University Press.

54. (a) Van Valen L. 1973. A new evolutionary law. Evolutionary Theory 1:1-30; (b) Vermeij 1987 (see Note 35).

55. Bengtson S, Lipps JH. 1992. Introduction. In: Schopf & Klein, p 427-428 (see Note 3).

56. When it can be checked, the fossil record does not seem to be all that incomplete. See: (a) Foote 1996 (see Note 5); (b) Foote M, Raup DM. 1996. Fossil preservation and the stratigraphic ranges of taxa. Paleobiology 22:121-140; (c) Valentine JW. 1989. How good was the fossil record? Clues from the California Pleistocene. Paleobiology 15:83-94.

57. (a) Gould 1988 (see Note 1); (b) Gould 1990 (see Note 26).

58. (a) Brand L. 1997. Faith, reason and earth history: a paradigm of earth and biological origins by intelligent design. Berrien Springs, MI: Andrews University Press; (b) Clark HW. 1946. The new diluvialism. Angwin, CA: Science Publications; (c) Clark HW. 1968. Fossils, flood and fire. Escondido, CA: Outdoor Pictures; (d) Coffin HG. 1969. Creation: accident or design? Washington DC: Review and Herald Publishing Assn.; (e) Coffin HG. 1983. Origin by design. Hagerstown, MD: Review and Herald Publishing Assn.; (f) Oard MJ. 1997. The extinction of the dinosaurs. Creation Ex Nihilo Technical Journal 11:137-154; (g) Snelling AA. 1991. Creationist geology: where do the Precambrian strata fit? Creation Ex Nihilo Technical Journal 5(2):154-175; (h) Whitcomb JC, Morris HM. 1961. The Genesis flood. Phillipsburg, NJ: Presbyterian and Reformed Publishing; (i) Wise K. 1989. Punc Eq creation style. Origins 16:11-24; (j) Wise 1991 (see Note 18); (k) Wise KP. 1992. Some thoughts on the Precambrian fossil record. Creation Ex Nihilo Technical Journal 6(1):67-71; (l) Wise KP. 1994. *Australopithecus ramidus* and the fossil record. Creation Ex Nihilo Technical Journal 8:160-165; (m) Wise KP. 1995. Towards a creationist understanding of 'transitional forms.' Creation Ex Nihilo Technical Journal 9(2):216-222; (n) Wise KP. 1996. North American Paleontology Convention 96. Creation Ex Nihilo Technical Journal 10:315-321; (o) Woodmorappe J. 1983. A diluviological treatise on the stratigraphic separation of fossils. Creation Research Society Quarterly 20:133-185.

59. (a) Clark 1946 (see Note 58); (b) Coffin 1983 (see Note 58); (c) Wise 1996 (see Note 58).

60. Wise 1996 (see Note 58).

61. Brand 1997, p 242-243, 299 (see Note 58).

62. (a) Battson 1994 (see Note 18); (b) Marsh FL. 1941. Fundamental biology. Lincoln, NE: Published by the author; (c) Wise 1989 (see Note 58); (d) Wise 1991 (see Note 18).

63. Wise 1989 (see Note 58).

64. Whitcomb & Morris 1961 (see Note 58).

65. Wise 1989 (see Note 58).

66. Ibid.

67. (a) Clark 1946 (see Note 58); (b) Clark 1968 (see Note 58); (c) Whitcomb & Morris 1961 (see Note 58).

68. Whitcomb & Morris 1961 (see Note 58).

69. (a) Clark 1946 (see Note 58); (b) Clark 1968 (see Note 58).

70. Fossils of photosynthetic bacteria are believed to be present in Precambrian strata, as noted in: (a) Schopf 1992 (see Note 3). However, their presence in Proterozoic stromatolites "has yet to be adequately documented," according to: (b) Walter, Grotzinger, & Schopf 1992 (see Note 8).

71. Snelling 1991 (see Note 58).

72. Wise 1992 (see Note 58).

73. Roth 1992 (see Note 40).

74. (a) Davies DJ, Powell EN, Stanton RJ. 1989. Relative rates of shell dissolution and net sediment accumulation — a commentary: can shell beds form by the gradual accumulation of biogenic debris on the sea floor? Lethaia 22:207-212; (b) Kidwell SM, Brenchley PJ. 1994. Patterns in bioclastic accumulation through the Phanerozoic: changes in input or in destruction? Geology 22:1139-1143; (c) Kidwell SM, Flessa KW. 1996. The quality of the fossil record: Populations, species, and communities. Annual Review of Earth and Planetary Sciences 24:433-464. See also Note 41.

75. Woodmorappe 1983 (see Note 58).

76. Brand 1997 (see Note 58).

77. Woodmorappe 1983 (see Note 58).

78. (a) Olson 1966 (see Note 39); (b) Wise 1995 (see Note 58). Please note that Olson is not a creationist.

79. Mehlert AW. 1993. The origin of mammals: a study of some important fossils. Creation Ex Nihilo Technical Journal 7:122-139.

80. Wise 1995 (see Note 58).

81. (a) Brand 1997 (see Note 58); (b) Wise 1989 (see Note 58).

82. (a) Holt RD. 1996. Evidence for a Late Cainozoic Flood/post-Flood boundary. Creation Ex Nihilo Technical Journal 19:128-167; (b) Oard 1996 (see Note 58); (c) Oard MJ. 1997. The extinction of the dinosaurs. Creation Ex Nihilo Technical Journal 11:137-154.

83. Ecological explanations of morphological trends are not inconsistent with evolutionary theory, but do provide a possible explanation that is consistent with the Flood. See references in Note 41 for examples.

APPENDIX 1. FOSSIL DIVERSITY PATTERNS

Pattern	Some Proposed Interpretations
Repeated biotic turnover Persistent pattern	Evolutionist: shows historical sequence of biotic replacement due to natural selection, environmental disturbances Creationist: shows sequence of burial during world-wide catastrophe; proposed controlling factors: water sorting; mobility; density; elevation of habitat; macrobiogeography; changing source areas
Coordinated appearances Persistent pattern	Evolutionist: Immigration events; erosional unconformities; recovery from catastrophe; accumulation of oxygen; sufficient calcium to grow skeletons Creationist: Change in source area
Coordinated disappearances Persistent pattern	Evolutionist: Mass extinction; background extinction; preservational bias Creationist: Destruction of source area
Increasing diversity Addition/replacement trend	Evolutionary expansion Creationist: Flood expansion
Disparity before diversity Addition trend	Evolutionist: Lack of developmental constraints; low competition and predation; incomplete fossil record Creationist: Result of fossil record first sampling ocean floor, plus higher-taxon stasis
Provinciality Replacement trend	Evolutionist: Break-up of Pangaea Creationist: Changing source areas of flood and changing configuration of depositional basins

APPENDIX 2. FOSSIL MORPHOLOGICAL PATTERNS

Pattern	Interpretations
Increasing complexity Addition trend	Evolutionist: Natural selection Creationist: Artifact of flood burial sequence
Species stasis Persistent pattern	Evolutionist: Genetic homeostasis Creationist: Lack of time in burial sequence
Higher-taxon stasis Persistent pattern	Evolutionist: Competition; first occupant advantage Creationist: Limits of variation imposed on pattern of creation
Coordinated stasis Persistent pattern	Evolutionist: Environmental stability; genetic homeostasis Creationist: Lack of time in production of fossil record
Species-level gaps Persistent pattern	Evolutionist: Saltational evolution Creationist: Lack of time
Patterns of gaps Persistent pattern	Evolutionist: Incompleteness of fossil record Creationist: Limitation of variation imposed on pattern of creation
Body size Addition/replacement trend	Evolutionist: Natural selection Creationist: Reflects flood-related factors, such as sorting by currents; in some cases, post-Flood speciation
Morphological series Mostly replacement trend	Evolutionist: Historical record of descent with modification Creationist: Flood-sorting factors; post-flood descent with modification
Increasing modernity Mostly replacement trend	Evolutionist: Result of historical sequence Creationist: Related to flood survival (*ad hoc*)
Ubiquitous specialization Persistent pattern	Evolutionist: Natural selection Creationist: Design, modified by natural selection
Lack of ancestors Persistent pattern	Evolutionist: Incompleteness of fossil record; saltational evolution Creationist: Ancestors never existed.

APPENDIX 3. FOSSIL ECOLOGICAL AND DEPOSITIONAL TRENDS

Pattern	Interpretations
Increasing habitat diversity Addition trend	Evolutionist: Evolutionary expansion of ecological opportunity Creationist: Expanding flood
Increasing terrestriality Persistent pattern	Evolutionist: Evolutionary expansion of ecological opportunity Creationist: Natural sequence of flood effects
Increasing mobility Addition trend	Evolutionist: Improvement through natural selection Creationist: Flood-sorting factors
Storm deposits Trendless pattern	Evolutionist: Accident of preservation Creationist: Changing stages of flood
Special preservation Trendless pattern	Evolutionist: Accidents of preservation Creationist: Special circumstances during flood
Depositional first appearance Addition trend	Evolutionist: Competitive superiority of newly evolved onshore clades Creationist: Greater likelihood of first preservation in high-energy deposit
Depositional environments Addition trend	Evolutionist: Accidents of preservation; geologic evolution *ad hoc* Creationist: changing stages of flood; decreasing available carbonate; lakes stranded by receding waters
Modes of preservation	Too little is known about this possible trend to make a meaningful analysis; for the decline in silicification, perhaps the flood water experiencd a change in chemistry, possibly related to volcanism

ANNOTATIONS FROM THE LITERATURE

BIOGEOGRAPHY OF THE SOUTHERN BEECH

Hill RS, Dettmann ME. 1996. Origin and diversification of the genus *Nothofagus*. In: Veblen TT, Hill RS, Read J, editors. The ecology and biogeography of *Nothofagus* forests. New Haven and London: Yale University Press, p 11-24.

Summary: The southern beech, *Nothofagus*, is restricted to the southern continents, both at present and in the fossil record. It is a prolific pollen producer, so it is very likely to leave evidence of its presence in the fossil record. It is sensitive to salt water, and is thought not to be able to disperse across the sea. The excellent fossil record and poor dispersal abilities of *Nothofagus* have led some biogeographers to regard it as one of the most reliable indicators of conditions in the past. However, the record of *Nothofagus* in New Zealand strongly suggests dispersal across the sea during the Cenozoic. If this is substantiated, *Nothofagus* biogeography may need some reinterpretation, and its status as a key to the past may be lost.

Comment: The presence of living *Nothofagus* trees on now-separated continents has led some to claim that the geologic time scale for continental breakup must be accepted. Some creationists have long suspected that a key to this problem was the possibility of over-sea dispersal of *Nothofagus*. This may not occur under normal conditions, but the high-energy events associated with a worldwide catastrophe would produce highly unusual conditions in which dispersal by transport of seeds on trees or parts of trees by marine currents might be expected.

CYCLIC SEDIMENTATION: MILANKOVITCH CYCLE

Brack P, Mundil R, Oberli F, Meier M, Rieber H. 1996. Biostratigraphic and radiometric age data question the Milankovitch characteristics of the Latemar cycles (Southern Alps, Italy). Geology 24:371-375.

Summary: Finely laminated sediments are found in numerous places, including the Italian Alps. Such sequences may show patterns

of repeating variation of lamina thickness. One such sequence involves hundreds of carbonate cycles in the Middle Triassic Latemar platform. These have been explained as due to the Milankovitch cycle of 20,000 years. At least 598 cycles are reported, implying a total time of about 12 million years. However, a combination of index fossils and radiometric dating indicates a maximum age of 4.7 million years for the deposits, and probably less than 4 million years. This suggests that the patterns in the laminae may not be a result of the Milankovitch cycle. The authors suggest that ancient carbonates may not supply sufficient data for unambiguous identification of Milankovitch cycles.

Comment: Possible rejection of Milankovitch cycles as the explanation for cyclic patterns of variation in laminated sediments should stimulate efforts to find better ways of explaining the origin of thin laminae in sediments. It seems remarkable that a lake should maintain relatively constant conditions of deposition over periods in excess of 100,000 years, much more so for the longer periods often suggested by the Milankovitch cycle interpretation.

EVOLUTION OF TURTLES

Rieppel O, DeBraga M. 1996. Turtles as diapsid reptiles. Nature 384:453-455.

Summary: Reptiles are typically divided into groups based on their skull openings in the temporal region. Turtles are grouped separate from other living reptiles. However, turtles have so many morphological specializations that comparisons with other groups are difficult. The temporal roofing of the stratigraphically lowest turtle does not match that of the fossils with which turtles have been traditionally grouped (anapsids). However, such features as jaw muscles and limb and girdle structure suggest an affinity with the lizards and their allies (lepidosauriform diapsids). This is further supported by several features of development. Acceptance of turtles as diapsids will greatly alter our understanding of their relationships.

Comment: Turtles are not clearly related to any other group, and may represent one or more separately created lineages.

MUTATIONS AND DEGENERATION

Andersson DI, Hughes D. 1996. Muller's ratchet decreases fitness of a DNA-based microbe. Proceedings of the National Academy of Sciences (USA) 93:906-907.

Summary: Since it appears that most mutations are harmful, it would seem that organisms would tend to degenerate. This has been proposed to happen unless variation is provided by sexual reproduction. Examples of degeneration are known among RNA viruses, which have unusually high mutation rates. This is the first report to show spontaneous degeneration among DNA-based organisms, specifically the bacterium *Salmonella typhimurium*. Cells were grown asexually, with repeated bottlenecking to promote random accumulation of mutations. After 1700 generations, 1% of the 444 lineages showed decreased growth rate. During the experiment, the mutation rate for a group of about 200 genes was calculated to be about 10^{-9} per base per pair per generation.

Comment: This experiment suggests that species tend to degenerate genetically, but the process is slowed by natural selection.

PALEONTOLOGY: SHARK AND THELODONT FINDS

Samson IJ, Smith MM, Smith MP. 1996. Scales of the thelodont and sharklike fishes from the Ordovician of Colorado. Nature 379:628-630.

Summary: Apparent scales of sharks and thelodonts have been discovered in the Harding Sandstone of Colorado. This is the stratigraphically lowest record for both groups. The discovery of apparent shark scales lowers their first appearance from the Lower Silurian (Llandovery) to the Upper Ordovician (Caradoc), supposedly 25 Myr. Thelodonts were previously reported from the Upper Ordovician (Ashgill), a difference of some 10 Myr. Possible acanthodians and heterostracan-like fish are found in the same location. This indicates that fish were already diversified before Silurian sedimentation began.

Comment: Lowering the first appearances for these groups of vertebrates crowds them together toward the Cambrian Explosion. The appearance of virtually all phyla near the bottom of the Phanerozoic strata is an outstanding feature of the fossil record.

PALEONTOLOGY: EARLY FOSSIL BIRDS

Hou L, Martin LD, Zhou Z, Feduccia A. 1996. Early adaptive radiation of birds: evidence from fossils from Northeastern China. Science 274:1164-1167.

Summary: Recently discovered fossils from Liaoning Province, China threaten the status of *Archaeopteryx* as the possible ancestor of all other birds. Two genera of birds are reported from rocks at about the boundary of the Upper Jurassic and Lower Cretaceous. They are listed here as Upper Jurassic, but this is controversial. *Confuciusornis* is a magpie-sized member of the enantiornithine birds, which are the most common fossil landbirds found in Cretaceous rocks. It has a horny beak, and lacks teeth. *Liaoningornis* is a sparrow-sized bird with characteristics of ornithurines, the group that includes all living birds. This species has features, lacking in enantiornithines, that suggest the existence of a modern type of bird lung with air sacs. *Chaoyangia* is found in Lower Cretaceous deposits in the same region, and is also an ornithurine bird. The existence of both major types of birds at the Jurassic-Cretaceous boundary argues against the hypothesis that *Archaeopteryx* is the direct ancestor of modern birds, with the enantiornithines as an intermediate. Instead, *Archaeopteryx* and the enantiornithines form one group, separate from the ornithurines and modern birds. Still unexplained is the fact that the most birdlike of the dinosaurs are primarily Upper Cretaceous, stratigraphically considerably higher than *Archaeopteryx* and numerous other birds.

An accompanying commentary (p 1083) notes that the rocks at the Liaoning Province have given Lower Cretaceous dates, reducing the force of the argument.

Comment: Although *Archaeopteryx* has been postulated to be the direct ancestor of other birds, several paleontologists have been skeptical. The diversity of birds found in Lower Cretaceous rocks seems too large to be accounted for by an origin with the Upper Jurassic *Archaeopteryx*. Alternative ancestors for the birds have been proposed, but no alternative well-preserved potential fossil ancestor has been identified. These discoveries in China underscore the problem by showing that both major groups of birds were buried together in Upper Jurassic or Lower Cretaceous deposits. Some Middle Jurassic footprints from Africa (see *Origins* 19:39 for comment) are a possible record of birds stratigraphically lower than *Archaeopteryx*.

PALEONTOLOGY: ICHTHYOSAURS

Motani R, You H, McGowan C. 1996. Eel-like swimming in the earliest ichthyosaurs. Nature 382:347-348.

Summary: Ichthyosaurs are marine reptiles superficially resembling dolphins or sharks and found only in Mesozoic rocks. The stratigraphically lowest ichthyosaur is *Chensaurus*, from the Lower Triassic of China. Compared to other ichthyosaurs, *Chensaurus* has a smaller caudal fin, more narrow body, and more vertebrae in the trunk of its body. This morphological structure implies that is was a less efficient swimmer than other ichthyosaurs. The authors suggest that *Chensaurus* may be a transitional form between terrestrial diapsid reptiles and more advanced ichthyosaurs, as illustrated by *Mixosaurus* and *Stenopterygius*, from Middle Triassic and Lower Jurassic rocks, respectively.

Comment: Mobility is one of the features thought by creationists to play a role in determining the fossil sequence. In this case, the first ichthyosaur to be buried and preserved appears to be the weakest swimmer of its type. *Chensaurus*, *Mixosaurus* and *Stenopterygius* appear to form a series of increasing mobility.

SPECIATION RATES

Johnson TC, Scholz CA, Talbot MR, Kelts K, Ricketts RD, Ngobi G, Beuning K, Ssemmanda I, McGill JW. 1996. Late Pleistocene dessication of Lake Victoria and rapid evolution of cichlid fishes. Science 273:1091-1093.

Summary: The African rift lakes are famous for their species flocks of cichlid fish. Lake Victoria has more than 300 endemic species of cichlids. Studies of bottom sediments indicate that the lake completely dried up during the Late Pleistocene. The lake filled again at about 12,400 radiocarbon years ago. This scenario implies that the speciation process is rapid enough to produce 300 new species in no more than 12,000 years.

Comment: Some creationists have long believed that speciation rates could be much more rapid than typically stated in the literature. This example seems to support such a belief, and is all the more remarkable because sympatric speciation seems to be required. One

might expect allopatric speciation to be more rapid than sympatric speciation.

STRATIGRAPHY: ANOMALOUS BLOCK IN THE OCEAN

Bonatti E, Ligi M, Borsetti AM, Gasperini L, Negri A, Sartori R. 1996. Lower Cretaceous deposits trapped near the equatorial Mid-Atlantic Ridge. Nature 380:518-520.

Summary: Rocks close to a seafloor spreading zone are expected to be young relative to rocks farther from the spreading zone. Thus it is surprising to find Lower Cretaceous rocks near the spreading center of the Atlantic Ocean. A further surprise is that the Atlantic was thought to have not been in existence in this area during Lower Cretaceous sedimentation. The anomalous Cretaceous rocks are a pelagic limestone, overlain by lower Tertiary siltstones of continental origin. One possible explanation for this anomaly, suggested by the authors of this paper, is that the block of material might have been transported back and forth by fault jumping along the nearby Romanche fracture zone. Fault jumping would mean that the boundary fracture between eastward and westward moving plates might jump to a new location. If the fault jumped past the block of material, the fault jump would effectively transfer the block from one plate to another, reversing the direction of movement of the transported block.

In an accompanying commentary (p 480-481), Rohr expresses some skepticism over this explanation. The block in question is at least 50 km wide and more than 200 km long, and it seems unlikely that faulting would jump such a large distance. An alternative explanation is that the block was trapped in a complex zone of multiple fractures, not permanently attached to either plate. Whatever the explanation, the phenomenon may well change our views of plate tectonics.

Comment: The theory of plate tectonics has been highly successful, but it does not explain all the data. We will have to wait to see whether the observation reported in this paper will result in changes to the theory.

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

TOWARD THE ORIGINAL CREATED KINDS

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TYPEN DES LEBENS. Scherer, Siegfried. 1993. Studium Integrale Biologie. Berlin: Pascal Verlag. 257 p.

This unique book is a creative contribution to the literature on speciation. Most chapters are written in German, with an English summary, and several key chapters are in English, with a German summary. The first section begins with a chapter by Scherer titled "Basic Types of Life." This chapter builds on the work of several researchers who have suggested that interspecific hybridization could be a useful taxonomic criterion. Frank Marsh (1941, Fundamental Biology) has suggested a taxonomic rank termed "basic type" or "baramin" which contains all individuals which are able to hybridize. Scherer further develops this concept, and suggests that the basic type is a systematic category, above the species level, that can be defined rather objectively. "Two organisms belong to the same basic type if (i) they are able to hybridize or (ii) they have hybridized with the same third organism." These two criteria are utilized in this and later chapters in an initial analysis of several plant and animal groups that seem to fit the definition of basic types.

Scherer also suggests that it may be possible to experimentally test the validity of a basic type by artificial insemination or pollination, but further work is needed to develop a precise definition of this experimental criterion.

Hybridization data available in the literature have been used by Scherer and the other authors in this book to describe 12-19 basic types, including both plants and animals. This is only a beginning, but it seems

to demonstrate that the "basic type" concept is a promising working hypothesis that may provide a basis for much additional productive research.

The basic types described at this time are at the subfamily or family level in birds and mammals, and at the tribe, subfamily, or family level in plants. Scherer submits the tentative suggestion that the term "micro-evolution" be applied to processes within a basic type [changes sufficient to be considered new species and genera]. He also suggests that within basic types, ancestral populations with a large hidden potential of variation have speciated into numerous specialized species with lower genetic potential than the ancestral population.

Chapter Two is a summary of models of speciation. It is emphasized that numerous speciation processes exist. The author suggests that a "largely disregarded model of speciation is diversification promoted by reduction of a high variation potential of the ancestral form."

Chapter Three is a revealing analysis of the roots of the species concept for Darwin and his colleagues. Darwin claimed to have used true induction, collecting facts on a large scale, with no theory in mind. However, those who have studied his education and his notebooks conclude that early in his life, Darwin was inclined toward belief in evolution [transmutation], and rejection of the rigid fixity of species that be believed was the biblical position. Transmutation was the starting point for his research. In reality, fixity of species was a concept from Greek philosophy that was inappropriately imposed upon the biblical creation account. Thus, when Darwin became an evolutionist, what he really did was to switch from one scientific paradigm [static species, from Greek science] to another, "none of which had anything to do with the mosaic creation account."

The Swedish systematist Linnaeus (1707-1778) has often been characterized as a supporter of fixity of species, but reality is quite different from that. Linnaeus at first believed in fixity of species, but as he studied his collections and struggled with the challenge of differentiating species and varieties he came to the conclusion that species were not the created kinds. His publications made this more and more clear as his career progressed. He concluded that new species, and even genera, seem to arise from hybridization of different species and genera. At one point he went so far as to suggest that God created as

many individuals as there were orders, and these were then mixed to form genera, species, and varieties.

The publications of Linnaeus that included his ideas on the origin of species and genera within created kinds were in Charles Darwin's library, but Darwin was unaware of these ideas until they were brought to his attention in 1867. There were many prominent scientists contemporary with Darwin who also recognized the probability of new species arising within created kinds. Darwin was unaware of the thinking of these more advanced contemporary colleagues, as he was not aware of the more mature ideas of Linnaeus on change in created kinds. Darwin's rigid, static creationist view of species was already old-fashioned in his own time, and when he rejected it he moved quickly to an insistence that all changes in life forms occurred by natural forces. In a 1915 article J.H.F. Kohlbragge accused Darwin of being unaware of the positions of his colleagues and incapable of mastering foreign languages.

The remaining chapters, in sections two and three, are analyses of the hybridization data for different groups of plants, birds, and mammals. The conclusion is reached that hybridization occurs widely within certain groups, and hybridization does not occur between these groups. These groups are at the tribe, subfamily, or family level, and the authors interpret them as basic types. If this is correct, microevolution has occurred within created types, sufficient for us to categorize the evolved forms as new species and genera. The following is a list of these basic types. Of course these available data are from only a small portion of the animal and plant groups, but it is a very interesting beginning. Those marked with an asterisk are considered to be tentative, probable basic types, but the others are based on more solid evidence.

Plants

Family Funariaceae (mosses)	5 genera	
*Family Aspleniaceae (ferns)	7-10 genera	700 species
Tribe Triticeae (grasses, family Poaceae)	36 genera	325 species
Tribe Geeae (family Rosaceae)	3 genera	67 species
Subfamily Maloideae (family Rosaceae)	15-30 genera	200-2000 species

Animals		
Family Anatidae (ducks, geese, swans)	9 tribes	148 species
Family Phasianidae (quail, turkeys, pheasants)	70 genera	203 species
*Family Cracidae (in the Galliformes)	10 genera	43 species
*Family Megapodiidae (in the Galliformes)	7 genera	12 species
*Subfamily Aegypiinae (Old World Vultures)		
*Subfamilies Accipitrinae and Buteoninae (Hawks and Buzzards)		
*Family Falconidae (Falcons)		
*Family Cathartidae (New World Vultures)		
Family Estrildidae (Estrildid Finches)	49 genera	131 species
Subfamily Fringillinae (Fringillid Finches)		3 species
Subfamily Carduelinae (Carduelin Finches)	39 genera	125 species
Family Canidae (dogs, wolves, foxes, jackals)	15 genera	34 species
Family Equidae (horses, zebras, donkeys)	1 genus	6 species
Subfamily Cercopithecinae(Old World Monkeys)	9 genera	50-60 species

This book is a creative presentation of a fascinating line of evidence that has not previously received adequate attention. It introduces a working hypothesis for defining basic types. This method, using hybridization data, provides a basis for much additional research. If further study indicates that this method yields consistent results over a wider range of plants and animals, it may provide a method for proposing objective hypotheses for the boundaries of basic created types.

GENERAL SCIENCE NOTES

FALSE FOSSILS

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WHAT THIS ARTICLE IS ABOUT

Fossils have fascinated mankind for millennia. They provide clues about the great intrigue of the past history of life. Unfortunately some fossils are not well preserved, and some things we call fossils are not fossils at all. Our fascination with fossils and what they represent can cause us to sometimes "see" what we want to see instead of what is really there. Some of the most intense scientific battles have been about the proper identification of objects which some consider to be genuine fossils and others consider to be false fossils. Examples of false fossils warn us to be cautious, especially when dealing with ill defined objects which, in spite of varied claims, may or may not be real fossils.

A CASE HISTORY

Just east of the gigantic world-famous Carlsbad Caverns in New Mexico, are some intriguing limestone layers consisting of closely packed pea-size spheres (Figure 1). How did these form? There are several ideas, and controversy over their origin has been smoldering for most of this century. The layers of rocks, which at a distance look very ordinary, immediately capture your attention when you get close and notice millions of small marble-like spheres. They are called pisoliths. The term comes from the Greek word "*pisos*," meaning pea. A rock consisting of pisoliths is called a pisolite.

The conventional wisdom during the early part of the century was that these pisoliths were formed by the action of algae growing over the surface of fine grains. The grains became larger as the algae facilitated chemical precipitation of lime (calcium carbonate) and/or the capture of fine sediments. As the grains were rolled around by moving water, growth would take place on all sides producing a somewhat spherical pisolith.

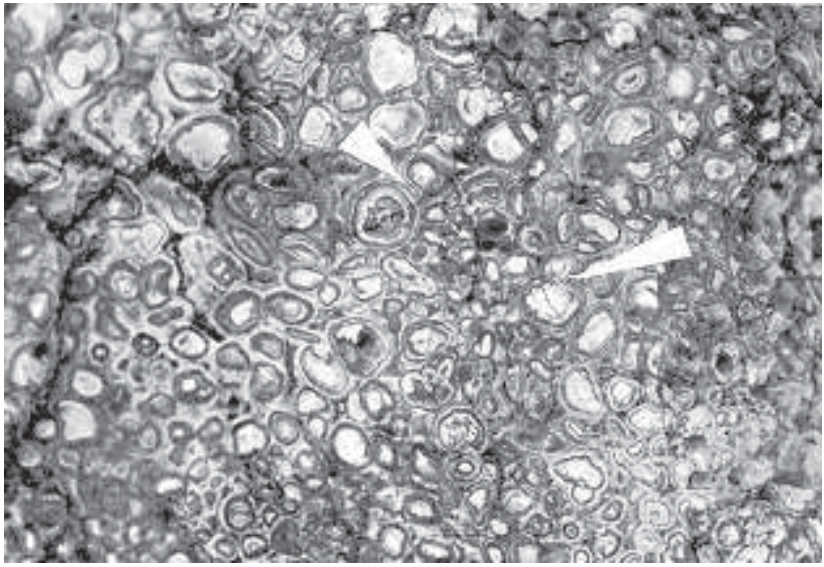

FIGURE 1. Life-size figure of the weathered surface of a pisolite from the Permian Yates Formation in Walnut Canyon near Carlsbad, New Mexico. The individual spheres are called pisoliths. The short arrow points to an example of polygonal fitting; the long arrow points to concentric layers going around two pisoliths, indicating growth after the appearance of the original pisoliths.

In 1929 the state paleontologist of New York, Rudolf Ruedemann,[1] emphasized the algal origin of these spheres, but a dozen years later two other scientists would disagree. J. V. Pia[2] reported that he could not find any algae, while Walter Lang[3] reported on a few algae, and questioned their significance in producing the pisoliths. At the same time Harlan Johnson[4] reported that he could not find any algal cell structure in the pisoliths, but he believed the majority of them were formed by the action of algae. About the middle of the century, a group of geologists (Newell, Rigby, Fischer, Whiteman, Hickox, and Bradley) published a book[5] on the geology of the region in which they discussed the origin of the pisoliths. While they discussed a number of reasons why algae could not have produced them, they ended up siding with the prevailing view that they had been produced by algae.

The most dramatic change in thinking about the origin of these spheres took place just a few years later when two investigators, Robert Dunham[6] and Carroll Thomas,[7] working independently, concluded that

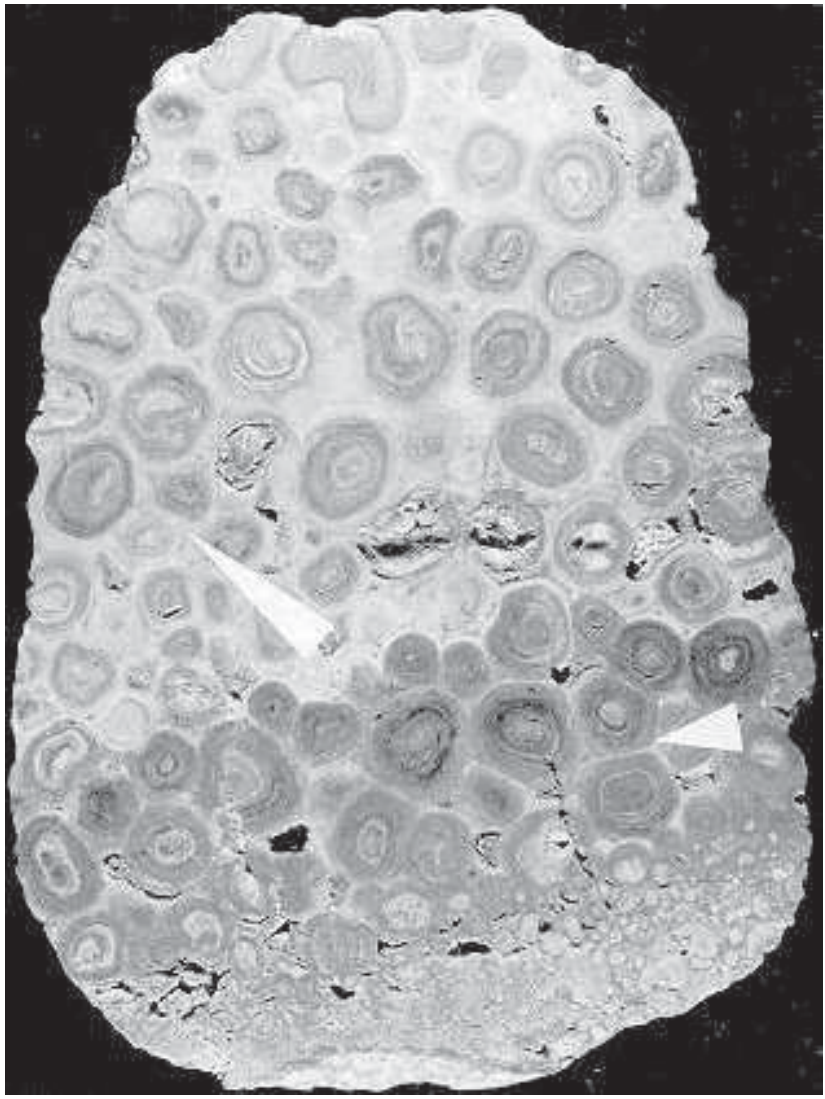

FIGURE 2. Polished slab of a pisolite. From the Permian Yates Formation in Walnut Canyon, near Carlsbad, New Mexico. Note the smaller pisoliths at the bottom (reverse graded bedding), the short arrow pointing to polygonal fitting of the pisoliths, and the long arrow pointing to lamina that surround more than one pisolith. The rock is 12 cm in length.

the pisoliths were not the result of the work of algae, but were formed inorganically, underground, by the gradual accumulation of their many lime layers (Figure 2) around an original nucleus. As water occasionally percolated down through the normally dry soil of the region it facilitated the replacement of the original lime sediments with layers of denser concentration which form the pisoliths. The common spherical concretions we find in many sedimentary rocks are thought to have formed in a similar way. In the region of Carlsbad Caverns where there are many limestone caves lined on the inside with millions of alluring stalactites and stalagmites which are formed from water transported lime, Dunham's and Thomas' novel model is not so hard to imagine. The common formation in soil of a hardpan layer below the surface illustrates how minerals can be easily transported underground by water. Some of the evidence presented by Dunham and Thomas includes: (1) Reverse graded bedding with the larger pisoliths on top of smaller ones (Figure 2). Normally in transported sediments it is the opposite, with the larger particles below. (2) The fitting of the pisoliths against each other (polygonal fitting) as though they grew next to each other (short arrows, Figures 1, 2). (3) Layers enclosing several pisoliths (long arrows, Figures 1, 2). These seem to unequivocally demonstrate that at least some of the lime layers are produced underground. Their formation would have to follow any process of development or emplacement of the spherical bodies. (4) The absence of algae. Algae which require light for growth would be essentially absent below the surface of the ground where Dunham and Thomas proposed the pisolites developed.

Soon some objected to the model. After giving due consideration to various possibilities, C. G. St. C. Kendall[8] opted for a composite origin involving both algae and inorganic precipitation. The most severe challenge came from two geologists, Mateo Esteban and Lloyd Pray[9] who strongly disagreed with the model and vaguely suggested some kind of formation in water and also just below the water-sediment line in a hypersaline environment. They did not suggest that algae were involved.

Despite the suggestions by Esteban and Pray, the model of underground formation, in the vadose region above the water table, has gained widespread approval.[10] It was soon applied to many similar deposits in neighboring Texas,[11] as well as other parts of the world including Italy, Canada and Morocco.[12] Recently the underground precipitation model has received further support by experiments that produce similar

structures in unconsolidated mud.[13] While not all are agreed, the strong prevailing opinion is that the pisoliths are not of algal origin.

WHAT IS A FOSSIL?

The question of whether the pisoliths mentioned above are produced by algae or by inorganic precipitation determines whether they are fossils. A fossil is any evidence of ancient life. If the pisoliths were not produced by algae, or some other living organisms, they are not fossils. While there is an abundance of thoroughly unquestionable fossils to be found, there are also many problematic forms in the rocks of the crust of the Earth that challenge our innate desire for definitive answers. Sometimes the term *pseudofossil* is used to designate a form that was thought to be a fossil but that turns out to be of non-living origin.[14] One dictionary describes a pseudofossil as an object mistaken for a fossil by an inexperienced person; however the case of the pisoliths mentioned above does not exonerate experts from the challenge of determining if something is really a fossil. The term *dubiofossil* is sometimes used when we are more sure that we don't know.

Determination of whether a peculiar form in a rock is a *bona fide* fossil can, in some cases, be extremely difficult. Examples abound. Preserved mud curls caused by drying have sometimes been interpreted as crab parts; drag marks caused by movement of objects during storms can resemble worm tracks; chemical precipitation, in rose-like shapes, of the mineral pyrite have been interpreted as medusae (jellyfish), as have gas-bubble markings;[15] and some supposed sponge-like fossil organisms (archeocyathids) have turned out to be forms produced by inorganic crystallization.[16]

The venerable *Treatise on Invertebrate Paleontology*[17] lists 69 published descriptions of "fossil organisms" originally identified as coral, algae, fungi, sponges, snails, etc., that are most likely of non-biological origin. These misidentified objects appear to have been produced by unusual depositional conditions. *Brooksella canyonensis* is a "fossil" which resembles a star-shaped crack. It has an impressive pedigree of interpretations, including: (1) the body fossil of a jellyfish, (2) the reverse imprint of an inorganic fracture system produced by gas evasion, (3) the result of compaction, (4) the imprint of a starlike feeding burrow, or (5) possibly the work of a worm.[18]

Numerous tiny "shells" in the Precambrian of Mongolia caused considerable concern, because they were found in an unexpected

location. The discoverers published additional papers supporting their authenticity. But the "shells" turned out to be produced by precipitation of mineral formations around gas bubbles during the preparation of the rock specimens.[19]

In the fossil record we occasionally find what are commonly called "worm tubes." These are elongated tubes of various shapes and orientation. Some are unquestionably genuine fossils, identifiable by the structural patterns left by the organisms that produced them. Others are subject to other interpretations. It is well known that gases and fluids escaping from sediments can form vertical and sinuous tubes. Some horizontal tubes that have been interpreted as being formed by organisms have turned out to be desiccation cracks which later became filled by other sediments.[20]

The problem of pseudofossils is particularly acute in the lowest parts of the geologic record, where evolutionists expect the earliest, simple life forms to have originated. Finding these earliest forms of life has almost become an obsession with some paleontologists. Creationists can interpret lowest fossils as representatives of created forms of microscopic life. Many indications of microscopic life at unexpected depth in rocks have been reported in the professional literature. On the other hand, several investigators have been able to simulate the shape of these presumed simple life forms by inorganic precipitation or by special depositional conditions. Spherical, tube-like, or coiled shapes, characteristic of fossil forms, are easily reproduced from simple inorganic chemicals in the laboratory.[21]

It is to the credit of paleontologists that considerable caution is now being expressed regarding the authenticity of most claims concerning fossils in what is considered to be the oldest sediments, the Archean. In referring to microfossils reported from at least 28 Archean localities, two specialists in this field, William Schopf and Bonnie Packer, state: "However, virtually all have recently been reinterpreted...as dubiofossils or as nonfossils: pseudofossils, artifacts, or contaminants."[22] Paleontologist Richard Cowen states: "Only a few reports of fossil Archean cells seem to be genuine, out of fifty or more claims."[23] Roger Buick at Harvard refers to a host of problems with the identification of most of these primitive fossils found at North Pole, Australia.[24] (It is called North Pole because, like the real North Pole, it is a notably desolate area.) An old geological dictum stating that "I never would have seen it if I hadn't believed it" seems to apply to many of these cases.

The pseudofossil problem also comes into focus with respect to stromatolites (Figures 3, 4), which are finely laminated sedimentary structures, usually in the centimeter to meter range and often having a mounded or wavy form. Stromatolites are formed underwater, as thin mats of microscopic organisms living on their surface trap or precipitate minerals, which are then incorporated into a layered structure. There is a question as to whether what appears to be a fossil stromatolite may have formed biologically, or whether it is just the passive accumulation of fine layers of sediment which has been subjected to deformation. In the latter case they would not be fossils. The sedimentologist Robert Ginsburg points out that "Almost everything about stromatolites has been, and remains to varying degrees, controversial."[25] Stromatolite specialist Paul Hoffman notes: "Something that haunts geologists working on ancient stromatolites is the thought that they might not be biogenic at all."[26] The well-known paleontologist Charles Walcott, who for twenty years was Director of the US Smithsonian Institution, described 5 new genera and 8 new species of stromatolites believed to be of biological origin. Each of these has since been reinterpreted as inorganic by at least one investigator.[27] Even presently forming "stromatolites" can be

FIGURE 3. View of Precambrian rocks of the Chuar Group near Kwagut Butte in the Grand Canyon of the Colorado River, Arizona. The mounded rocks scattered in the vegetation are interpreted as stromatolites. The arrow points to one of them.

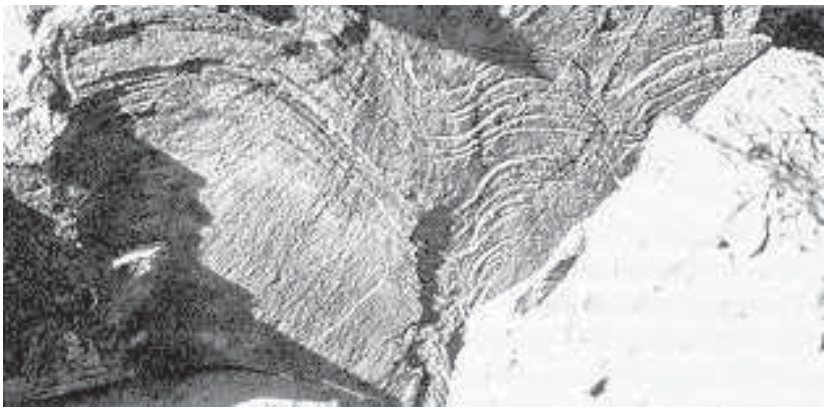

FIGURE 4. Cross-section of a stromatolite from the region of Figure 3. Note the wavy layers in the stromatolite. The specimen is about 40 cm across.

enigmatic. A number of "stromatolites" described in various parts of Scandinavia have been reinterpreted more recently as being of non-biological origin;[28] however, there are many unquestionable living stromatolites over Earth's surface.

Stromatolites are also found in the deep rocks, and their interpretation is more equivocal from both the creationist and evolutionist perspectives. Stromatolites are an important part of the evolutionary scenario of early life; but like many of the fossils in the deeper rocks, their identification is problematic. Some widely accepted examples of ancient stromatolites have been reinterpreted as precipitation and soft sediment deformation.[29] Paleobotanist A. H. Knoll of Harvard points out: "no Early Archaean stromatolites are known to contain micro-fossils. Thus, abiological alternatives must be considered."[30]

The correct identification of fossil stromatolites in deep rocks is important to the question of the origin of life. Estimates of the age of these fossils is complicated by the recent discovery of living stromatolites actively forming in rock cavities such as are sometimes found in coral reefs. These deposits are called endostromatolites. Sediment accumulation on an endostromatolite is facilitated by bacteria that do not require light as an energy source. Claude Monty, a biosedimentologist from the University of Liège in Belgium, suggests that endostromatolites can form in rock cavities at depths of at least 3 km.[31] This raises the question as to whether some stromatolites in the deeper rocks, possibly growing

in caves, might be endostromatolites of recent origin. The status of our knowledge regarding these ancient, or assumed-ancient, stromatolites is inadequate, and firm conclusions cannot be drawn.

LIFE ON MARS

The planet Mars has several similarities with Earth. It has been considered as the most likely place beyond Earth where life could exist in our solar system. Occasionally we even fantasize about little green men from Mars. Evolutionists sometimes wonder if life could have evolved independently on our close planetary neighbor, and some creationists wonder if life could have been created there. The extent of life throughout the Universe is one of our most profound questions.

In 1884 the French astronomer E. L. Trouvelot thought that he could see slow color changes in some of the grayish areas of Mars, thus implying seasonal changes in the Martian vegetation. Three years later the Italian astronomer Giovanni Schiaparelli noted long lines on the surface of Mars which he called "canali." Early this century the American astronomer Percival Lowell pursued the same theme and thought he observed a network of canals on the planet. He reasoned that they were too straight to be of natural causes and suggested that they were built by the inhabitants of Mars to bring water from the poles to their crops near the arid equator. Such speculations were laid to rest a few decades ago when the United States and the Soviet Union sent space probes to Mars. They did not find any intelligent life. Highly sensitive detectors found no evidence of life in the Martian soil in the region where the space probes had landed. They did not find any canals either, but instead discovered huge canyons and abundant evidence that huge volumes of water were involved in the sculpturing of parts of the planet. Any suggestion of life on Mars has now been essentially reduced to the possibility of present or past microbial life.

Accounts of fossils purported to represent simple life, that are then disproved by subsequent research, are becoming an old and too often repeated story. The Orgueil Meteorite has been studied for well over a century. The meteorite fell as many fragments in 1864 at Orgueil, France. It contained many carbon compounds which suggested a possible association with living things. This engendered a search for fossil evidence of past life in the meteorite. Several unusual microscopic forms considered to be fossils were found. Their origin became the topic of an unusually

lively debate that lasted for years.[32] Some of the fossil evidence turned out to be pollen interpreted by some as recent contamination, and some resembled inorganic structures found in furnace ash. The general conclusion has been to doubt the authenticity of any fossil forms. The Orgueil Meteorite provides little, if any, convincing evidence for the existence of extraterrestrial life.

The search continued. During the late 1960s, when space probes and astronauts were first sent to the Moon, there was initial considerable excitement, followed by disappointment, when it became apparent that there was no life on the Moon. In recent years vast expenditures have been made in listening for radio messages from outer space. Thus far the search for messages from extraterrestrial intelligence has been futile. Much effort has been invested in looking for life beyond Earth. Fossils, dubiofossils, and pseudofossils have played a major role in this search. In several aspects the debate concerning microbial life on Mars has been remarkably similar to the one about the Orgueil Meteorite.

In August 1996 David McKay and his colleagues at the National Aeronautics and Space Administration Johnson Space Center and Stanford University announced that they had found evidence of past life on a meteorite presumed to have come from Mars.[33] The potato-size meteorite is assumed to be around 4.5 billion years old. It supposedly escaped from Mars, and, after an extended sojourn in space, landed on Earth's Antarctic ice an estimated 13,000 years ago. This meteorite, which is designated as ALH84001, is thought to have come from Mars because it is similar to other meteorites that have been found in the same Antarctic region and have gas bubbles whose composition is similar to the atmosphere of Mars, and not of Earth. There is little disagreement, at least within the planetary scientific community, about the origin of this meteorite. But there is considerable debate about the evidence for life in ALH84001. The opposition began immediately after the announcement of its discovery.[34] Arguments in favor of living forms include the presence of organic compounds, magnetite crystals thought to have been produced by microorganisms, and carbonate minerals which are often associated with life. All of these arguments and others have been challenged, either as not representing life, or as indicating contamination from Earth's environment.

Perhaps the most interesting suggestion by McKay and his group was that tiny filaments and ovoid microscopic structures found in the

FIGURE 5. High-resolution-scanning electron microscope image from the meteorite ALH84001. The elongated tube-like form in the middle is less than 1/100th the width of a human hair. It is considered to be a prime example of a possible fossil from Mars. Photo courtesy NASA.

carbonate minerals of ALH48001 represent fossils (Figures 5 and 6). If it could be demonstrated that these are genuine fossils, much of the rest of the debate would be irrelevant. Are these elongated forms evidence of past life, or do they represent pseudofossils. The so-called fossils found have a slight resemblance to bacteria, but it has been pointed out that the fossils are too small to represent normal bacteria. On the other hand, it is argued that there are organisms on Earth much smaller than ordinary bacteria. Others point out that the so-called worm-like fossils (Figures 5, 6) could be produced by crystalline growth on the edge of layers, or they may be just the protruding edges of mineral layers. They also could be only artifacts resulting from the complex specimen preparation process. In referring to the evidence for life in AHL84001, planetary scientist John Kerridge of the University of California at San Diego states "Now I think they don't have a shred of evidence to back it up."[35] The last chapter about life on Mars has not yet been written. An ambitious program giving further study to the planet is under way. Final conclusions should not be drawn until we have more data, but the present fossil evidence is highly dubious.

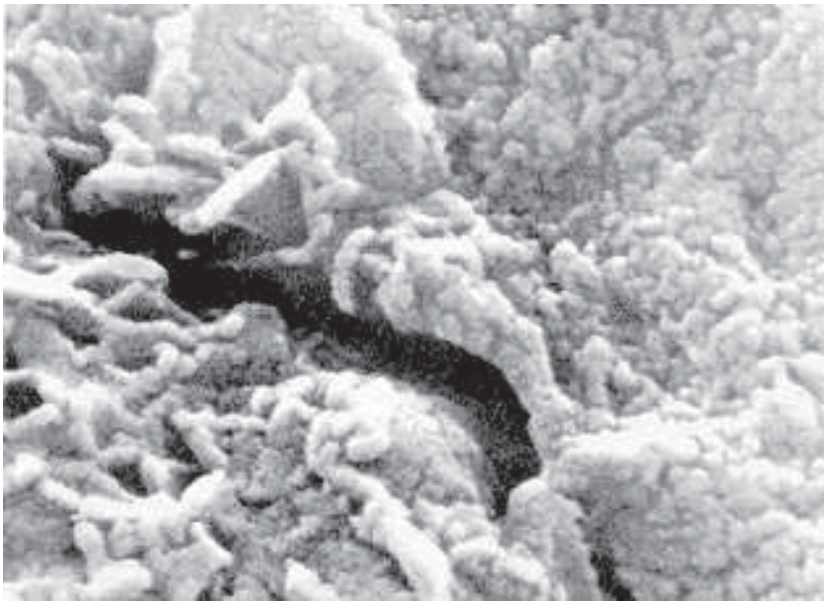

FIGURE 6. Electron microscope image of possible bacterial-like organisms thought to have come from Mars. The fine filamentous structures, which are less than 1/100th the diameter of a human hair, were found in carbonate minerals from the meteorite ALH48001. Photo courtesy NASA.

CONCLUSIONS

There are many good fossils to be found around the world. There are also many questionable ones. Unfortunately there are too many genuine pseudofossils. Determining whether a particular form is a genuine fossil is not always easy; it can also be a problem to identify a genuine pseudofossil. Our desires to discover and to proclaim our discoveries can lead us into strange pathways where the questionable can become very real to us. The long list of pseudofossils now bedecking the scientific literature should warn us to be cautious about any unwarranted claims about fossils. In the realm of poorly defined structures that look like fossils, reserving judgment is a virtue.

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