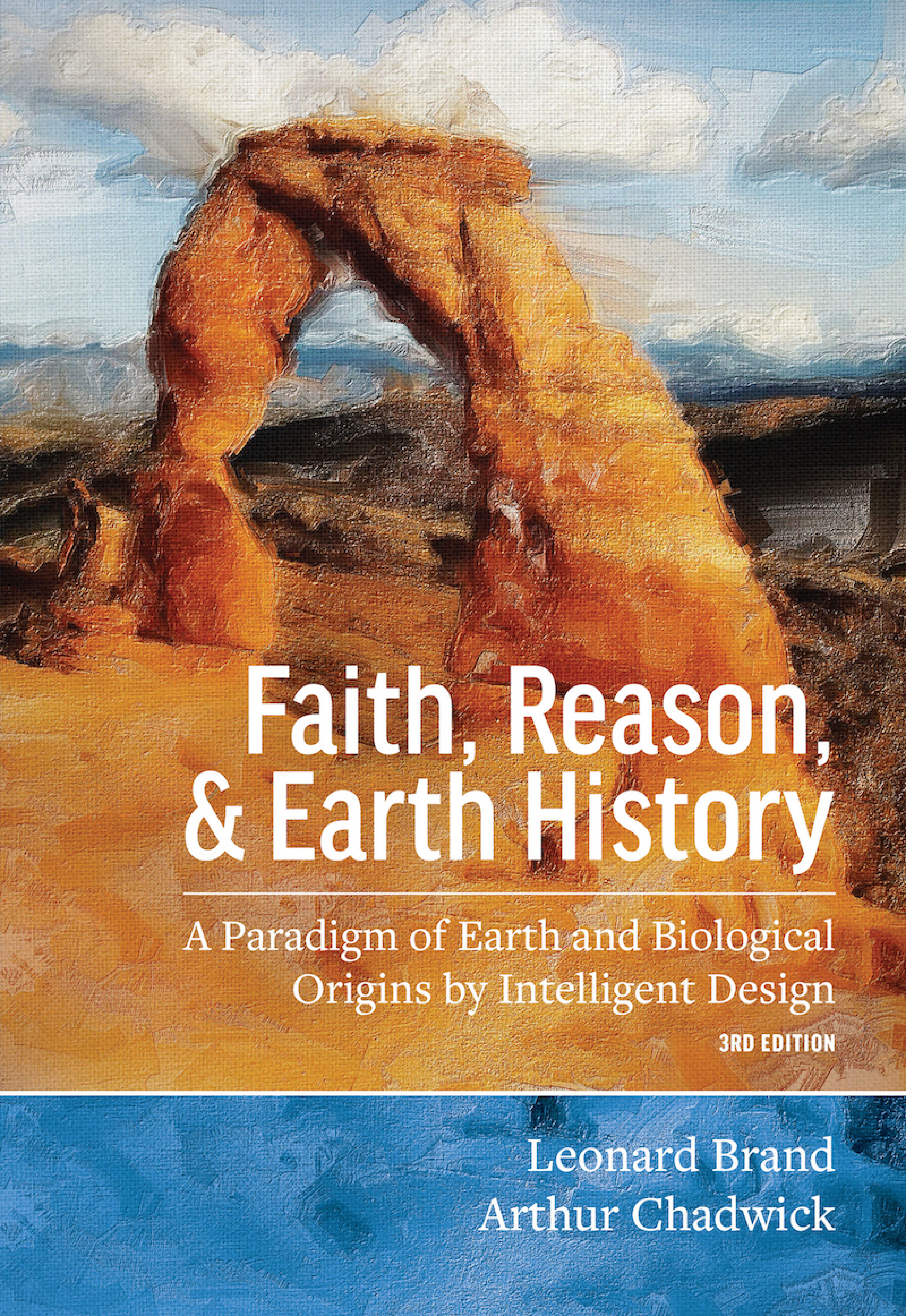

Faith, Reason, & Earth History

A Paradigm of Earth and Biological Origins by Intelligent Design

3RD EDITION

Leonard Brand
Arthur Chadwick

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Contents

Preface

The following pages present an overview of how the scientific method works. That understanding is then applied to an analysis of data in biology and earth science to illustrate how a scientist who is a creationist thinks. This book outlines an interpretation of earth history that assumes there is a Creator. Many scientists contend that a person who believes in creation cannot possibly be a good scientist and that creationism is incompatible with the scientific method. A central thesis of this book is that a creationist can indeed be an effective scientist. That thesis is supported by personal experience and by observation of individuals who are creationists and are also productive scientists.

The approach taken here is also based on the observation that it is inappropriate and incorrect to characterize noncreationist scientists as unintelligent or uninformed people who believe in a ridiculous theory. We may indeed differ on some important philosophical issues, but the noncreationist scientists whom we know are capable, knowledgeable individuals who can give a lot of good evidence to support their understanding of earth history. A constructive approach to an alternate view of earth history needs to concentrate on careful analysis of data and the development of new, credible interpretations of the data. The conflict is not between biblical faith and science but between biblical faith and current majority interpretations of scientific evidence.

During the years since publication of the first and second editions of this book, much has happened in science in general and in the study of origins in particular. Molecular biology has advanced on several fronts, including the sequencing of the genomes of humans and many other animals and the growing prominence of the field of epigenetics. New fossil discoveries have added to an understanding of previous life forms. The Intelligent Design movement has come into wider public knowledge and is the focus of much criticism from those who object to concepts requiring any type of design in origins. Our own research has contributed helpful concepts for improving this book.

This third edition follows the same basic approach as previous editions, but much of the book has been updated and reorganized, and the addition of a coauthor with new perspectives has resulted in significant improvements (my dad always said, "Two heads are better than one"). However, it is not possible to present a comprehensive and complete coverage of the literature in all parts of such a broad topic. This edition, like the others, should be read as an introduction to a way of thinking about origins. The reader is encouraged to read further in the references listed herein and in the abundant and increasing literature of the topics included so as to continue growing in an understanding of this fascinating effort to integrate faith and science.

In this book, we often use the terms "interventionism" and "informed intervention." Responses from readers indicate that these terms need more explanation. In some places, the word "creationism" could be used, but we use the term "interventionism" for a couple of reasons. The biblical creation, in the strict sense, is what happened at the beginning—the origin of life forms and of physical features of our earth so that it can support life. But much of what creationists talk about involves earth and biological history that occurred after the initial creation.

Informed intervention is more inclusive—a view of history that recognizes (1) the important role of intelligent intervention in history, including the original creation; (2) intervention in geological history; and (3) God's communication to us through the Scriptures. This view of history also must deal with the biological and geological changes that have resulted through the centuries from the operation of normal physical and biological processes to make a unified picture of earth history since the creation. To try including all of this in the term "creation" is like including all of evolutionary and geological theory in the term "abiogenesis." Clear communication requires words that are not ambiguous. For this reason, we refer to the philosophical approach presented here as interventionism.

This term, by itself, does not define the nature of the intervention. Some persons may use the word to include a variety of interpretations, including the concept of a God who starts the universe and leaves it to develop, or theistic evolution, or more literal interpretations of the Bible. We use the term "interventionism" in reference to one version of the concept that reflects our confidence in the literal scriptural account of origins and history (Gen. 1–11).

Interventionism, as we understand it, also includes God's continuous involvement in maintaining the universe. How does He do this? A favorite hypothesis is that God continuously maintains the constancy of His laws of chemistry and physics so that the universe continues to operate as intended. If He stopped this maintenance activity, the entire universe would simply cease to exist. Might God someday tire of this maintenance activity and end it for a time before starting again right where it left off? That might be an intriguing possibility to consider, but if it happened, we would never know the difference, and even our scientific research would not detect it. We typically do not focus on this maintenance part of God's work simply because we know nothing about it. However, recognition of God's continuous upholding of the universe and life is a significant part of interventionism.

An objection could be raised at this point because of a common scientific philosophy that does not accept the existence of any supernatural interventions. It might suggest that God cannot interfere with the operation of any part of the universe because it would violate the laws of nature. But that objection is based on too shallow a view of God and His "laws of nature," which we suggest are not self-existent but are laws that God invented to operate His universe.

Many scientists insist upon the use of methodological naturalism in science (the philosophy that does not allow any supernatural explanations for any event or process). But does God actually follow that rule? Also, what is a miracle? We will discuss this in chapter 5.

There is one last reason for using the term "interventionism." In the scientific community, terms like "creation," "creationist," and "creationism" have acquired very negative connotations, and it is not just because of disagreement over the concept of creation. For many, these words conjure up images of court battles over what should be taught in high-school science classes, of debates, of careless science, and of sarcastic and derisive comments about "those evolutionists." The term "informed intervention" (also "interventionist" and "interventionism") as we use the term does not include such a political agenda. Our goal is to discuss these issues in a way that does not divide people with differing views but uses an approach that helps us understand each other, if we are willing.

In summary, interventionism is an understanding that God has intervened at times in history and is still intervening. He created a comprehensive set of laws that we refer to as the "laws of nature." He constantly maintains the unchanging operation of those laws so that the universe and life continue on a daily course through time. Interventionism includes the divine creation of life and the universe and God's sustaining involvement in geological and biological history since the initial creation. The events of history normally occur through the operation of God's laws of nature. But from time to time, God, as a reasoning Being who can make decisions and take action, does things that we call miracles. Miracles appear mysterious because we do not understand the whole range of His laws and cannot grasp the greatness of God and the options open to Him. He does not violate His laws but uses them to accomplish His purposes. Many miracles are associated with God's actions as He deals with the sin problem. We can work as scientists because the daily workings of nature follow God's laws of nature, and we can rely on them. However, we will come to wrong conclusions if we are unwilling to accept that God has intervened at appropriate times, using His power to do things that we call miracles.

Acceptance of a literal biblical creation is not a denial of science. Instead, science practiced under this biblical interventionist worldview explains much and leads to the discovery of many things missed by others. This worldview, we predict, will eventually provide better explanations as new evidence (related especially to geological time and large-scale evolution) is discovered that will force a reinterpretation of things that now seem to contradict it.

It is somewhat dangerous to publish information like that contained in this book because some may attribute it more authority than it deserves. George McCready Price published books on creationism and geology several decades ago, and there are people today who react to challenges to his writings as if the Bible itself were being challenged. A book, and particularly this one, should not be used to get "the answers." It should be read as the informed thinking of experienced scientists on the topic at this time. As new information becomes available and as science changes, some information in this volume will need to change.

We assume that the reader is familiar with basic biological concepts, but no previous knowledge of geology is assumed. A book of this type cannot include a comprehensive analysis of philosophy of science or geology and evolutionary biology (it is a book, not a library). Our purpose is to include sufficient information on these topics as a basis for discussion of the issues and to illustrate how to integrate these topics into a coherent approach to an interventionist paradigm of earth history.

Many individuals have contributed to the development of the ideas contained herein, and it would be impossible to thank them all or, in many cases, even to remember who was involved in various stimulating discussions in hallways or at meetings. Questions from the students in our classes have challenged us to search for better explanations, and discussions with other friends, especially those who disagree with us, have often clarified issues. Suggestions from two specific students, David Nelsen and Matt McLain, had an impact on this third edition, and another student, Carl Person, increased our perception of the field of epigenetics. The following individuals have read and criticized all

or part of the manuscript for this or earlier editions: Earl Aagaard, John Baldwin, Gerry Bryant, Brian Bull, David Cowles, Raoul Dederen, Matthias Dorn, Joseph Galusha, Jim Gibson, Thomas Goodwin, Lester Harris, James Hayward, George Javor, Phillip Johnson, Elaine Kennedy, Del Ratzsch, Arthur Shapiro, William Shea, Bernard Taylor, Lewis Walton, Clyde Webster, Kurt Wise, and several anonymous reviewers. They did not always agree with our approach, but they all contributed to making this a better book.

The following are some of our goals in writing and updating this book:

- To present a comprehensive introduction to a paradigm that combines faith in Scripture with a realistic respect for the scientific process
- To help readers understand science, including its strengths and its human weaknesses
- To encourage readers to recognize that science is not the only, nor necessarily the best, tool for learning about our origin
- To encourage creationists to respect scientists and to see the value of scientific data, even though we may disagree with significant parts of science's interpretation of earth history
- To reduce the destructive verbal attacks and sarcasm of Christians toward evolutionary scientists, encouraging Christians to remember that God loves and seeks everyone, including evolutionary scientists
- Ultimately, to encourage readers to trust the Word of God, even though we do not have all the answers to our questions

The illustrations in this book, other supplementary illustrations, and six PowerPoint presentations are available for use in lecturing and teaching. They can be accessed at http://medicine.llu.edu/freh-illustrations. Any use of these materials should give credit to *Faith, Reason, and Earth History: A Paradigm of Earth and Biological Origins by Intelligent Design,* third edition, by Leonard Brand and Arthur Chadwick. Copyright © 2016 by Andrews University Press.

CHAPTER 1

What Is Science?

Overview

Have you ever seen an animal peel such a tiny wrinkled fruit as a raisin? Chipmunks do. I have watched numerous chipmunks sit and manipulate a raisin in their paws. When they run away, there is a little pile of raisin peelings where they were sitting. Chipmunks are such adorable creatures to study, but what is the difference between observing the cute things they do and scientific study? To qualify as science, the observations or experiments must be done in a systematic, planned way so other scientists can verify the study by repeating the experiments or observations to see if the results come out the same. Random observations won't do. Scientific study is designed to answer a question or to test a hypothesis. The research may answer the question or just lead to other questions to be studied. The idea to be studied could come from anywhere, but we must be able to test it by the scientific process. Science, as we define it, is a systematic search for truth through experimentation or observation. It is a powerful method for discovery, but there are some limitations, as we shall see. Some ideas or events cannot be studied by science (like the miracles of Jesus or which automobile design is more esthetic).

The Impact of Darwinism

Charles Darwin's theory of evolution has been very successful as a good scientific theory. A few decades ago, an article was published titled "Nothing in Biology Makes Sense Except in the Light of Evolution."[1] That article illustrates the scientific community's confidence in the evolution theory and the extent to which it has been successful in organizing and explaining a broad range of biological data.

Chipmunks provide an example of this success. Only one species, *Tamias striatus*, lives in the eastern half of the United States, but the western states have twenty-one species of chipmunks (fig. 1.1).[2] 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, including dense brush, semidesert pinyon pine forests, yellow pine forests, and high altitude lodgepole pine forests. Many unsuitable habitats such as deserts or grassy plains separated small populations of chipmunks in isolated geographic pockets. As each population became adapted to its habitat, some populations became different species through natural selection. However, in the eastern United States, the original forest environment was relatively uniform, and few natural barriers were adequate to isolate small populations of chipmunks and thus to produce new species. Evolution not only provides explanations such as these but also suggests experiments to test these explanations. In many cases, the theory successfully predicts the outcome of the experiments, giving scientists great confidence in evolution.

For nearly 1,900 years, most of the Christian world accepted without question the creation account in the book of Genesis. Then, in a few decades, Charles Darwin and his colleagues changed all that. For many people today, evolution is the only valid account for the origin of all 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?

Figure 1.1. Diagrammatic illustration of the distribution of chipmunk species in the United States. Each symbol is in the middle of the geographic range of a species. Figure by Leonard Brand.

The history of science shows that even very successful theories sometimes need improvement or replacement. Therefore, it is appropriate to continue examining the foundations of evolution theory and to ask hard questions. Are all parts of the theory equally well supported? Have we overlooked or underestimated some important evidence? Do aspects of our logic need to be cleaned up? Such probing benefits both science and religion if appropriately conducted. We must be honest with the uncertainties in the data and be careful to distinguish between data and interpretation. The following pages outline an approach to these and similar questions that affirm the integrity of the scientific process while maintaining a context of faith. We must approach the task with humility and open-mindedness and recognize when the data point to dimensions of reality beyond our current understanding. Above all, it is essential that we treat each other with respect, even if we disagree on fundamental issues.

The success of science has encouraged a tendency to believe whatever science claims. An understanding of both the strengths and the limits of science can enable us to relate to it more realistically. Therefore, we begin this exploration by examining the scientific process (chapters 1 through 4) and comparing conventional and interventionist approaches to science (chapters 5 and 6). We then apply our understanding of the scientific process to a comparison of different theories of origins (chapters 7 through 19). The final chapter is a brief summary of the core issues covered in the book.

A Definition of Science

Science can be defined as a search for truth through repeated experimentation and observation. We can recognize two parts of that endeavor: First is the content of science—the things that science has learned and the system of organizing that knowledge. Certainly this is an important part of science. But if we stop here, we miss the most exciting and valuable part—the process of searching and discovering something new. Through the next few chapters, we seek to better understand this process of discovery.

The Scientific Process: The Search

Scientists, in the process of discovery, formulate hypotheses or theories, collect data, conduct experiments to test theories, and develop generalizations called scientific laws. This scientific search process has two primary parts: (1) the collection of data and (2) the interpretation of data.

The activities of a scientist can all be clustered into these two categories. Collecting data is an absolutely essential step in science. It can be exciting, or it also can be quite routine. Then determining what the data mean is the most rewarding and creative aspect of research—the realm of ideas and the application of those ideas to make sense of the data and formulate a plan to continue the search through further data collection.

Science is quite freewheeling, and different people approach data collection and interpretation in different ways. Working in labs and field-research sites, people learn to do science from experienced scientists.[3]

When the scientist has an idea, it is expressed as a question that can be addressed with the scientific method. For example, while watching squirrels, we hear them make a sound. Are the squirrels communicating? And if so, what are they communicating to other squirrels? If we are in the desert and see several types of rock formations containing fossils, we may ask how those rocks and fossils originated. What is the process by which they got there? After posing questions, we try to determine what kinds of data are needed to answer them. It is often necessary to break a question down into more specific questions.

What type of data could answer the question about the squirrel calls? It would help if we at least knew under what circumstances those calls were given. For example, is the call given when a predator is approaching or when a neighboring squirrel comes close to the caller's food cache? As we observe the squirrels, we write down everything about the circumstances. These data could begin to answer our questions. The rocks and fossils are a little harder. We cannot watch them form, but we can observe what is going on today when rivers and streams and ocean currents deposit sand, mud, or other sediments. We can compare these modern processes (modern analogues) with the characteristics of the rocks to see which deposit is most similar to the rocks we are studying.

Imagine that we are archaeologists who have discovered several broken pieces of glass from an ancient ruin (fig. 1.2). If we are honest, we cannot argue with descriptive data like these—the shape or composition of the objects. These facts are objective data—features that can be weighed, measured, and defined by anyone with the same results. But no matter how accurately we weigh and measure, the data are still just broken pieces of glass. The research is incomplete until we can make sense of the data through interpretation.

Interpretation involves examining relationships among pieces of data. In this case, the relationships need to be expressed in terms of what an object was like and how it was used. We probably could not answer these questions

Figure 1.2. Pieces of glass "discovered" by archaeologists. Figure by Leonard Brand.

directly from the data since they only tell us what the broken pieces of glass are like. We have to relate them to what we already know about similar objects and archaeological theories. Then we can devise a hypothesis about what the glass object was like (fig. 1.3A). Interpretation is not an objective process. We must use creativity and imagination, but we cannot let them run wild. The data create boundaries for our hypotheses—the color patterns should make sense and the curvatures of the reconstruction must fit the shape of the glass pieces. The possibility of objectivity is reduced by a couple of other factors. In science, data are often not as objective as the shape of pieces of glass, and how we describe data and even what data we collect are usually influenced by our theories.

Is our hypothesis correct? How would we know? A lot of data are missing, so we can't be sure. As often happens in science, another scientist may look at our interpretation of the data and decide that it was not done correctly, so he or she develops another hypothesis (fig. 1.3B). Broken vases, like jigsaw puzzles, likely go together in only one way. However, if the majority of the pieces are missing, we can probably arrange the remaining ones in several different ways that look logical. For this reason, there can be differences of opinion about our glass object. In science, especially in fast-moving fields, interesting dialogue is common between people who have different interpretations. But what we ultimately want to know is which hypothesis is more nearly correct. How do we determine this? The only way is to search for more data.

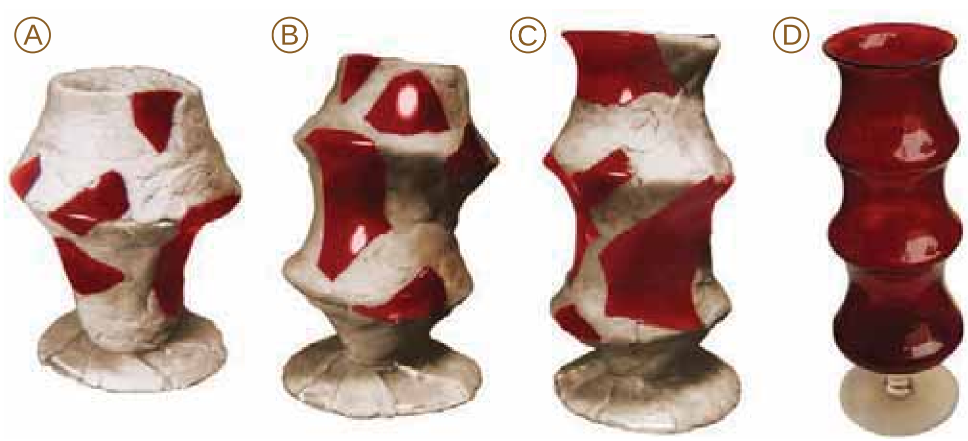
Perhaps we are successful in our search and find two more pieces of glass. One has a ridge on each end, which fits with the second hypothesis. But the other piece, with a flared top, does not fit either hypothesis. So we develop a new hypothesis that fits all the current data (fig. 1.3C). Now is it correct? That is still not certain, since we don't even know how much data are missing. In this case, we are going to cheat and look at the original (fig. 1.3D). Part of our hypothesis was about right, but other features were still incorrect.

The glass vase illustrates the self-correcting aspect of science: as we gather more data, we improve our chances of eliminating incorrect ideas. The accumulating data show where problems in our hypotheses or theories still lie and help us think of better hypotheses. Of course, complications appear along the way. What if the glass pieces are actually part of something quite unrelated to a vase, but we are considering only hypotheses about vases? Our theories influence our interpretations of data, and wrong theories can slow down the scientific process. In that case, an improved understanding of nature may depend on new, creative interpretations of existing data or may await the discovery of additional data that clarifies our thinking.

Factors That Make a Theory Useful to Science

In the 1790s, a priest named Spallanzani did some fascinating experiments with bats.[4] He covered the eyes of some bats and the ears of others. From the results, he

Figure 1.3. Hypotheses of the shape of the vase (A, B, and C) and the original vase (D). Figure by Leonard Brand.



reached the conclusion that bats have to use their ears, not their eyes, to navigate successfully at night. Spallanzani could not hear the ultrasonic sounds the bats were using. Consequently, his conclusions did not make much sense with the knowledge available at that time. But the data still supported his conclusion.

The prominent scientist Cuvier responded by proposing a theory that bats use a highly specialized sense of touch to find their way around in the dark. He had no evidence for his theory, but he was more prestigious in scientific circles and more scientists accepted his explanation.[5]

More than one hundred years later, Spallanzani was vindicated when the discovery of echolocation made sense of his observations. Bats give out ultrasonic cries, listen to the echoes, and use them to find their way around.

A good scientific theory or hypothesis has several specific characteristics. The first one is illustrated by Spallanzani and his bats:

1. A theory organizes and explains previously isolated facts.

When a new field of inquiry is just beginning, there may be a lot of facts. But it is hard to see how they relate to each other (like the bats and their use of their ears for navigation), and people may have different ideas on how to put them together. A successful theory makes sense of these previously unrelated facts. This happened with the new research one hundred years after Spallanzani.

2. A good theory also suggests new experiments and stimulates scientific progress.

Donald Griffin's theory of echolocation suggested experiments to test that theory. Experiments are not selected randomly. They are generally chosen because some theory suggests they will yield new insights. Experiments are done to test a theory.

This introduces another characteristic of a good scientific theory:

3. It should be testable.

We should be able to think of data that may potentially falsify the theory. If it is not possible to do that, then the theory may not be very useful. Echolocation could be tested by experiments, and the theory passed the test.

To further illustrate what is meant by a testable hypothesis, compare these three hypotheses:

A. Ants behave the same way in undisturbed underground tunnels as in glass observation chambers.
B. Goldfish need oxygen to live.
C. Extrasensory perception exists.

Which of these three can be tested? How would you prove or disprove the first hypothesis? Probably there is no way to find out what ants do many feet underground without seriously disturbing them. If we disturb them, we cannot possibly determine what they are doing in undisturbed tunnels. If we really want to understand ant behavior, we have to know the answer to this question, yet it is unanswerable. Science often has to live with such uncertainties.

Is the second hypothesis testable? A suitable experiment would be to seal up the goldfish bowl and see what happens, or provide the fish with an artificial atmosphere that does not contain oxygen. If the fish survive the experiment, then the hypothesis has been disproved.

Can the third hypothesis be tested? One can design an experiment in which a man who claims to have powers of extrasensory perception is asked questions about thoughts or events in another place. If he can answer the questions correctly, it would indicate that something unusual is happening, but we still would have to determine exactly what it was. However, if he could not answer the questions, he might still claim that he usually can do so but was unable to because the scientist was watching him. If that happens, what are we going to say? The experiment could not disprove the concept.

Keep in mind that the discussion above is describing the ideal situation, but science often goes beyond ideal, testable phenomena. Theories about the distant universe or about events in earth history may not be genuinely testable because we were not there and cannot get there, but they still may constitute legitimate science. Science is not always as objective and straightforward as we might wish.

4. In experimental science—such as chemistry, physics, or physiology—experiments done to test a theory or hypothesis should be repeatable.

An experiment should be defined in precise, quantitative terms so that somebody else in another lab can do the same experiment and get the same result. Do fish in different research labs respond in the same way to a lack of oxygen? In contrast, hypotheses about subjective concepts like human opinions or attitudes are very difficult to test with repeatable experiments.

5. The last characteristic of a useful theory is that it predicts the outcome of experiments that have not been tried yet.

There is a reason this is important. If we do an experiment to test a theory and then, after finishing the experiment, we try to show that the results support our theory, that is not convincing. But now let's go back to the 1790s. Spallanzani's work suggested that if we could hear all that a bat hears, we would hear the sounds that a bat uses for navigation. More than a century later, that implied prediction was tested, and Spallanzani was right. The fact that the ultimate result was predicted in advance gave great credibility to the theory of echolocation.[6]

These five characteristics of a useful theory do not say that the theory has to be true. Is that disappointing? We hope our theory is true, but how would we know? That is what we are seeking to discover with our experiments. We don't know ahead of time whether a theory is true. We must wait for the results to come in, and often that can take a long time. A theory can be wrong and still lead to significant scientific advancement before we find out it is wrong. We discuss this concept more in a later chapter.

The Source of an Idea Is Not What Determines Its Scientific Value

How do we get the ideas that we formulate as hypotheses? The scientist Archimedes had an interesting experience as the result of a task given to him by the king. The king had been given a crown by some of his subjects. They told him it was pure gold, and the king asked Archimedes to determine whether that was true. This was a delicate task because somebody's head might have been in danger. Archimedes was thinking about this, the story goes, when he went to the public bath. His alert mind noticed that when he got into the tub, the water raised along the side. An idea occurred to him: perhaps an object put into water displaces a volume of water equal to the volume of the object. He was so excited, he forgot his clothes and ran down the street yelling, "Eureka [I found it]!"

Part of the story may be apocryphal, but apparently Archimedes did get information from his bath observations that helped him accomplish his task. By putting the crown in water, he could determine its volume. Then he could weigh it and calculate its density, which was not the density of gold. Someone probably lost his or her head over that, but it wasn't Archimedes. Archimedes's experience illustrates how chance observations sometimes lead to an idea. Of course, it was important that Archimedes's mind was prepared to recognize the significance of his chance observation.

Another example comes from research done on white-footed mice (genus *Peromyscus*).[7] We needed to catch mice on the dry, barren islands in the Gulf of California. We set traps in the valleys in a typical *Peromyscus* habitat and caught only two or three mice per one hundred traps, as would be expected. While walking along the beach looking for rattlesnakes and fish-eating bats, we saw something scurry over a rock. Out of curiosity, we started turning rocks over and found a *Peromyscus*. We "knew" that *Peromyscus* do not live on beaches. But when we set traps along the beach, we caught thirty mice instead of the expected three. The mice on these islands had moved into a unique habitat, apparently making use of the food supply washing in from the ocean. A chance observation of a mouse darting over a rock led to a discovery we would never have made otherwise.

Previous experience or known theories are also important in suggesting ideas. It is known, for instance, that if two birds are in conflict over a territory, the bird defending its own territory has a psychological advantage and nearly always defeats the intruder. A friend and I (Brand) wondered if chipmunks might show the same behavior. Our research revealed that chipmunks are not as territorial as birds, but they do become more aggressive when close to their nests.[8] Known concepts about birds helped us devise testable hypotheses on chipmunk behavior.

Scientists sometimes say that an idea came to them in a dream or just occurred to them. This seems very unpredictable. How can science function that way? It can because ideas can come from all kinds of places in all kinds of ways. Where an idea comes from cannot be defined in objective terms,[9] so what does that do to science? The characteristics of a scientifically useful theory are helpful here. Can the theory be tested? That is the answer. Archimedes's bathtub observation could be tested by experiments. Where an idea originates is irrelevant. If we can do experiments to test it, any idea can be scientifically useful.

Picture a scientist visiting a primitive culture and watching a witch doctor treat patients with magical herbal cures. She hopes to find some plants with medicinal value. Is that an acceptable source for scientific ideas, or must those ideas arise through the normal scientific process? Since she can test the plants to see if they really are medicinal, it does not matter where the idea comes from. Could productive research ideas even come from the Bible? Think about that, and we will discuss it later.

Data Do Not Lead Scientists Automatically to Truth

Some influential people, like Francis Bacon, promoted the idea that data faithfully lead us to truth.[10] However, Bacon was overly optimistic. Data almost never directly suggest the interpretation, and data do not guarantee that our interpretation of the data will be correct. The scientist must relate the data to theories and "known facts," working creatively to interpret them. In our study of the broken glass pieces, we had to relate those data to information we already knew in order to develop an interpretation. Of course, some of the theories and "known facts"—and thus the interpretation—might be wrong. Scientific explanations develop through time as we interpret data, evaluate our conclusions, and learn from our mistakes.

When the data do not all seem to point to the same conclusion, scientists generally choose the conclusion they think is supported by the greatest weight of evidence. But we always have only part of the potential data, and our own preferred theory can influence our evaluation of the data. When Galileo Galilei was arguing that the earth rotates around the sun, there was some important evidence that seemed to say Galileo was wrong. The apparent weight of evidence at a given time may actually point in a wrong direction. The best we can do is to trust that continued research will reveal such mistakes in time. Of course, in evaluating the weight of evidence, some sources of information may be considered much more reliable than others. Scientists will always trust research journals more than newspapers. Informed interventionists will take the Bible account of origins more seriously than other scientists will.

Does Some Truth Exist outside of Science?

There must be true answers to our questions about nature, and our theories and scientific models are tools that assist us in the search for those ultimate truths. Yet an idea that is true in an ultimate sense may not be scientifically useful (fig. 1.4). To say that something is "not scientific" could mean two very different things. It could mean that the idea is false, or it could mean that science cannot determine whether it is true because it cannot be tested. If we were able to see from God's perspective, we could define a portion of human ideas as true and recognize others as false. We would find that science is able to test some of these true ideas and to convince us of their truthfulness (e.g., gravity). Science can also test some of the false ideas and show that they are false (the sun rotating around the earth). Other ideas in both the "true" and "false" categories cannot be tested scientifically.

There are things in religion that are not amenable to scientific investigation. Science cannot test them. This doesn't mean they are false. They just may be outside the realm of what science can deal with. Did Jesus actually heal people? We each have our opinion, but science cannot answer this question. Many other questions similarly cannot be answered. An honest approach to the philosophy of science and/or religion needs to admit these human limitations, and we will consider this in more detail in the next chapter.

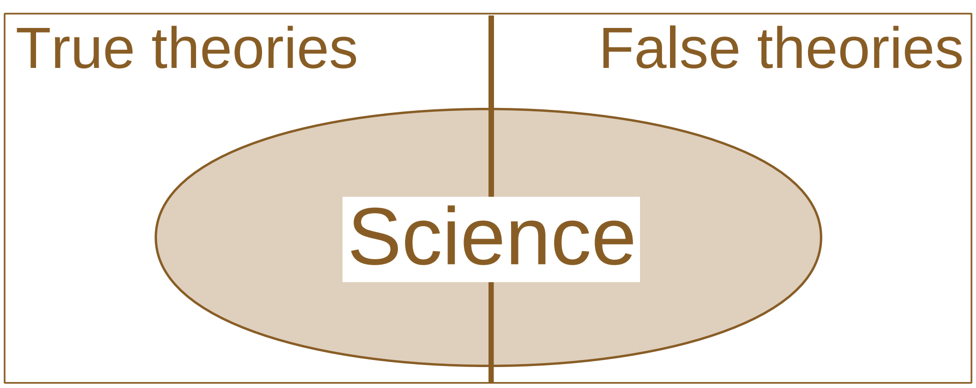


Figure 1.4. Relationship of science to true and false theories. Some theories in each category can be tested, and some cannot. Of course, we do not know what percent of these are in each category. Figure by Leonard Brand.

CHAPTER 2

The Path to Scientific Discovery and Its Limits

Overview

A theologian once stated that he would lay every belief and doctrine on the line to be accepted or rejected according to the findings of the physical sciences. Is that realistic or necessary? Is so much confidence in the scientific process appropriate? Developing an intelligent, informed answer to this question requires an understanding of the strengths and limits of science. This discussion will help provide a foundation for discussing the relationship between science and faith. We must use the appropriate type of logic in defining our scientific studies and in interpreting the results, and it is important to understand the limits of logic. The effectiveness of our research design will be influenced by our sample size, our experimental controls, and our use of quantitative data where possible. Scientists are human and are apt to be biased, but the way scientists criticize each other's work, hopefully in constructive ways, helps reduce bias. Study of the events in earth history has its limits, but it is still a rewarding topic. One of our tasks is to learn critical thinking—to understand the difference between data and interpretations of those data and to evaluate the interpretations in relation to the worldview underlying them.

Logic and Its Limits

We will first consider experimental design—a plan for carrying out a research project with good data, enough data, and the right data to answer our questions. This can also be called research design, since some research, such as the study of fossils or rocks, might consist of observations but not experiments. A part of the research design is logic. Logic is an important research tool when it is used judiciously. The philosopher Charles Kettering once remarked: "Beware of logic. Logic is an organized way of going wrong with confidence."[1] Careless use of logic can lead us astray.

We aim to do the research with objectivity, not bias, but this is not as easy as it may sound. There are some basic principles that will keep us on the right track. Accepting everything that scientists say or rejecting everything is the easy way out because it doesn't require thinking. We cannot escape the need to think and evaluate scientific concepts.

Experimental Design

Good research design is important since it guides us in collecting the most helpful type of data. We will first discuss what determines how much data we have to collect.

Limits in Sample Size

It can be shocking to learn that science does not provide absolute answers. One reason it cannot is that we never have all the data. A hypothetical research project illustrates how this affects the scientific process. This research aims to determine the abundance of a certain kind of bacteria in the human mouth. Some bacteria are present in every mouth. They may have no evident effect on a healthy individual, but they can cause problems if one's resistance is lowered. It is impossible to check everyone on earth for the abundance of bacteria, so our only practical option is careful, selected sampling. Out of the billions of people on earth, we can only sample a few hundred, or perhaps a thousand.

Even if the sample is small, it is unrealistic to think we can collect and count every bacterium, so we still must reduce our data set. We devise a standard sampling technique, taking only a milliliter of saliva from each mouth as a sample. Even in that sample, thousands of bacteria may exist, so we likely cannot count them all. To solve this problem, we dilute the sample and take a small percentage of it, count the bacteria, and estimate how many were in the total sample. As a result, we have to base our conclusions on a very small bit of data compared with what we want to know.

When we get that number of bacteria, it still is not going to be the same for every person. Some people have few bacteria, while others have many, and it may be quite different in different cities or countries. Our result is not an absolute answer but a conclusion based on this small sample.

All research is like that. We never have all the data. We just study a sample. I (Brand) was once doing research on chipmunks in northern California.[2] Golden-mantled ground squirrels also were common, and they behaved differently from chipmunks. The chipmunks commonly climbed trees, but the golden-mantled ground squirrels did not. After making this observation many times at various locations, I could have concluded that golden-mantled ground squirrels do not climb trees. That would have been a well-supported conclusion based on a substantial number of observations. But then I went to the eastern side of the Sierra Nevada Mountains in the dry pinyon pine forest. The golden-mantled ground squirrels behaved differently there and were climbing all over the trees. If I had drawn a conclusion and published it based on my earlier sample, I would have been wrong because my sample was too small at that point. The conclusion would have been valid for some populations of the squirrels, but it would not have been a correct generalization for all golden-mantled ground squirrels.

As scientists, we analyze the sample we are able to collect, but we don't know if enlarging the sample will change the picture completely. Practical realities dictate that we often have to live with this uncertainty, but the value of science is not reduced. It just reminds us that science is a continuing search that never runs out of interesting questions to stimulate our curiosity.

Are We Using Correct Logic?

Sometimes experiments or observations don't tell us what we think they do because we have not used the appropriate type of logic. An old joke illustrates this point with the help of an imaginary trained flea named Herman. We want to find out where Herman's ears are. Not all creatures have ears where we expect them to be. Some insects have ears on their legs, on their abdomens, or even on their antennae. First, we see if Herman wants to perform. "Jump, Herman," we say, and he jumps. He obviously heard us. So let's see if we can find his ears. Perhaps they are on his antennae, so we remove his two antennae. "Now, Herman, jump!" He jumps again, indicating that his ears are not on his antennae. Where else might they be? Maybe on his front legs. So we take his front legs off. "Herman, jump!" No problem—he still jumps. His ears apparently are not on his front legs. Often insects have ears on their back legs, so we take them off. "Now, Herman, jump!" Herman doesn't jump, so his ears must be on his back legs. Why are you laughing? What is the problem? Of course—he needs back legs to jump. The example is obviously absurd, but it illustrates a very real problem in logic, which in many other, more complicated, situations would not be so obvious. We can make this same mistake and collect data that actually answer a different question from the one we thought we were answering. It is not always so clear that this has happened.

Consider another brief example: "If I am out of gas, my car won't start. My car won't start. Therefore I am out of gas."

Do you agree with that statement? The problem with the conclusion is that there could be other reasons the car won't start. This seems obvious; but if we are studying very complicated and sophisticated processes, it can be more difficult to see if we have made this same mistake in our logic. Now look at the following assertion: "If I am out of gas, my car will not start. My car does start. Therefore I am not out of gas."

The difference between these two statements is very important for the scientific method. The first one tries to say that we can prove something—that the car is out of gas—because it will not start. But it is not possible to prove things in science because there can always be other complicating factors we haven't considered. The second statement uses a different approach—"disproof" or falsification. Proving something wrong and thus eliminating a bad theory or hypothesis is easier than proving something right. So the second example is more realistic.[3] If a theory withstands efforts to disprove it and is not disproved, then we have more confidence in it. This is more like the way science works. Even this method has its limits, since we may think we have disproven a hypothesis when we actually did not have enough data to disprove it or we misunderstood the data. Disproof is still an important tool in science, as long as we remember that it does not give us absolute truth but is merely a practical way to decide what is the weight of evidence at the present time.

We always use logic in interpreting data. The nature of the logic that we use must be carefully considered, along with the limits of that logic. Deductive and inductive reasoning are both important in science. Deductive logic starts with a generalization and uses it to interpret the data in a specific case.

Earlier in my experience as a researcher, I (Brand) might have seen some small squirrels in a tree and concluded that they were chipmunks since ground squirrels do not climb trees. That is a correct use of deductive logic, but the conclusion is not reliable because it is based on a false assumption about ground squirrels. If the assumption turns out to be wrong, the conclusion may be wrong. Does this mean that deductive logic is not useful? No, but we need to be aware of its limitations. Science moves on, and we must realize that scientific conclusions are tentative. They may hold up or they may not; we just have to wait and see.

The other approach is inductive reasoning. Induction begins with individual observations, such as the many data points on the number of bacteria in mouths, and uses these observations to develop generalizations. These generalizations are essential in science. The generalization becomes the assumption that helps us predict and then interpret the data from another experiment. The problem with induction is that we really cannot predict the unknown. The bacteria level may be quite different in some other place.

A resolution to these problems is quite important in order to understand science. Scientists and philosophers of science have directed some interesting and disturbing statements to this issue. This may sound like we are putting down scientific logic, but there are answers to the dilemma. "The ability of induction to deal with a future case collapses, and since this is the only useful aspect of induction, we are faced by total collapse. Thus I must report to you that discouraging news has leaked out of the citadel of logic. The external walls appear as formidable as ever, but at the very center of the supposedly solid fortress of logical thinking all is confusion."[4] These problems in science may seem disturbing. Do they mean that science is not useful? No, obviously not. "As practical tools, no one doubts the continuing value of the armaments. But in terms of ultimate and inner strength, the revelations are astounding indeed. The ultimate basis for both types of logical thinking is infected, at the very core, with imperfection."[5]

The phrase "practical tools" may be the answer to the dilemma. If we expect science to predict with accuracy what we will find in our next observation, then we often are going to be disappointed. These two types of logic are very important tools that we must use, but they do not assure absolute truth. We can recognize their role as being extremely useful and valuable while being realistic and aware that logic is only a tool that helps us organize our thinking. In our research, we make the generalization that the logic suggests. It helps us see what experiment we should do next. It helps us think in an organized way, but it does not give us absolute truth. To illustrate this concept further, consider an example from an actual research project:[6]

> Data from field observations: All chipmunk nests found in this study were found high in trees.
>
> Conclusion: Chipmunks nest in trees.

This sounds logical. The researcher collected data, used induction, and reached the conclusion that chipmunks nest in trees, at least during the summer. That is also predicting that other chipmunk nests will be in trees. What is the correct interpretation of that conclusion? Here is one way to look at it:

> "CHIPMUNKS NEST IN TREES."

It is an absolute conclusion; that's the way it is. But another way to look at this conclusion can be illustrated by restating it as follows:

> Under the conditions of this research, in the places where the research was conducted, the nests that could be found were in trees.
>
> "Chipmunks nest in trees" is a hypothesis to be explored further.

Now we have a realistic understanding of what we have found. This is a hypothesis based on what we know so far. It may not hold up in the future after more research, but it is still a useful summary (a *progress report*) of where we are at this point in our understanding of chipmunks.

Another helpful analogy is provided by comparing inductive and deductive reasoning to the information or "tools" needed to read a road map. If we correctly use these tools and make the right choice at a highway intersection, that does not mean we have reached our destination. The highway will bring us to other decision points where we must use the same tools again. If we persist in wisely using these logical tools, we will continue to make positive progress on our journey. Science is always a *progress report* of where we are in this dynamic search for understanding.

There is another level in scientific reasoning that goes beyond data collection, induction, deduction, or reading road maps, and that is developing theories that explain our findings. Knowing that the chipmunk nests we see next will probably be in trees does not explain why they are there. Developing hypotheses or theories about why something works the way it does requires a creative process that goes beyond the observational data. We saw this in operation in the dependence on existing theories and "known facts" in analyzing the broken pieces of glass found by an archeologist.

Experimental Controls

An important part of experimental design is the use of experimental controls. The word "control" has a specific meaning in science. Scientific "control" does not refer to keeping the experimental conditions constant, although that is also important. A control is a known and previously tested standard for comparison with our experimental data. The control is just like the experimental situation in every way except for the specific point that is being tested.

The following partly hypothetical example tests Spallanzani's conclusion that bats use their hearing to navigate in the dark. We observe bats flying in a dark room with wires strung from floor to ceiling to see how well they can navigate. Normal bats are very good at avoiding obstacles, and they touch the wires only 1.3 times per fifteen minutes. To see if Spallanzani was right, we put earplugs in the bats' ears. They now touch the wires an average of

38.7 times per fifteen minutes and soon stop flying, so they must need their ears to navigate.

This is a great experiment, but does it mean what we think it means? Could the results be caused by other factors? What can we compare it with? To see what we really have done to the animals, we must have a control as a standard against which to compare the experiment. This is a real experiment that was done by Spallanzani in 1798.[7] He found that bats with earplugs did not navigate very well. But maybe a bat with a plug glued in its ear is just too uncomfortable to use its navigational ability. To test this, a control was done in which both the control and the experimental bats had little brass tubes glued in their ears. The tubes in the control bats were left open so they could hear, but the experimental bats had their ear tubes plugged. Both groups had the same amount of discomfort and extra weight, but the controls could still hear because the tubes were open. The control bats with the open tubes were just about as successful at navigating the maze as the normal bats with no plugs in their ears, and so it does verify the original conclusion.

This example illustrates how essential the control is for clarifying whether we are testing what we thought we were testing. Sometimes even good scientists do not use adequate controls, and sometimes we know too little about the phenomenon to understand what controls are needed. Does this mean that we can't do the research? No. As we do more experiments, we learn what controls we should have had earlier, so we repeat the experiments with adequate controls.

The nature of our experimental design is extremely important, but it is not always easy to know when we are using poor logic. As we do more experiments, we learn what mistakes we made earlier, so we go back and repeat the experiments with a better design. This tells us that science is a dynamic process that changes and improves as time goes on. It also indicates that we cannot accept scientific conclusions as absolute truth. They are statements that may need revising as time goes on.

Quantitative Data

Once, while studying fossil trackways,[8] I (Brand) observed modern animal behavior for comparison. A paper by another scientist stated that salamanders in water do not walk on the bottom but swim from place to place. In trying to determine whether that was correct, I spent a couple of hours catching some of the abundant salamanders in a mountain pond and watching their behavior. Then I made an entry in my notebook that the statement was mostly right—that although the salamanders do sometimes walk on the bottom, they usually swim.

When I had finished catching the animals, I began collecting quantitative data. With a watch in hand, I timed the activities of many salamanders to determine how much time they spent walking on the bottom. Watching slow-moving salamanders is not recommended for those who get bored easily. But with patient accumulation of data, it became evident that about 75 percent of the time they spent moving, they were walking on the bottom. Why was my first conclusion without quantitative data so completely wrong? To a human observer, a salamander slowly plodding along on the bottom of a pond is not very conspicuous. The salamander that attracts attention is the one swimming up to the surface to get air. Our minds are not made like computers; they don't evaluate all incoming data equally. If they did, we would go crazy trying to keep track of so many details. Minds are designed to pick out the obvious, important things. Consequently, they are not good at comparing a very obvious action with something that is subtle. Counting or measuring the phenomenon being studied helps us avoid the partial and sometimes misleading impressions that often result from nonquantitative observations. Quantitative data are another important part of an effective research design.

Another illustration of the importance of careful logic and careful observation comes from the study of the spores of fossil plants under the microscope.[9] These spores represented a variety of plants whose physical remains made up the bulk of Paleozoic coals. In this case, I (Chadwick) was trying to determine the differences in types of plants represented by spores from several different coal deposits. Upon examining the slides, I was repeatedly impressed by a type of large, nondescript spore that seemed to be on all the slides, in some cases in great abundance. Yet when I examined the publications of researchers who had originally studied the coals, these spores were not even mentioned. It seems that the researchers had chosen to record the obvious, clearly defined spores they were used to seeing and had completely overlooked, or had ignored, this spore, which in some cases comprised up to 80 percent of the spores present on the slides. Why were they missed? Probably because the spores were unfamiliar to the investigators and were generally nondescript in appearance.

Can a Scientist Be Biased?

An investigator tried an experiment five times. In one of those experiments, he got the results he wanted, so he published that one, but not the other four. Scientists are human, so we have to consider the possibility that biases may exist.[10] Unfortunately, more outright fraud occurs than scientists would like to admit. One geologist published more than 350 scientific papers on the geology of the Himalayan Mountains in Asia over a twenty-five-year period and was acknowledged as a world expert on the subject. Then it was discovered that he had been buying fossils that were not from the Himalayas at all. He published papers describing where in the Himalayas these fossils had been found, drawing conclusions on the stratigraphy and ages of the rocks from the fossils. He had never even been to some of the areas where he claimed to have collected the fossils and studied the geology.[11] The man probably wanted to make a name for himself, and he certainly did!

An editorial from *American Scientist* stated the following:

> I believe there are very few scientists who deliberately falsify their work, cheat on their colleagues, or steal

> from their students. On the other hand, I am afraid a great many scientists deceive themselves from time to time in their treatment of data, gloss over problems involving systematic errors, or understate the contributions of others. These are the "honest mistakes" of science. They are the scientific equivalent of the "little white lie" of social discourse. The scientific community has no way to protect itself from sloppy or deceptive literature except to learn whose work is suspect as unreliable.[12]

The article goes on to discuss the fierce pressures on young science faculty—many must be successful in their research and in publishing their results in order to be promoted or even to keep their jobs. If research is not going well, the pressures become very strong, as the editorial points out, to use little white lies to make things look better. It is tempting to interpret the data optimistically.

Although these things do happen, we still think most scientists are more honest than that. However, there are other biasing factors that can happen to even those of us who seek to be honest. These can be unconscious things that we are unaware of. For example, I (Brand) was studying fossil vertebrate trackways in the Coconino Sandstone, a deposit of cross-bedded sand like the deposits formed by sand dunes. I was at an abandoned commercial quarry looking for tracks on the sloping surfaces of the cross-beds (fig. 2.1). A biology student research assistant, with no geological training, was looking for tracks on the exposed top of a series of cross-beds that had been eroded flat (fig. 2.1A). I was about to tell him there wouldn't be any tracks there when he called me over to look at the numerous ones he had found. I had believed, for what seemed like good reasons, that trackways would be only on the sloping cross-beds. Without help from this "naïve" biology student, I probably would never have found the tracks on the flat surface. I had an unconscious bias that prevented me from seeing what was right in front of me.

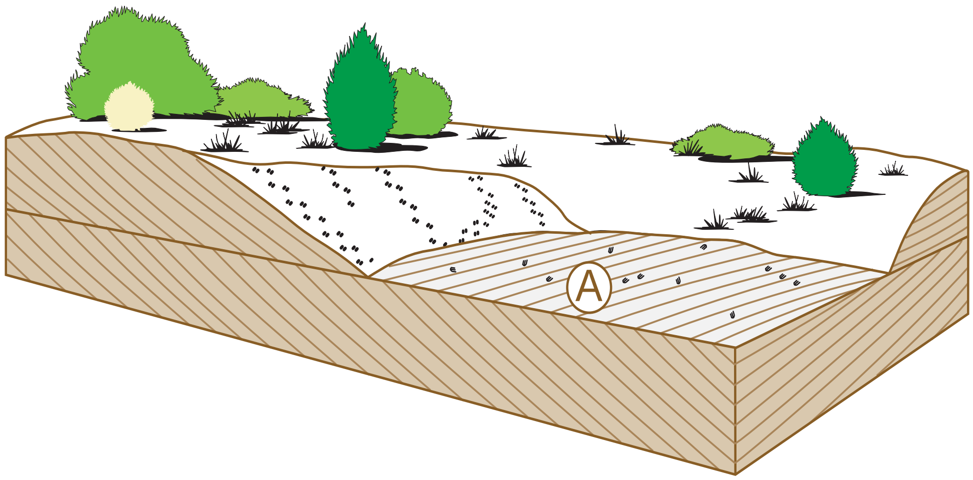


Figure 2.1. Cross-bedded sandstone showing a cross section of the sloping cross-bed surfaces and (A) the horizontal, flat-top surface of the lower set of cross-beds. This surface was exposed by erosion of the cross-beds that were above it. Figure by Carole Stanton.

Science and Objectivity

Understanding the nature and limits of objectivity in science places us in the best position to compensate for the problems these limits can produce. One limit can arise when a theory becomes well entrenched in scientific thinking. Such a theory is not easy to change. And a scientist may find it difficult to be objective in evaluating a favorite theory. Neither is it easy to buck the tide and go against a popular theory.

In the study of evolution and informed intervention, we may be considering only how to fit the data into our favorite theory and not be willing to let science tell us whether parts of our theory of earth history could be wrong. Actually, it is scientifically valid for a person to be convinced that life was created or that life has evolved. That is not the problem (this proposition will be defended later). All scientists work within the framework of some worldview. But if we make ourselves aware of the work and the ideas of other people, it can help us avoid some bad mistakes as we utilize our worldview to suggest testable hypotheses. We consider this problem in chapter 5.

Bacon and Popper on Science and Objectivity

The scientific process has limits, but these are not all bad. The tendency to hang on to known theories makes science somewhat conservative and also keeps it from running after every crazy idea that is suggested. There are advantages for science to be conservative and to resist change as long as there is a mechanism to bring about change when it is needed. There is such a process, and we will get to that later.

Are scientists objective, impersonal, and unbiased? Sir Francis Bacon thought so. He proposed a scientific methodology to describe how science works. According to Bacon's method, scientists who empty their minds of all preconceived ideas and theories and then collect data are objective and cannot be misled. But others have problems with that philosophy. Karl Popper, a prominent philosopher of the twentieth century, wrote "Science: Problems, Aims, and Responsibilities,"[13] in which he outlined his understanding of the scientific method. He refers to Bacon's theory as "Bacon's naïve dogma." Popper explains the scientific process as follows:

1. We stumble over some problem.
2. We try to solve it by proposing some theory.

Right here, Popper and Bacon part company. Bacon says we should eliminate all preconceived ideas or theories from our minds. Popper says the opposite: we start our solution by proposing some theory to resolve it. Think about Bacon's idea for a moment. How would we go about purging our minds of all preconceived ideas? How would we know which ideas to get rid of? Even if we were successful, a mind purged of all such theories would be an empty mind, not merely unbiased. Popper says that Bacon is wrong and that we should start our solution by proposing some theory. Then Popper suggests a third point:

3. Learn from our mistakes, especially those brought home to us by other scientists' discussion and criticism of our experiments.

Popper briefly summarizes his view of the scientific method as problems, theories, and criticisms.

Scientific Objectivity: A Result of Group Interaction and Criticism

Look a little closer at what Popper means by criticism and how it relates to objectivity. If scientists are not all that objective, how does science make progress? Popper states that "it would be a mistake to think that scientists are more 'objective' than other people. It is not the objectivity or the detachment of the individual scientist, but science itself." Scientific objectivity "consists solely in the critical approach; in the fact that if you are biased in favor of your pet theory, some of your friends and colleagues . . . will be eager to criticize you, that is to say, to refute your pet theories if they can." He maintains that it is this "friendly hostile cooperation of scientists, that is their readiness for mutual criticism,"[14] that makes for objectivity.

To put that in simpler words—you develop a theory, you try to test it, and you defend your conclusion if you can. You may be biased toward your pet theory, but other scientists will not necessarily share your bias. In fact, many other scientists are observing and evaluating the arguments that you present. If scientists are careless in their research, you can be sure that someone will eventually detect their carelessness and publish it for all the world to see. Those who argue with you may also be biased, but the willingness of scientists to criticize each other's ideas helps us each see where an idea is strong or weak. Whatever objectivity science achieves comes from this mutual criticism. In science, *objectivity comes from group interaction,* not from individual scientists being objective.

Popper makes a statement that would sound very odd if it were not for this context: "There is even something like a methodological justification for individual scientists to be dogmatic and biased." That may sound strange, but hear him out. "Since the method of science is that of critical discussion, it is of great importance that the theories criticized should be tenaciously defended. For only in this way can we learn their real power; and only if criticism meets resistance can we learn the full force of a critical argument."[15]

Even a good theory may not have a fair hearing if someone does not take hold of it and try hard to develop it. *Objectivity comes from group interaction, not from the individual.* Scientists who think they have it all together and need not listen to anyone else are probably not going to be effective contributors to science.

The Scientific Perspective in Space and Time

The perspective from which we view many things affects whether we can gain a realistic understanding of them. From a valley, mountains look very high, but the view from a spaceship provides a more realistic perspective. In reality, mountains are tiny wrinkles on the surface of the earth, but they do not appear that way from our normally limited perspective. Study of cosmology provides another example: humankind is small compared to the universe, so it took us thousands of years to discover that the earth revolves around the sun.

We also view our world from a limited perspective in time, and this makes it more difficult for us to study historical events. Earlier, we discussed the reconstruction of a glass vase. When we are attempting to answer historical questions about glass vases, our main problem is that we cannot go back in time and observe what happened. Sometime in the past, people were making those vases and using them. A scientist who lived then could observe how they were made and what they were used for and could have all the data to reach reliable conclusions. Time passed, people died, and all we have left is some broken glass. Most of the data are gone; consequently, the conclusions that can be reached from study of this evidence have very definite limits.

When studying earth history, we have the same problem as with the vases. A scientist who lived throughout earth's history and observed the formation of rocks and fossils and the changes in living things would have all the data to reach sure conclusions. Today, scientists have to rely on the fossils and rocks for the study of earth history and the history of life. These provide limited circumstantial evidence, but much of the crucial data are gone forever. The data we have may seem to point convincingly to one conclusion, but there could have been additional factors affecting geological processes in the past that we know nothing about. This could lead us confidently in a wrong direction.

The study of things that happen now is what science does best. The physiology of blood flow can be studied in rabbits that have blood flowing in their veins right now. Experiments can be done in the laboratory repeatedly until we understand what is happening inside the rabbits. In much of physics, biology, chemistry, and other disciplines, the same is true. It is also at least partly true in the study of the genetic process that controls microevolutionary changes in populations of organisms today. In the study of the past, however, science has a problem. No one has ever seen a mountain rise (except for some volcanoes) or observed the formation of rocks in the geologic column. Yet it is still fascinating to study those phenomena, and it is helpful to put things in a historical perspective. For example, wars and tensions between nations are more easily understood if we consider the history of past conflicts rather than considering only the current situation. One difference in the study of earth history is that science does not have a written historical record. We try to reconstruct that history and we can make progress, but we must be aware of serious limitations in the study of ancient events.

In discussions of the history of life, statements that evolution is as much a proven fact as the law of gravity sometimes appear. It seems they refer not only to the genetic process of change but also to the origin of all life forms by evolution. Can we honestly make that type of statement? The study of the history of life is the study of a series of events that happened sometime in the past. We cannot make those events happen again. Thus it is unrealistic to say that the historical dimension of evolution (or any other theory about the past) is as much a proven

Figure 2.2. Cross-bedded sandstone in the Navajo Sandstone, Zion National Park. Figure by Leonard Brand.

fact as the law of gravity. A very great difference exists between these two phenomena.

How does geology deal with this problem of history? Consider, for example, the study of cross-bedded sandstones (fig. 2.2).

Geologists study the origin of these sloping cross-beds by comparing the features of the sandstone with situations where sand is being deposited today. They dig trenches into desert dunes and compare the details of the layers of sand inside the dunes with the layers we find in sandstone to see if the dunes are a reasonable analogue for the rock formation. Could the sand in this sandstone have been deposited in the same way as the sand in a modern desert dune? Other analogues must also be examined and compared with the desert dunes to determine which has features most like those of the rock formation. It is like taking a multiple-choice quiz:

Which is the most likely modern analogue for the sandstone?

A. Desert dunes
B. River sandbars
C. River deltas

D. Ocean beach deposits
E. Underwater dunes
F. None of the above

The most significant difficulty in this process arises if the true answer is actually "none of the above." We probably would not have any way of knowing that, and we would choose one of the analogues observed. In this case, science becomes, as Kettering has put it, "an organized way of going wrong with confidence."

What if the rock formed in a very large-scale flood, larger than anything observed today? Such an event would no doubt involve processes very similar to some of the options listed above. The difference would be in scale—both extent and speed of deposition. The process in many respects might mimic one or more of the modern processes. So even though the rock might be the result of a large-scale flood, we wouldn't know it. We would likely choose a smaller-scale modern analogue as our answer. Of course, a large-scale event should leave some characteristic features in the sediments; but having never observed such an event, we might be slow to recognize these features. Indeed, we might have only a vague idea of what to look for.

In the study of history, we can't be sure we have the right analogue. Yet we must have it to reach the right conclusion. Consequently, liberal doses of humility and tentativeness are in order when we study what has happened in the past. That is true for noninterventionists and interventionists alike. Does that mean that geology and paleontology are not effective sciences? Not at all. It just means that scientists in those fields have to be at least as cautious as other scientists and often have to have more humility so as not to make the unwarranted claim that they know for sure what happened at some distant time in the past.

Hopefully, this helps us understand that when we discuss evolution and informed intervention, none of us, no matter what philosophy we start from, is in a position to make dogmatic scientific statements about somebody else's point of view on the subject. Ridiculing someone who is also searching honestly for understanding is never constructive.

Relation of Science to Total Experience

Science does some things very well. Despite its limitations, science is still a very productive activity—a powerful way of improving our world or of approaching truth. Science is at its best when studying the characteristics of objects and processes that can be observed and quantified. When analyses of these data are combined with the mutual criticism among scientists that improves our level of objectivity, science is a great tool for discovering truth.

But the contribution of science in some areas is more limited, as in the study of values, religion, and ancient history. And our scientific knowledge at any point is only a progress report along the road to understanding. If we see it in that context, we will be more realistic and will better comprehend the meaning and role of science. One philosopher said, "The old scientific ideal of episteme—of absolutely certain, demonstrable knowledge—has proved to be an idol. The demand for scientific objectivity makes it inevitable that every scientific statement must remain *tentative forever.*"[16] If an idea is not tentative, it has become dogma, and science cannot function with dogma.

Scientific knowledge changes and theories have a life-span. Theories in science are often replaced by better theories. Since science moves faster now than it used to, the average life-span of theories is probably getting shorter. Thus it is advisable not to get too attached to our favorite theories. We need to be ready to move on as science progresses with new data and theories.

Think of scientific ideas as arranged on a continuum from well-studied fields at one end of the continuum (e.g., the effects of gravitation) to fields at the other end (e.g., parts of molecular biology) in which science is challenging the frontiers of our knowledge. The fields of molecular biology and molecular genetics are very active disciplines, but major portions of those fields are still very young. Concepts that were accepted as true ten or twenty years ago (or sometimes even last week) are no longer considered correct. Textbooks in molecular biology are already partly out of date before they reach the intended audience. Our understanding will undergo many more changes in those areas.

It is not realistic to put science into one box and either believe everything or doubt everything. Either of these approaches would be the easy way out since they do not require thinking. There is no good way to avoid the need to think and evaluate, to critically analyze what we read, and to keep science in proper perspective in relation to the human values and religious values that make our lives meaningful.

In 1889, a prominent geologist, Thomas Chamberlin, delivered a paper to the Society of Western Naturalists titled "The Method of Multiple Working Hypotheses." In the paper, later published in *Science*, Chamberlin identified three methods of developing explanations: what he referred to as "ruling theories," working hypotheses, and multiple working hypotheses.[17] Chamberlin asserted that working with "ruling theories" consisted in seeking to make observations agree with an existing, dominant theory, clearly a method that would not encourage objectivity. The second method, developing a single working hypothesis, leaves more room for objectivity but soon may tempt the investigator to establish a new "ruling theory." Chamberlin then advocated the use of multiple working hypotheses. In this endeavor, the investigator lays out, generally in writing, all conceivable explanations for the observed phenomenon, including explanations that he or she may not like. He or she then seeks to eliminate as many of the competing explanations as possible by experimental investigation. We have developed one such set of working hypotheses above in the discussion about the origin of sandstones. One of the hypotheses is always "none of the above," meaning the correct answer may not be one of our choices and may not be something we can explain with our present tools.

This method seems to be the most promising avenue for seeking true explanations and is a very important concept if we use it wisely. We are not likely to continue using all the hypotheses for long, but this method forces us to open our minds and think about a variety of possible explanations and not get stuck on our pet theory or the first idea we arrive at. It gives us options to test with our research, to find which will be supported by the accumulating evidence. This method is especially relevant in geology (remember, Chamberlin was a geologist) and other types of historical study since it is challenging for us to picture what might have happened in the unobserved past.

Another prominent geologist in the early 1900s urged geologists to give serious consideration to outrageous hypotheses.[18] This term refers to ideas that at first seem too radical to be taken seriously. William Davis reminded us that many successful hypotheses seemed outrageous and were rejected when first proposed, including continental drift and J Harlen Bretz proposed catastrophic carving of the network of gorges in eastern and central Washington. When we make a list of multiple working hypotheses for some research question, we increase our prospects for success if we are not afraid to include some "outrageous hypotheses."

Data and Interpretations and Critical Thinking

How do we know what is true? Epistemology is the study of how we acquire and evaluate knowledge and how to determine what is true, or at least evaluate what is most likely to be true.[19] As we seek to find answers about the history of life on planet earth, critical thinking will be essential. To think critically is to evaluate what we learn rather than trusting it all. One of the first steps is to recognize the difference between data and statements of interpretation of the data. For example, the biologist Jerry

Coyne wrote a book titled *Why Evolution Is True*.[20] As the title indicates, he wishes to convince us that life arose by evolution. He states that "all of us—you, me, the elephant, and the potted cactus—share some fundamental traits. Among these are the biochemical pathways that we use to produce energy, our standard four-letter DNA code, and how that code is read and translated into proteins. This tells us that every species goes back to a single common ancestor."[21]

He seems pretty confident of his conclusion—we all trace our lineage back to a single common ancestor. We could just trust his expertise and believe the statement, or we can recognize that *trust* is not the issue. Scientists disagree with each other all the time, about many things, so instead of blindly trusting, we apply critical thinking, beginning by asking what parts of that statement are based on data and what parts are his interpretation. If we have studied biochemistry, we probably are confident that we can trust the statement that all these organisms "share some fundamental traits. Among these are the biochemical pathways that we use to produce energy, our standard four-letter DNA code, and how that code is read and translated into proteins." These are his data. He then follows with his interpretation—"This tells us that every species goes back to a single common ancestor." To understand the basis of his interpretation, we need one more bit of information. What is his worldview, the set of assumptions that provide his framework for understanding life and our universe? His book clearly indicates that his worldview begins with his belief that the explanation for origins does not include a Creator. The naturalistic evolutionary origin of all life is one of the assumptions that underlie his thinking.

Later in the book, he goes on to state, "The most commonly suggested alternative takes us into the realm of the supernatural." The alternative he refers to is that we all have the same biochemistry because the Creator made us all with that same biochemistry, which God invented. Coyne rejects this alternative because his *worldview* does not allow it. If we understand how all of these elements—*data*, *interpretation*, *assumption*, and *worldview*—are involved in his thinking process, we can understand what he is really saying and why he is saying it. Then we are in position to evaluate the strength or lack of strength of his argument and whether we wish to follow him to the same conclusion. This illustrates the basis of critical thinking.

CHAPTER 3

Highlights of the History of Science

Overview

This chapter presents an overview of the history of science (fig. 3.1). The origins of the theory of evolution and the philosophy of naturalism can be best understood if put in their historical context. Science had its beginnings in ancient Egypt, Mesopotamia, and Greece; spread to China and the Muslim countries; and finally settled again in Europe, where it was centered for much of history. Science and religion at times were mutually supportive and at other times experienced some difficult episodes. A reaction against the abuse of power by church and government and against using supernatural explanations for whatever science couldn't explain led to a naturalistic paradigm that still dominates science. We outline the development of the theory of evolution with its dependence on deep geological time and on the growing influence of naturalistic thinking. Christian reactions to Charles Darwin's theory included George McCready Price's revisionary geology, then constructive research work by biblically oriented scientists, and the Intelligent Design (ID) movement.

The Beginnings of Science

Greek Science

Early scientific efforts in Mesopotamia, Egypt, and Asia Minor did not much resemble modern science, but individuals were beginning to develop concepts of the structure of the universe. Beginning in the fifth century B.C., the most highly developed science was in Greece. Three famous representatives of this era were Socrates (470–399 B.C.), his student Plato (429–347 B.C.), and Plato's student Aristotle (384–322 B.C.). They were interested both in human conduct and in the physical world.

Aristotle, Plato's greatest pupil, wrote in many disciplines, such as ethics, politics, biology, cosmology, and logic. He developed quite a coherent system of thought, though many of his ideas were wrong. His work was the inspiration for the sophisticated Greek science of the Hellenistic age. Unfortunately, many later scholars did not continue his careful inquiry; they looked to the old Greek masters for truth.

The Decline of Greek Science

Greek science flourished until the Roman domination and then began to decline. It was almost dead by A.D. 200. Finally, Rome decayed, the Germanic barbarians overran Europe, and Greek culture largely disappeared. During the Middle Ages, the Muslims occupied large areas in the Middle East, northern Africa, and parts of Europe. During this time, the centers of learning were in Arabic countries. These scholars learned from the Greeks and from the highly developed science of China,[1] to which they added their own contributions and became the keepers of European science.

Europe Rediscovers Its Past

Beginning in about the twelfth century, Christian Europe began to rediscover its own scientific heritage, along with the contributions of the Muslims and the Chinese. During the time of the Renaissance (1300–1650), many

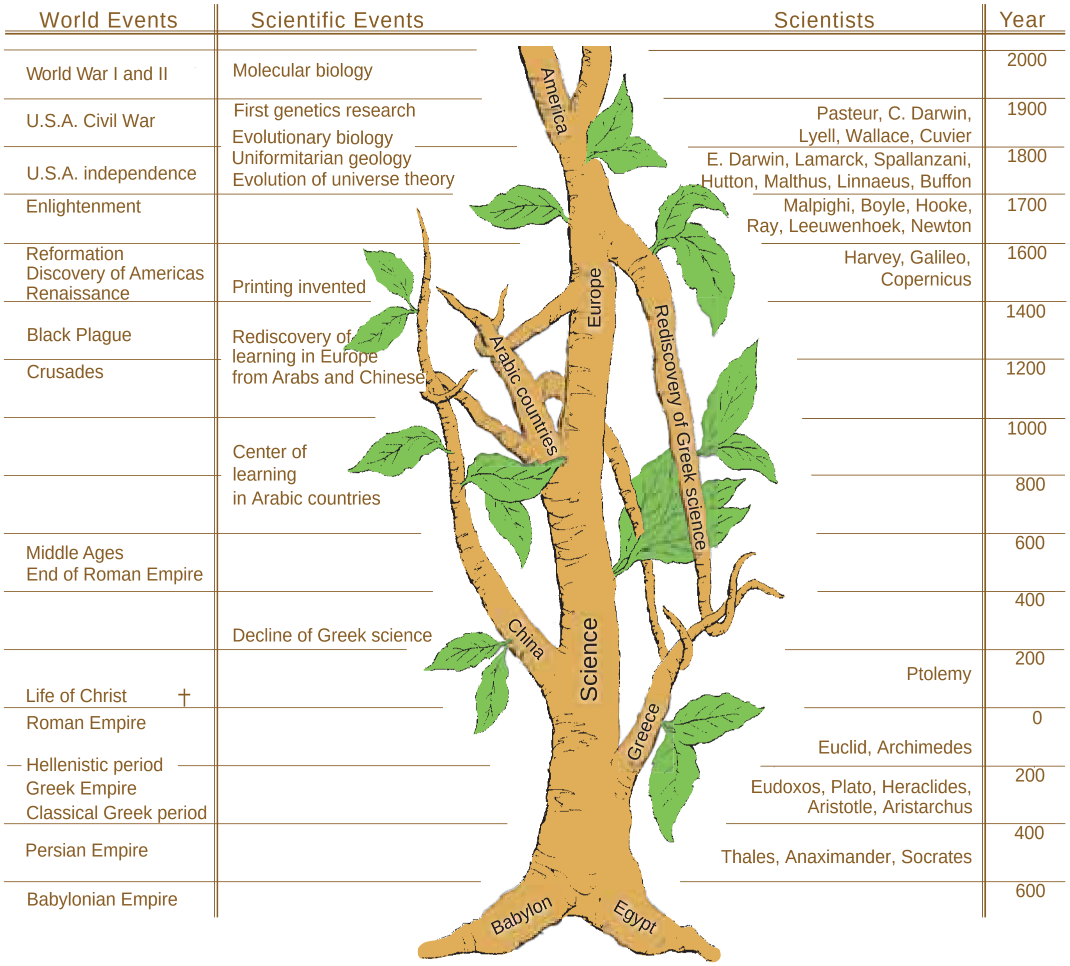


Figure 3.1. A brief summary of the history of science in its cultural, political, and religious context. Intertwining of branches represents flow of scientific information between cultures. Figure by Joy Chadwick and Robert Knabenbauer.

original Greek manuscripts were translated. Scientists in the Middle Ages did little experimentation. The beginning of European technology, with inventions such as the printing press (1454), smelting methods, and magnetic compass (from China), began to transform society and to aid science.

In this way, Europe in the Middle Ages recaptured Greek thought, mastered it, and developed new skills and a new intellectual approach. By the mid-sixteenth century, Europe was fully in possession of its intellectual history, and scientists began to think that the golden age for science was in the future. The way was prepared for modern science. We will follow a few important areas of study in those earlier centuries.

Cosmology

In the area of cosmology, which concerns the nature and origin of our universe, Plato conceived of the planets as moving in perfect circles (the perfect orbit), and scientists then thought the earth must be the center of the universe. From this time forward, scholars knew the earth was round, and some early calculations of its size were fairly accurate.[2] Eudoxos (409–356 B.C.) made the first mathematical model of planetary motion. In it, the planets were carried on theoretical spheres carried by other spheres. This model could account for the observed phenomena of planetary motion. It was geocentric—that is, the earth was considered to be in the center of the universe. Some scientists thought of the planetary spheres as not just theoretical mathematical spheres, but hard, physically linked transparent spheres made of "crystalline." In the Middle Ages, this idea became dogma.

Not all ancient cosmologists were in complete agreement with the geocentric theory. Heraclides, a contemporary of Aristotle, suggested that the earth rotates on its axis, and Philolaus (470–385 B.C.) suggested the same even earlier. In a classic case of anticipating a future development, Aristarchus (310–230 B.C.) suggested that the sun and fixed stars are motionless and the earth and planets rotate around the sun, with the earth circling the sun once a year. He also suggested that the earth rotates on its axis. His ideas, however, were not widely accepted. Instead, the geocentric theory was further developed and refined to account for new data. Ptolemy (A.D. 85–165), the last of the great Greek astronomers, wrote *The Almagest*, a comprehensive treatise on cosmology.[3] He believed in a geocentric cosmology and argued that the earth is stationary. These were reasonable conclusions given the information available at the time.

A fundamental concept of this work was the reduction of the apparent irregularities of planetary motion to mathematical law. For example, Mars, Jupiter, and Saturn rotate more slowly than Earth, and Earth overtakes them.

Consequently, they appear to go backward (fig. 3.2). Also, some planets (like Mars) vary in brightness because of the changing distance from Earth throughout the year. Ptolemy explained these observations with two devices. One is an eccentric, a sphere whose center is not Earth. Another is an epicycle, a small sphere that rotates around a point on the perimeter of a larger sphere, the deferent. These mechanisms could mathematically explain the data with surprising accuracy. But the complexity of the theory was becoming a bit worrisome.

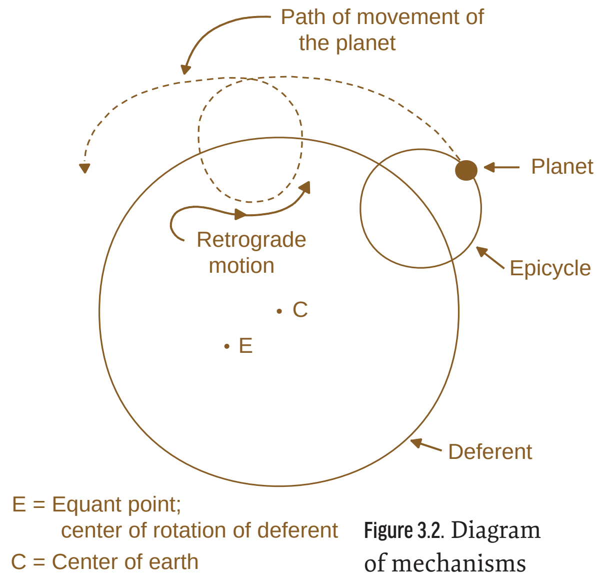


Figure 3.2. Diagram of mechanisms used in Ptolemaic astronomy to explain the movements of planets, including the retrograde (backward) motion of some planets. Figure by Leonard Brand.

Copernicus (1473–1543) was a cosmologist who responded with creative, visionary thinking that resulted in his heliocentric theory, presented in a book titled *On the Revolutions of the Celestial Orbs*.[4] It was still in some ways similar to the geocentric theory, with spheres carrying the planets and with the outer sphere carrying the fixed stars (fig. 3.3). The important feature of his theory is that the focus changed from the earth to the sun. The sun was in or near the center of the universe, with the planets rotating around it.

Most scientists rejected his book. Scientists do not readily accept radically new ideas, and Copernicus's theory was contrary to the teachings of the Church, which had actually originated with Aristotle. Also, part of the data did not favor the Copernican system. With the help of the Italian scientist Galileo Galilei (1564–1642) and others, the Copernican theory gradually gained favor.

Spontaneous Generation

During the Middle Ages it was commonly believed that organisms arose spontaneously. Anyone could observe that mice would appear if a pile of rags was left in a corner

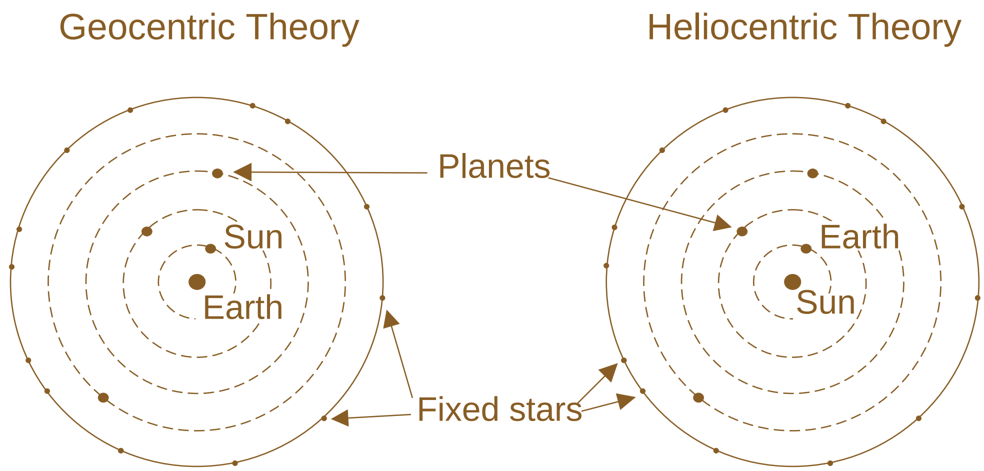


Figure 3.3. Comparison of the geocentric theory and the heliocentric theory as understood by Copernicus. Figure by Leonard Brand.

and that maggots would materialize in meat without having come from anywhere. Also, microbes would appear spontaneously in nutrient broth. Even scientists believed that these organisms developed spontaneously. To be sure, some doubted this theory, and their attempts to disprove it make a long and interesting chapter in science.

Between the seventeenth and nineteenth centuries, a series of experiments by Francesco Redi (1626–1697), Lazzaro Spallanzani (1729–1799), and Louis Pasteur (1822–1895) gradually wore down confidence in spontaneous generation. The spontaneous origin of maggots in meat was refuted first; it took longer to show convincingly that microbes do not appear spontaneously in nutrient broth. An elegant set of experiments by Pasteur finally eroded the foundation for belief in spontaneous generation.[5] However, it wasn't long before the stage was set for the reappearance of a theory of spontaneous generation in a more modern form (see chapter 7).

Relationship of the Church to Science

The Christian concept of a consistent, law-giving God who can be trusted provided the foundation for modern European science.[6] The creation of the universe by a rational, intelligent God explains why the universe is so intelligible and open to our scientific investigation and why nature exhibits uniform processes and patterns. A secular scientist does not have such a foundation for understanding the universe and must generally accept these concepts as mere assumptions.

But the Church made mistakes along the way. It did not always go well for scientists who proposed new ideas. Oresme (1323–1382) discussed the theory that the earth rotated, but then he denied it because he thought the theory contradicted the Bible. His belief in a stationary earth really came from Greek science, not from the Bible. Galileo supported the Copernican theory, and for this, he was tried and put under house arrest by the Church.

Actually, the Church has been blamed for what began as a scientific dispute between the followers of two incompatible theories of the structure of the universe. There were other complicating factors, including religious politics affecting Pope Urban III and Galileo's abrasive personality, which exaggerated his problems with church leaders.[7] At the time of Galileo's problems, other astronomers, including Johannes Kepler, were openly teaching and writing about heliocentrism without rebuke. Pope Urban VIII, a friend of Galileo's, gave his blessing to Galileo's planned book on the motions of the solar system. Urban asked him to give a balanced presentation of both geocentrism and heliocentrism, since he believed that bodies in the heavens perhaps move in ways not understood on Earth. Galileo agreed, but he did not keep his promise; in the book, he openly insulted the pope. This was too much, and Galileo was summoned to Rome to answer for his arrogance. According to one historian, one of the most common myths about the Galileo affair is that "he was condemned by the Catholic church for having discovered the truth," and this myth is "used to justify the incompatibility between science and religion." He concludes that "this thesis is erroneous, misleading, and simplistic."[8]

This is an example of the danger of basing one's theology on contemporary scientific thinking—science may move on and leave that theology without a foundation.

This is still a significant problem today, with many Christian theologians basing their theology on the theory of evolution even as new evidence is challenging Darwinian theory.

Naturalism and Its Historical Context

There was a time when scientists believed their scientific work was guided by an understanding of the Creator and His work. An example of their belief in a Creator God is a book by John Ray.[9] Why did this change? The historical context makes the change easier to understand. Through several hundred years of history, there was a progression of thought away from belief in the biblical Creator God and closer to the modern concept of naturalism—that science cannot accept the idea of a God who has ever performed miracles.

In centuries past, there were many phenomena in nature with no evidence-based explanations available. Explanations were lacking for many functions in our bodies, such as what makes the blood flow, and for how the universe operates. It was common to invoke miracles as explanations for these challenging physical or biological features.

As knowledge advanced, it was discovered that these features could be explained by normal, nonsupernatural physical and chemical laws. Prominent scientists including Ray, Isaac Newton, and Robert Boyle sought to counteract the tendency to give supernatural explanations of everyday processes that we can study in the laboratory and understand. Their thinking combined two main concepts: (1) nature is a "law-bound system of matter and motion" and (2) "nature is a habitation created for the use and edification of intelligent beings by an omnipotent, omniscient, and benevolent God." In this philosophy, God made the universe for humanity's benefit, but He created it to function according to a definite set of laws.[10]

Others were not eager to keep the two parts of this philosophy together. They applied the idea of nature as a law-bound system of matter and motion to origins and the history of life, as well as to everyday processes we can study in the laboratory, and argued against the possibility of creation. The supernatural was pushed further and further away and in time replaced with purely naturalistic explanations. There was a growing belief that God was no longer needed to make the universe work, something that Newton foresaw and warned against.

Trends in society are a part of the historical context that helps explain why this change in thinking occurred and when and how it did. At the same time that science was moving toward the modern era, there were changing attitudes toward authority of various kinds. There was a growing weariness of autocratic, authoritarian abuses of power by both church and state. For centuries, the state and the cultural caste system prevented much of the population from experiencing freedom of thought and action. The Christian church in its Middle Ages form had demanded adherence to its belief system and power structure, often with the support and power of the state. The result of "heretical" thinking could be, and very often was, death. The people were ready for a change, ready to reject the dominating authority of both church and government. As part of this urge for freedom, the scholarly world was ready to move away from the authority of the Bible with its stories of miraculous events. Methodological naturalism (MN) became the expected foundation for scientific thinking.

MN, the paradigm (or worldview) that explains everything in terms of material, law-bound processes will not accept any miraculous or supernatural processes. When these convenient supernatural or mystical explanations, common in the Middle Ages, were finally removed from our thinking, the result was increased incentive to search for natural, law-bound, evidence-based explanations. The increasing dominance of naturalistic scientific thinking was associated with the modern era of impressive progress in science. The success of this new mind-set, at the time, appeared to eliminate the need for any miraculous actions anytime in the history of the universe. If there was a God, His role in the universe was in question. There developed a growing optimism that science could explain everything by naturalistic, materialistic processes. Was this the correct answer to the problem? Or has the change gone too far and missed some limiting factors along the way? We will deal with that question in more detail in chapter 5.

Data and Philosophy

As science progressed, new cosmological theories emerged, but they were increasingly couched in terms of the growing commitment to naturalism. The stars were once thought of as perfect and unchanging. But in the sixteenth and seventeenth centuries, astronomers discovered spots on the sun and craters on the moon, and they realized that the heavens actually are changeable. The philosopher Immanuel Kant (1724–1804) and others devised a theory of the evolution of the universe through the operation of the laws of motion, beginning with uniformly dispersed matter.[11]

A similar revolution was taking place in geology. A greater recognition of the significance of earthquakes, volcanic eruptions, floods, and landslides aroused more interest in geology, but until the 1700s, no coherent theory existed in geology. Some geologists believed the biblical flood was a reality that caused the geologic deposits. Another interpretation was that multiple creations and catastrophes have occurred and that Genesis only records the latest such cycle. Others argued that the Bible should not be used at all in interpreting geology.

The first to publish a comprehensive theory of geology was James Hutton (1726–1797). His book, *Theory of the Earth*,[12] was a completely uniformitarian explanation of geology (geological history explained by the same geological processes and natural laws observable today) with millions of years in earth history, with "no vestige of a beginning—no prospect of an end." Then Charles Lyell (1797–1875) wrote *Principles of Geology*,[13] published in

1830–1833, and further developed Hutton's ideas. Lyell's book was more readable than Hutton's and was widely influential. This book was the beginning of geology as an organized science and was also very important to the rise of evolutionary thought, because without uniformitarian geology and its long span of time, the general theory of evolution could not have been viable. Uniformitarianism used a method of interpretation based on "actualism"—answering questions about the unknown by using only data on what actually can be observed in experiments or field observations. This meant that hypotheses about biological or geological history would be tested by comparison with processes that occur now. The pendulum swung to a completely naturalistic philosophy—one that would accept only theories and explanations that did not require any supernatural activity at any time in the past or present. (MN is further described in chapter 5.)

The first coherent theories in subjects like geology, paleontology, and biological change developed at a time of increasing rebellion against religion and against authoritarianism in general. Undoubtedly, it was necessary for the concept of an unchanging universe to be rejected before those disciplines could prosper. The intellectual atmosphere of the times also influenced the nature of the specific theories that developed. Naturalistic thinking was beginning to dominate the intellectual world, and influential scholars in geology and biology were strongly influenced by it. Many scientists did believe in a Creator God, but their ideas did not prevail as the majority view.

The Development of the Theory of Evolution

For centuries, people thought that species did not change after they were created by God. This belief in fixity of species, which originated primarily from Greek science, began to unravel at least as early as the mid-1700s. A number of individuals developed concepts that later contributed to Charles Darwin's theory of evolution.

Compte de Buffon (1707–1788) recognized the evidence for variability of organic forms. He suggested that organisms have changed through the operation of a system of laws, without divine action, to produce the great variety that we see in nature. He said that weaker species die out, and he anticipated, at least partially, the concepts of natural selection and the struggle for survival. William Charles Wells (1757–1817) suggested that new forms arise by chance variations and even applied natural selection to humans. Jean-Baptiste Lamarck (1744–1829) had a strictly materialistic view of nature. He had learned that change occurs in the geological structure of the earth, so he thought it likely that animals would also change since they depended on their environment. He postulated an evolution theory (called his development hypothesis) with evolution of new species and evolutionary progression from the simplest forms of life to humanity. He discussed the evolution of humankind explicitly.

His mechanism for this process was quite different from modern evolutionary thinking. He said that as animals and plants interact with their environment, changes are caused by (1) felt needs, (2) use and disuse, and (3) the inheritance of acquired characters. In other words, if an ancient protogiraffe felt the need to reach higher to get more food, its neck would get longer because of its stretching to reach new heights. This acquired characteristic would be inherited by the next generation.

Erasmus Darwin (1731–1802), the grandfather of Charles Darwin, also proposed a theory of evolution. Thomas Robert Malthus (1766–1834) was an economist who wrote *Essay on the Principle of Population*,[14] a study of the nature of the growth of human populations. Insights gained from reading his book laid the foundation for Charles Darwin's understanding of the concept of survival of the fittest—many excess individuals are produced but will not survive.

By the early 1800s, these ideas were present in the scientific world, but they had not been put together in one coherent theory. Edward Blyth, a man about the same age as Charles Darwin, probably made a significant contribution to Darwin's understanding of natural selection, though Darwin never gave him any credit.[15] Blyth wrote articles on natural selection in *The Magazine of Natural History* in 1835 and 1837. "The leading tenets of Darwin's work—the struggle for existence, variation, natural selection and sexual selection—are all fully expressed in Blyth's paper of 1835."[16] However, Blyth was not an evolutionist; he viewed natural selection as a conserving rather than a creative force, maintaining kinds of animals by eliminating the weak individuals. Patrick Matthew, a fruit grower, also published the principle of natural selection over two decades before Darwin's book.[17]

In October of 1844, Robert Chambers published *Vestiges of the Natural History of Creation*, a book that is credited with being the strongest influence preparing the way for acceptance of Darwin's theory.[18] It was a fully evolutionary view of life but without a mechanism to explain evolution.

The process that led to the development and acceptance of Charles Darwin's theory of evolution was a fascinating saga. As a young man, Darwin (1809–1882) became convinced that animals and plants change through time, and he began working on a theory to explain that change.[19] He was not the first to develop a theory of evolution, but he achieved a truly creative leap with insights that went beyond the ideas of others. The theory did not come together easily in Darwin's mind.[20] As Bowler puts it, "Although scientific hypotheses must be tested by observation and experiment, it is obvious that all the great scientific theories arose from major leaps of the imagination, from new ideas about how nature *might* work, which were only subsequently shown to have some factual validity."[21] This is evidenced by the fact that Darwin's theory was more widely believed by scientists after about 1940 than it was in his lifetime.[22]

Darwin based his theory not on any scientific measurements but on subjective reasoning.[23] Early in his career, he had decided that the Bible was not reliable, and he determined to develop a theory explaining life forms by natural processes. *The Origin of Species* was one long argument that interpreted evidence in a way to fit his theory, and he well knew that some of the evidence did not support his theory. For example, he went to some length to explain why the fossil record did not contain the evidence expected by his theory. For Darwin, in many instances, theory took precedence over evidence.[24]

Charles Darwin tried the study of medicine and theology before his famous voyage around the world (1831–1836) on the Beagle as a gentleman guest of the captain.[25] He read Lyell's book during the trip and made many observations and collections. He came back to England and studied his collections and also studied variation in domestic animals. From these and other sources, he got the idea that variation and selection were the cause of biological change over time. From reading Malthus's book on population growth, he recognized that far too many individuals are produced, and thus natural selection is needed to eliminate the less fit individuals.

During his trip on the Beagle, Darwin spent his time in study of biology and geology. On his return to England, he began publishing his findings, developing his scientific credibility initially with his geological work,[26] and becoming very involved in the Geological Society of London. His published descriptions of biological discoveries in such places as the Galapagos Islands further enhanced his scientific standing, and these contacts with the leading scientists of his time assured that his later theorizing would come to the attention of the scientific world.

Darwin was well aware of strongly antagonistic reactions to earlier evolution theories proposed by Lamarck, Chambers, and Erasmus Darwin, and he planned his strategy carefully to surmount this problem. He moved away from London so that his work would not attract public attention. While working on his evolution theory, he corresponded with many other scientists and attended scientific gatherings in London. Once he was well acquainted with someone whom he believed could be trusted, he invited that person to his home and introduced his theory. It was his plan to gather a select group of trusted, influential scientists whose support would help introduce his theory to a hostile public. This plan was quite effective. According to Bowler, "there can be little doubt that Darwin's initiative succeeded (where it could very easily have failed) because he had already planted the seeds of a political revolution within the scientific community."[27]

Darwin's theory of natural selection was not accepted by the majority of biologists until about 1940.[28] Many of the biologists of Darwin's time were skeptical of natural selection as a mechanism of evolution, but they supported Darwin for philosophical reasons. Darwin's evidence for biological change through time convinced them that a naturalistic explanation for biology was possible and offered them a substitute for belief in a Creator.[29] Ultimately Darwin's success rested on "the exploitation of evolutionism by those who were determined to establish science as a new source of authority in Western civilization, in place of theology."[30] The result of all of this is summarized by Bowler: "It hardly seems to matter whether you love Darwin's message or hate it; you cannot escape the fact that it helped to overturn the traditional Christian world view."[31]

This time of philosophical transition occurred while the beginning of fields like genetics and molecular biology were still decades away. Biologists were ignorant of the complexity of life and thought that living protoplasm was quite simple. It was easy for them to envision life arising and evolving by itself. Had a naturalistic theory of evolution been first proposed at the end of the twentieth century, when knowledge of the intricacies of molecular biology was rapidly growing, it is not likely that it would have been so readily accepted.

In 1844, Darwin wrote an essay on his theory but was too cautious to publish it then. He was startled out of his caution when another biologist, Alfred Russel Wallace (1823–1913), developed the same theory. In 1858, papers by Darwin and Wallace were presented to the Linnaean society, and in 1859, Darwin's book, *The Origin of Species*, was published.

A number of biologists in Darwin's era, including Linnaeus, had proposed that considerable change has occurred within the created groups of organisms. Acceptance of this concept could have retained belief in a Creator while recognizing the evidence for biological change. Darwin was unaware of this movement, and it was not in harmony with the prevailing intellectual trend toward naturalistic thinking.[32]

An interesting episode in the relationship between Darwin and Wallace was their difference of opinion over the origin of the human brain.[33] Darwin believed that humanity arose by the same gradual process of change that produced all other life forms. Darwin and his colleagues readily envisioned a natural progression from the apes to some of the "primitive human cultures," which they believed to be only slightly superior to the apes, and finally to the superior races of Western humanity. Wallace, in contrast to Darwin and the other great biologists of that time, had years of experience with the natives of the tropical regions, and he saw evidence that these "primitive" cultures were not mentally inferior. Wallace did not see evidence for an evolutionary progression in the human races, and he questioned why people in those simple cultures would have brains evolved so far beyond what was needed for their survival. He also insisted that "artistic, mathematical, and musical abilities could not be explained on the basis of natural selection and the struggle for existence."[34] Wallace contended that there must have been divine influence in the origin of the human brain, and Wallace and Darwin differed strongly on this issue.

Darwin's work was the culmination of two hundred years of secular influence on developing ideas. It was important for his trend of thinking that at the time he began to suspect that species could change, he had at his disposal the writings of men such as Lyell, Lamarck, and Erasmus Darwin. Charles Darwin was also influenced by the strong trend toward naturalism in science.[35]

The first coherent theories in geology and much of biology developed at a time when the general attitude among learned people was to reject formal and restrictive religion. Thus belief in creation finally was eroded also. Even a Christian must recognize that it was not wrong for Darwin and others to ask hard questions. Truth is not weakened by honest inquiry. The Bible does not say that animal species have never changed or that the earth is the center of the universe. The Church insisted on holding these ideas anyway, and many scientists responded by throwing God entirely out of their interpretations of origins.

After Darwin

After the naturalistic theories of evolution and uniformitarian geology became the ruling paradigm, many people, including some scientists, still believed in creation, but they did not respond by using their understanding of creation to develop a competing scientific paradigm.

The Bible predicts that near the end of time, people no longer will believe that "by God's word the heavens came into being and the earth was formed" (2 Peter 3:5, NIV) or in the flood. That prediction certainly came true in the twentieth and twenty-first centuries as the intellectual community, in particular, abandoned such beliefs. At the beginning of the twentieth century, the general population was creationist, but the scientific community was not. Those who did believe in creation did very little to respond actively to this situation.

One leader seeking to better understand how to relate geology and the Bible was a school teacher, George McCready Price. He had no training or field experience in geology, but he began reading the literature and critiquing scientific theories of uniformitarian geology and evolution. He wrote several books including *Illogical Geology*[36] and *The New Geology*.[37] He believed in a literal seven-day creation and a worldwide flood and rejected several basic geological concepts including glaciation and the idea that there is order in the fossil record. These were the key elements in the theory he developed.

Geological theory proposes that the stack of rock layers (the geological column) that contains the fossils was laid down layer after layer through millions of years of time (541 million years for the Phanerozoic rocks which contain most of the fossils). These fossils are in a particular sequence. For example, the lower layers of the fossil record (Cambrian) contain almost entirely invertebrates. Dinosaurs and many other types of reptiles occur only in the middle third of the Phanerozoic rocks (the Mesozoic), and human fossils are found only at the very top in the Pleistocene. This is explained as an evolutionary sequence—that is, no mammals are in the lowest layers because they had not evolved yet. Price said that this theory was not right, that there really is no reliable order to the fossils, and that science has invented the order to fit the evolution theory.

Actually, fossils do occur out of the expected order in a number of places in different parts of the world, as Price knew, and geologists recognize that. The real point of contention was the explanation given for this observation. Geological theory says that the fossils are only out of order in areas where overthrusts or mountain building (tectonic) activity has pushed older layers of rock up over the top of younger rocks. Price believed that overthrusts were just an invention to explain away the out-of-order fossils.

In subsequent decades, interventionist scientists with more geological education and experience recognized that the overthrusts are real and that there is an order to the fossil record. It isn't surprising that a global geological catastrophe might move mountain-sized blocks of rock over other rocks. The order of fossils in the geological sequence is more difficult to explain in the catastrophe, and this remains one of the primary unanswered questions for interventionists.

The Bible provides the most important concepts about origins but does not give us the details. It doesn't say anything about Paleozoic rocks or Mesozoic reptiles. We try to understand those, but we cannot equate our specific theories about such things with Bible truth.

A major influential factor in convincing many people to accept flood (catastrophic or short-age) geology[38] was the book written by John C. Whitcomb and Henry Morris, *The Genesis Flood*.[39] Since then many more educated interventionist geologists, paleontologists, and biologists have been seeking answers to our questions about earth history and its relation to the Bible.

Interventionist Research: Building a New Paradigm

Since the 1970s, interventionists have been using interventionist/short-age geology paradigms to better understand geological history. The approach used in this work is based on the conviction that if we really believe that Genesis contains truth, we do not need to be afraid of data. We do not need to be afraid to go out and look at the rocks and fossils and do genuine scientific research. This concept is developed in chapters 5 and 19.[40]

Early biblical geologists in the eighteenth to early nineteenth centuries explained at least part of the geological record as the result of the biblical flood, but their explanations did not hold up against new discoveries. This is not surprising in these early attempts, since geology was an infant discipline and no one had a well-developed geological theory. Those early efforts to reconcile geological theory with the Bible were not continued, and the concept was essentially dropped. However, in the twentieth and early twenty-first centuries, Bible-believing geologists have been seeking to learn and grow with advancing geological research and have been developing improved theories for understanding geology from a biblical perspective. This can be seen in the newer geological concepts to be discussed in the last chapters of this book.

The ID Movement

Another line of study, a challenge to naturalistic theories of the origin of life, began with a book titled *Evolution: A*

Theory in Crisis.[41] Michael Denton challenged the adequacy of evolution to explain the origin of the biological world. University of California law professor Phillip Johnson studied the theory of evolution and became convinced that the philosophy of naturalism and the theory of a naturalistic origin of life forms cannot stand up to critical scrutiny. He reached the conclusion that naturalism is essentially a religion and that if this naturalistic philosophy could be challenged and brought into open discussion, its weakness would become evident. His books[42] and his other writings have been an inspiration to others, and a group of very capable individuals with advanced degrees in biology and philosophy have formed what is called the Intelligent Design movement. They are typically not concerned about geological aspects of origins, and do not advocate creationism. The movement focuses on just one fundamental issue: life, with its pervasive evidence for design, could not result from natural law alone but requires an intelligent designer. Their work has the important goal of putting questions of the origin of life out on the table for open discussion based on *evidence*, not on naturalistic *assumptions*. This movement has resulted in a number of books developing this theme.[43]

CHAPTER 4

Understanding Science

Overview

From the time of Francis Bacon, the goal of science was widely understood to be to establish empirically which theories are true. Modern philosophers of science have recognized this goal as unrealistic. A theory can never be proven, because at any time, new data may reveal it to be incorrect. In the history of scientific ideas, this has happened repeatedly. Philosophers like Karl Popper, Thomas Kuhn, Imre Lakatos, Larry Laudan, Del Ratzsch, and others have developed more realistic views of science that recognize the human element in science. Science is a very productive, rational activity, but it is much influenced by sociology, the history of ideas, human subjectivity, and the order in which scientific discoveries were made. Science can best be understood in light of these influences. Progress is not just the stepwise accumulation of facts but can involve the overthrow of one explanatory system by a different, incompatible one. It is easier to determine which theory is resulting in more productive research than to determine which is true. Science is a fascinating, very human activity.

Philosophy of Science from Bacon to Kuhn

So far, we have discussed the nature and limits of science and some of the major features in the history of science. Philosophers of science in the latter half of the twentieth century have contributed additional insights into the scientific process.

Francis Bacon's ideas were followed later by the philosophy of science called positivism. The positivist philosophy was especially concerned with two questions regarding theories. The first question is demarcation—identifying the boundary between science and nonscience and determining which side of the boundary a theory falls on. The second question concerns confirmation of theories—how to determine if a theory has been demonstrated to be correct or verified. According to positivism, the goal of science is to use empirical data to verify or confirm the truth of a theory. A theory is valid science (on the correct side of the boundary between science and nonscience) if it can be verified by scientific observation. Everything that could not be so verified was nonsense. Thus science was considered the only route to understanding; all other purported knowledge was not knowledge at all. This materialistic outlook considered the material and physical universe to be real, but there could not be any human religious or ethical knowledge unless such knowledge was independently verified by science.[1]

The philosophy of positivism declined as it became evident that its concepts of science were unrealistic. Karl Popper emphasized that just because a series of observations supports a statement, it does not finally establish it to be true. We never know when new observations may demonstrate the statement, or at least part of the statement, to be false.[2] We may hypothesize that all crows are black and support the statement by observation of one thousand black crows, but then finding one white crow can prove the statement to be false. Of course, most scientific theories are more complex than the color of crows, but no matter how simple or complex they are, we can never demonstrate a theory to be true because it is always possible that new data in the future may falsify the theory. Science is always a continuing search that does not reach absolute truth.[3]

Popper's philosophy of science abandoned the rigidly rational criteria of the traditional positivist view and recognized the human element in science. He saw that there is always a need for human choice or judgment in research.[4] Science was no longer seen as resting on a solid foundation but was compared by Popper to a building erected not on solid bedrock but on piles driven into a swamp. They are not driven down to any natural base but are driven in until "we are satisfied that the piles are firm enough to carry the structure, at least for the time being."[5] In this new view of science, it was no longer reasonable to claim that topics outside of science were nonsense.

The human element in science became even more evident in the philosophy of Thomas Kuhn[6] that "has placed humans and human subjectivity (in the form of values of the community of scientists) in the center of science."[7] Kuhn's book, *The Structure of Scientific Revolutions*,[8] has changed our understanding of scientific progress.[9]

The Traditional View for Understanding the History of Science

In the traditional view of scientific history, science is primarily a stepwise accumulation of facts, one on top of the other. This is repeated in a continuous chain of progress toward our modern scientific views. The historian of science who follows this approach tries to determine where, when, and by whom each specific fact, as recognized today, was discovered. The historian also tries to determine how we got rid of the myths, superstitions, and errors that prevented this fact from being discovered sooner.[10] Implicit in this view is an assumption that whoever discovered this fact long ago was thinking the same way people do today. Looking back at the history of chemistry, one could easily assume that the chemist who discovered oxygen was thinking of the periodic chart as we know it. Upon discovering a new gas, he or she decided that it fit right up there in that spot on the chart.

Is this really the way progress was made? The discovery of oxygen serves as an example as we try to answer that question. Scientific textbooks often have a little bit of the history of scientific discoveries in them but, as Kuhn points out, their overly brief historical accounts can obscure the facts. One textbook said that "oxygen was first prepared by Joseph Priestley" and included the method he used. It then said, "It remained for Antoine LaVoisier (1775 to 1777) to show the important role that oxygen plays in combustion and respiration."[11] That description tells who and when, but it does not tell us much about the process of discovery. Perhaps we can forgive the author whose goal was to tell us about chemistry, not about the historical process. A chemistry text by Linus Pauling noted that LaVoisier advanced a new theory of combustion, hinting that some real changes in thinking occurred at that time.[12]

That is about all the history we get in science textbooks. They assume, generally, that the scientists of another era were thinking as we do and that the old ideas some of these scientists helped replace were just superstition, not really science. However, that view does not seem to work. The old ways of thinking cannot always be called superstitions and myths. A more careful study reveals that those scientists of long ago often were using research methods just like those in use today. The people studying oxygen were collecting and interpreting data the same way we do now. Out-of-date theories were not necessarily unscientific. They simply have been replaced by other scientific theories.

Kuhn's New View for Understanding the History of Science

This brings us to Thomas Kuhn's new way of looking at scientific history. Thomas Kuhn was a physicist who subsequently specialized in the history of science. Kuhn introduced the term "paradigm" in science (i.e., a broad, explanatory theory, such as the theory of evolution) to refer to a set of shared rules that define a scientific discipline.

Kuhn suggests that significant progress is made through scientific revolutions in which an entire paradigm is replaced by another one. The main point that leads to a correct understanding of the history of science is that we must evaluate scientists' views and discoveries, not in comparison with our views, but in light of their own surroundings and the science of their time.[13] We must evaluate Priestley's work in light of known facts and concepts of his time, not in comparison to our science today. Priestley and LaVoisier in the late 1700s were working within the phlogiston theory. Everything, according to this theory, has either caloric or phlogiston, one of which is lost when the substance burns. If it is a metal that burns, it loses phlogiston (which has a negative mass) and thus weight. Some things, such as paper or wood, lose caloric rather than phlogiston when they burn.

Another old concept was that acidic substances contained something called the principle of acidity. This was part of the chemical theory Priestley and LaVoisier worked with. They knew nothing of our periodic chart of the elements or of oxidation reactions. When Priestley collected that new kind of gas, he called it air without its usual amount of phlogiston. LaVoisier did the same experiments. He said the new substance was an atomic principle of acidity and formed a gas only when that principle had united with caloric. That does not sound like anything we learn in chemistry class today; it is an entirely different way of thinking. Priestley never comprehended what he had discovered. He did not know he had discovered a new gas called oxygen, and he never accepted the oxygen theory of combustion.

LaVoisier had already done experiments that convinced him that something was wrong with the phlogiston theory. He was ready to question the very basis of existing chemical theory. He was convinced that burning objects absorb something from the atmosphere. Consequently, he was willing to recognize what the discovery of oxygen implied for chemical theory. He did not just discover a new fact and fit it into existing theory. Rather, his discovery led him to the development of the oxygen theory of combustion—a new theory that led to the reformulation of chemistry and overthrew the phlogiston theory.

Progress did not occur by adding one fact to another. Rather, it came about when one entire paradigm was replaced by another—a scientific revolution. This is an example of Kuhn's view of scientific progress. When we evaluate scientific discoveries in light of the thinking of their time, we find that scientists then were practicing essentially the same kind of science we do now, even though the thinking was very different. In the process of research, scientists' work sometimes leads to the overthrow of old paradigms. Kuhn says this is the primary form of scientific advance. He recognizes that facts often do add on to one another. However, according to Kuhn, really big changes in scientific thinking occur when one theory is entirely replaced by another in a scientific revolution, and science then works within that new paradigm.

The old chemical theory was not just superstition. In its time, the theory met all the criteria for a useful scientific theory. In fact, chemists working under the phlogiston theory did not have the information necessary to lead them to the new theory. It was when chemists made the right discoveries, including the discovery of oxygen, that they were able to develop the new theory, which we now take for granted.

Note, too, that the data did not dictate the theory. Within a short passage of time, two very different ways of interpreting the data of chemistry were used. True, the data make boundaries for our theories. But with the data available at any given time, there is likely room for a variety of scientific theories, such as phlogiston and the alternative chemical theory—the oxygen theory of combustion. Which theory is accepted at a given time has a lot to do with sociology, with the experience of the researchers, and with historical accidents as to what experiments were done and in what sequence.

I (Chadwick) saw another scientific revolution occur early in my career. We were told in graduate school that while we could determine the sequence of proteins with great difficulty, we would never be able to sequence DNA, because the paradigm for sequencing would not accommodate a molecule with only four different elements. I assumed that was true and taught that to my students, until one day in the hallway outside my office, another molecular biologist casually told me that he had just sequenced a piece of DNA. After I had overcome my reluctance to believe him, he showed me in his laboratory. He said, "Sequencing DNA is as easy as reading a newspaper!" Now whole factories are devoted to DNA sequencing, and for a few dollars, you can send off a sample of DNA and have the sequence in a day or two. In fact, we often sequence proteins by reading the DNA or mRNA from the gene for that protein and converting the DNA sequence to amino acid sequences!

One of the most commonly cited examples of such a scientific revolution was the emergence of the theory of plate tectonics in the early 1960s. Before the 1920s, Alfred Wegener, an astronomer, had proposed that the earth's surface was made up of movable continents that had spread far apart, creating the Atlantic Ocean. He was subjected to widespread derision because he was not a geologist and because he could not supply a mechanism for the needed driving force. It was another thirty years before observations on the seafloor convinced geologists that the continents were indeed moving and had moved considerable distances in the past. These observations motivated the development of the theory of plate tectonics. However, the transformation of the geological community required another decade or more as older geologists, committed to the static model of the earth, either died off or converted to the new paradigm.[14] It was a true scientific revolution in the field of geology.

Summary of Kuhn's Changing Views of the History of Science

Kuhn concluded that scientists do not generally try to disprove their theories. Rather, each scientist typically accepts a particular scientific paradigm and works within that paradigm. They do not try to test the paradigm but assume it is true and use it to guide their scientific work within the paradigm's domain. Kuhn called this process normal science because that is what scientists normally do. The testing of a paradigm occurs over the long term, not at each step along the way.

Within normal science, one important factor that keeps scientists focused on the current paradigm is the education process. The scientists write textbooks and tell students which paradigm is correct. This helps maintain a constructive unity in science, but it also makes it difficult for a competing paradigm to gain a fair hearing.

As normal science progresses, anomalies may be discovered—phenomena that do not seem to fit the expectations of the paradigm. If these anomalies persistently defy efforts to resolve them, this can lead to what Kuhn called a crisis state for the paradigm. Science never abandons a theory or paradigm without replacing it with another one, but a crisis may stimulate a few creative scientists to develop an alternate paradigm. At this time, when new paradigms are just being developed, it is not clear which paradigm is correct. The choice between the old paradigm (which has only failed in its efforts to solve a few significant problems) and the new one (which has not yet established a research track record) is often made for less than objective reasons. Such choices can even be described as a "conversion" process that leads scientists to see things in an entirely new and different way than they saw them before.[15] If the new paradigm replaces the old, a scientific revolution has occurred, and normal science now proceeds under the new paradigm. The revolution process cannot be defined by rigorous logical criteria, but revolutions occur as the result of a changing consensus of opinion among scientists working in that field.

Other Modern Philosophers of Science

Kuhn's core concepts are still relevant, and it is still recognized that science is influenced by subjective human elements. There were other important philosophers of science in the twentieth century.[16] Paul Feyerabend went so far as to urge that we should not try to define a scientific method because rational boundaries defined by a scientific method will inhibit progress toward finding some legitimate new knowledge.[17] We will briefly consider the works of Laudan[18] and Lakatos,[19] who have provided sophisticated contemporary philosophies of science. J. P. Moreland[20] and Ratzsch[21] have written helpful analyses of the philosophy of science from a Christian perspective.

Lakatos believed the history of science is best described as competition through time between competing research programs. A research program consists of a core theory and a set of auxiliary hypotheses. The core theory is central to the research program and is protected from falsification by the "protective belt" of auxiliary hypotheses in order to give the core sufficient opportunity to be fully developed. When potentially falsifying data appear, it is the auxiliary hypotheses that are modified or replaced. The theory that all life has arisen by evolution is an example of a core theory, with its protective belt of changeable auxiliary hypotheses of specific evolutionary mechanisms.

A research program is considered progressive or degenerating according to several criteria, the most important of which is whether it is successful in predicting novel, hitherto unexpected findings, at least some of which can be successfully corroborated. Thus the choice between competing research programs is not based on our ability to determine which one is truer, but on the programs' relative ability to increase scientific knowledge. Science is still perceived as a rational activity, but it is now recognized that science is affected by sociology, economics, and other very human factors.[22] Paleontologist David Raup analyzed some episodes in science and compared common concepts of science and religion. He concluded that if the common understanding were correct, "it follows that scientific research is objective because the scientist is not influenced by prior expectations and is willing to let the chips fall where they may. I think these statements contain a fair amount of bunk."[23]

The history of science shows that a theory may be successful in stimulating scientific progress and consequently be widely accepted by the scientific community and yet later be rejected because the accumulating evidence no longer supports it. Consequently, if at a given time there is a strong consensus among scientists regarding the truth of a particular theory, this consensus may result from philosophical or sociological factors rather than from a body of evidence demonstrating the truth of the theory.[24] For example, could the scientific consensus that all life forms resulted from evolution be a consequence of a common antisupernatural philosophical commitment rather than from the adequacy of the evidence? It seems likely this is so.

Creativity and Conformity in Science

In a book titled *The Essential Tension*, Kuhn discusses the tension between creativity and conformity in science.[25] Normal science is driven by the conformists who accept the theory and work out the details. On the other hand, creativity arises with mavericks like Albert Einstein and Copernicus who have their doubts about accepted theories and come up with new ideas. Kuhn feels that science needs both types. Without conformists, we would not accumulate adequate data to discover that a new paradigm is needed. But occasionally science needs mavericks—creative people who think new thoughts.

An article in *The Scientist*[26] says that scientists are becoming too much like chefs—they tend to follow a recipe for research rather than thinking creatively. Another article in that publication says, "New ideas are guilty until proven innocent."[27] This article urges scientists to try out new ideas. "Perhaps the only thing that saves science is the presence of mavericks in every generation."[28] Science is a fascinating enterprise and has need of all kinds of people. When the United States was developing, it needed mavericks who were willing to brave the unknown wilderness, but it also needed the solid, stable people who would follow behind them and build the structure of the nation. Science is the same way.

CHAPTER 5

Naturalism and an Alternative

Overview

Mainline science follows the pervasive rule or philosophy of methodological naturalism (MN), which rejects any hypothesis that involves or implies supernatural action at any time in history. An evaluation of MN finds that it is not necessary in experimental study of ongoing natural processes. However, in a study of history, origins, it is important to decide what to do with MN because it rules out any events like creation or supernatural influences in geological history. A better alternative philosophy can recognize evidence that may point to possible supernatural influence in such *events*, even though science cannot study the (nonnatural) *causes* of these purported events. This alternative philosophy is described, and its beneficial, productive role in science is illustrated. It can be, and has been, used to guide successful, publishable scientific research.

An Alternative Philosophy to MN

Science has taught us that the universe operates according to the laws of nature—the laws of chemistry and physics. How does a believer in a Creator God understand these laws? If you are sitting in my house with a solid roof over you, the laws of physics and chemistry that keep the roof intact will keep your head dry. But that will change if I pick up a bucket of water and dump it over your head—you will get very wet. No laws of nature have been violated, but the course of events has changed. Perhaps many or maybe even all events that we call supernatural miracles or interventions are similar to this.

We propose that God is wise enough to invent "laws of nature" that are sufficiently comprehensive to maintain the functioning of the universe while still allowing God to invent and make complex things like living organisms whose bodies function because of the laws of chemistry and physics. Those laws would allow God—as a reasoning, personal, mobile Being—to make decisions and take action, just as humans do all the time.

God took action and constructed living things that function according to His laws of nature, just as humans routinely construct machines that function through chemical and physical laws. We understand that process of invention because we do it routinely. Later, God inserted a unique force into earth's balanced geological structure to cause a global catastrophic flood. No laws were violated. These were just intelligent decisions and actions taken by a Being who knows all His laws and knows how to interject the right forces to change the course of events. Is it logical for finite humans to decide whether we will allow Him to do that? Do our speculations affect how God works?

The philosophy of MN, which does not properly address whether God exists, does not accept any hypotheses that involve or imply divine intervention in the history of the universe. Is it possible that an alternative, nonnaturalistic philosophy could also be successful in guiding the scientific process?

A Critique of MN: What Is Its Proper Role?

In a public discussion on the issue of teaching science in public schools, a prominent scientist stated that even if creation were right, he would have to deny it to remain a scientist. To understand why a reputable scientist would make such a statement, one must understand the role of naturalism in science. MN 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.”[1] Science cannot do experiments to test whether a supernatural act occurred or how it occurred. This concept is clear enough and is also accepted by interventionists, but naturalistic scientists have gone a step further and decided to accept only theories that do not imply or require any supernatural activity at any time in history.[2]

MN may sound reasonable and, for many decades, has been almost universally accepted as a primary rule in science—in fact, it is portrayed as the only method that works.[3] But we choose to apply critical thinking to MN, to understand the basis for it and analyze whether it is an appropriate concept. We will look more closely at MN and its actual influence on the practice of science.[4] Isn’t there a way that we can follow Alvin Plantinga’s advice for Christians to make use of all that we know as Christians while doing valid science?[5]

MN in Two Aspects of Science

To examine how MN is used in science, we will consider how it functions in two different types of scientific pursuits: (1) experimental/observational study of ongoing processes, what happens in the laboratory today, and (2) the study of history—events in biological and geological origins and history.

Experimental Science

It is routinely claimed that science can only function if we follow the principle of MN.[6] Is this really true? The first category above, experimental science, includes use of experiments and carefully designed observations to study processes we can observe. Examples may be studies of chemistry in a laboratory or perhaps study of physiological processes in lab animals. Since these involve processes that occur right now, in front of our eyes, we can do the experiments over and over again to verify the reliability of our findings. Then we can seek to explain our data, in reference to what is known about chemistry or physiology. In our interpretations of these *ongoing* processes, we all recognize that it is essential to base our explanations on the evidence if our interpretations are to be valid. We cannot use supernatural explanations for our observations of *ongoing, law-bound* processes, even if we believe in an intervening, miracle-working God.

Naturalistic thinking is portrayed as essential for the success of science in order to keep supernatural explanations out of science. But there is a question we need to ask. If you are a scientist doing these experimental studies, are you tempted to use supernatural explanations? Do you have to remind yourself not to do that? Do you know of any active scientist who is tempted to think that God is tinkering with the chemicals in his or her experiments or a physiologist who is tempted to think that his or her observations have a supernatural cause? If the answers to these questions are no, then what is the practical role of MN today in experimental science? Is it needed at all?

We suggest that over the last few centuries we have learned that ongoing, observable daily processes in nature reliably follow the laws of chemistry and physics. Even scientists who actively believe in God realize that however God manages the universe, He doesn't normally do so by tinkering with the daily law-bound operations of nature that He created. That principle has been taught to us by the accumulated experience of modern science. Our scientific findings have revealed that God must be a mathematically oriented super scientist type, using His laws to run the universe. He is not a capricious magician who tinkers with the daily processes we study in our experiments.

It is still commonly stated that MN is necessary for the successful functioning of science. But it does not seem that any scientist engaged in experimental study of natural processes finds it necessary to ponder whether they should use supernatural explanations for their research findings. Recognition of the reliability of physical/chemical law is an adequate guide. If this is so, then what is the practical role of MN in experimental/observational research? Does it have any essential role at all? It seems to be irrelevant, a relic of history, a lesson we needed to learn, but that lesson now has made MN obsolete and unnecessary in this part of science. That doesn't mean that the concept of MN will damage experimental study of ongoing processes, but MN just isn't necessary. Even if God does perform a miracle and instantly heals someone of his or her cancer, that doesn't tell us anything about normal disease processes.

Scientific Study of History: Of Origins

But then why are we discussing this? If MN won't damage experimental science, why do we care about MN? The reason becomes evident in the study of the other category listed above—the study of origins, the history of life on earth. In the study of history, there are some issues that differ significantly from experimental research of ongoing processes.[7] *In the study of history, the decision of what to do with naturalism is not so straightforward.*

As we ponder questions about history, there is a need to consider, for example, whether the processes that govern the *functioning* of a living cell are also adequate to explain the *origin* of living cells, or if an intelligent agent is needed for their origin. Can science answer questions like this with evidence-based work? If so, what would be required to do so? If the answer can't be given with evidence-based work, how can it be science? Can science adequately answer how living cells came to be?

In study of the past, there are questions about whether certain *events* happened or not. Examples of the events we are discussing could include the deposit of a single layer of sediment, the arrival of the first living cells, the death of the last dinosaurs, or the rate a sedimentary layer was deposited. As we study events, we are likely to also encounter a deeper question: a question that addresses the *cause* of an event or a sequence. We will first discuss *events*.

Science seeks to understand events and their causes, but causes are very different from events. Science can commonly determine if an event happened, even if we can't study the cause. Did General George Custer attack an overwhelming force of Native Americans because he had presidential ambitions? The cause of that disaster was an "intelligent" cause—hatched in the mind of Custer. Since it was initiated by an "intelligent" decision, does that mean science can't study the battle and its outcome? Although there has been much advance in understanding the brain, we can't fully comprehend the mind of Custer. But that doesn't keep us from looking at the evidence and testing whether the event, the Battle of the Little Bighorn, happened. We can also study the secondary causes of the actual deaths of the soldiers.

In other historical studies, in geological and biological history, science can ask whether a geological or biological event happened, whether or not we can understand the ultimate cause. We would like to understand the causes of these events, if they are amenable to the methods of science. It is valuable to know if there really was a mass extinction of life forms at the end of the Cretaceous, even if there has been much uncertainty about the cause of that event. That event can be evaluated by study of the evidence left behind, even if we cannot observe, reproduce, and be absolutely certain of its cause.

We can study some potential causes with the methods of science, but some others can only be acknowledged as possibilities that cannot be studied by science. We suggest that unknown or even possibly untestable causes should not be rejected by assumption alone. This would apply especially to more controversial issues in study of the history of the earth and the history of life. How did life begin? Did life begin through a sequence of essentially random encounters of molecules over time? Or was it because of an intelligent cause,[8] maybe even an intelligent plan by a supernatural cause? Many readers will immediately respond, Wait a minute, don't you know that is exactly what naturalism rejects!? Yes we do know, but that concept is exactly what we are seeking to evaluate.

Why should we care about this? Why are we going through all the trouble to analyze naturalism if it won't damage experimental science? For an answer, come back to the event of the origin of the first living cells. In scientific publications, the origin of life is consistently described as the result of random, unguided natural processes with no intelligent input. How much evidence is there to support this theory? In chapter 7, we will learn that there is *virtually no evidence* to support this conclusion about history, and no scientist can go back in time to observe it. Then why is science so firmly committed to this conclusion? It is because the philosophy, the assumption, of methodological naturalism requires it, no matter what the evidence. As Richard Lewontin has famously stated:

> Our willingness to accept scientific claims that are against common sense is the key to an understanding of the real struggle between science and the supernatural. We take the side of science in spite of the patent absurdity of some of its constructs, in spite of its failure to fulfill many of its extravagant promises of health and life, in spite of the tolerance of the scientific community for unsubstantiated just-so stories, because we have a prior commitment, a commitment to materialism. It is not that the methods and institutions of science somehow compel us to accept a material explanation of the phenomenal world, but, on the contrary, that we are forced by our a priori adherence to material causes to create an apparatus of investigation and a set of concepts that produce material explanations, no matter how counter-intuitive, no matter how mystifying to the uninitiated. *Moreover, that materialism is absolute, for we cannot allow a Divine Foot in the door* (italics supplied).[9]

If we were to acknowledge that the origin of life involved intelligent intervention, naturalism would be dead. Since MN requires the naturalistic (materialistic) origin of life, in spite of the lack of any genuine supporting evidence, we have to ask what other demands MN might be making on us without adequate supporting evidence? This is why we take the time to analyze naturalism.

We can all agree that science has no way to explore a supernatural process. That is beyond the range of scientific study. But science can still examine evidence to determine if an *event* happened—even the event of the beginning of life on earth. Is the evidence compatible with life's origin occurring by strictly natural causes? Or does the rapidly accumulating biochemical evidence make that too unlikely to be worth serious consideration? Do we wish to know the answers to questions like that, without basing the answer on an *a priori* assumption, as Lewontin expects? If not, why not?

If science is objective, it can explore that question and at least evaluate the probabilities for different possible scenarios of life's beginning. That is, it can do so if not blocked by a thought-stopper—the rigid application of MN that refuses to allow that question (was life designed?) to be asked. Why should science be controlled by dogma—including the dogmatic use of MN? If science doesn't yet have an evidence-based answer to how life began, can we be candid enough to say that? Some do have the candor to say that, and they are worthy of our respect.[10]

A Research Procedure

Any worldview can introduce a bias into research, but our task is to define an approach to research that does not bring with it a bias against naturalism or a bias against an interventionist view. It simply seeks to allow various worldviews to ask questions and suggest hypotheses to be tested by the methods of science. If we succeed in this plan, then we can show that arguments against the use of interventionist worldviews in scientific study are not valid.

Our research plan may begin with observations from science, including field or laboratory observations, or observations from published literature in science. These observations, along with our worldview, may prompt new questions about the phenomena under study. The new questions could arise from any source (science, philosophy, religion), but they must be questions that can be addressed with the methods of science (as illustrated in the example below). After learning from the scientific literature what is already known about the topic, a research plan can be defined with clear methods of data collection and analysis, and the research can begin (science).

An example will help explain this concept. The Miocene/Pliocene Pisco Formation in the coastal plain of Peru contains a rich assemblage of fossil marine vertebrates, including a large number of whales. A high percentage of these are very well-preserved, articulated skeletons with the bones undamaged by invertebrate scavengers. Many of the whales even have their baleen food-filtering apparatus (made of a protein, keratin) preserved and in its normal position in the mouth.[11]

In modern environments, such good preservation of a whale would require burial within days, or months at most. However, the Pisco sediments that entombed the whales were interpreted as accumulating on the sea floor at rates of only a few centimeters per thousand years—far too slow to preserve the whales. Geologists and paleontologists who had studied the Pisco whales during at least twenty years either had not noticed this glaring inconsistency or had not taken it seriously enough to seek an answer and discuss it in published scientific papers.

Along with other earth scientists, we studied the Pisco Formation, and we quickly noticed the contrast between assumed slow sediment accumulation rates and the rapid burial necessary to preserve complete whales. Why did we notice it? In contrast to previous researchers, we approached the research from a worldview that did not assume long ages of time for the geological record. We began with an open question: "How long did it take for these sediments and fossils to be deposited here?" Our thinking was not controlled by uniformitarian assumptions, but it allowed the option of a short time period for the Pisco (consequently also questioning the accuracy of radiometric dates). We proposed the hypothesis of a much more rapid process than MN would allow (which does not provide adequate time for inferred evolutionary changes in the Pisco Formation vertebrate fossils). Our goal was to test that hypothesis in the part of the Pisco that we studied, not to force our data into our hypothesis whether it fits or not. If we are seeking truth (as scientists should), how could we be satisfied with an effort to force the data into a preconceived idea?

The evidence from the whales and the diatomaceous deposits did support rapid burial of the whales and rapid accumulation of the sediments that entombed them.[12] So what did this research accomplish? Which of these options are correct?

1. We proved the biblical flood—NO. The word "proof" should not be used here, and the Pisco is only one rock formation out of many.
2. We showed the entire Pisco Formation formed very rapidly—NO. We did not eliminate the possibility that some parts of the Pisco formed more slowly.
3. We disproved MN—NO. We simply didn't use it or allow it to restrict our thinking.
4. We used different research methods from other scientists—NO. Our data collection and analysis used standard research procedures.
5. Our hypothesis was scientifically productive; it led to discovery and understanding of evidence that others had not recognized—YES.
6. This research is compatible with the proposal that questions and hypotheses not utilizing the principle of MN can be scientifically successful—YES.
7. The evidence supports our hypothesis of rapid burial—YES.
8. We tried to study a miracle—NO. We studied a sequence of depositional *events*, not their ultimate

> *cause*. Rather than trying to study any miracle, we simply allowed our worldview to open up our thinking to a broader range of options. Could the rapid deposition burying the whales be part of a larger process initiated by intelligent action? It could be, but the scientific process could not address that.

In our research and interpretation of data are we entirely unbiased? No, we are human like everyone else. But we do have a couple of advantages over many others. Reading the abundant anticreationist literature clearly reveals that those who write that material know little or nothing about how a scientifically educated creationist thinks.[13] They only understand their own worldview. However, as interventionists who are deeply involved in research and publication, we are very familiar with our own point of view and also with the mainline scientific research literature and theories in our field. Thus we are constantly comparing and thinking of how we can test between specific concepts from these different worldviews. The other advantage is that since we don't constrict our thinking to MN-based interpretations, we are more likely to notice features that can appear, from a mainline MN mind-set, to be just oddities with no significance, such as well-preserved whales in slowly forming sediments. When we pay attention to them, some turn out to be very significant. In this and other research, keeping our thinking free from the artificial restrictions of MN opened our eyes to see things that others had not seen. This convinces us that MN as it is used today is mostly a detriment to science, not an asset.

Interpreting Published Data

The principles illustrated in the example above also apply to how an interventionist worldview may evaluate evidence from the published literature. For example, consider the numerous cases of preserved biomolecules like proteins or DNA in ancient fossils.[14] These same biomolecules in the modern world have short half-lives of thousands of years or less. However, the chronology based on MN requires, and radiometric dating provides, ages for the fossil biomolecules of many millions of years. The short half-lives of biomolecules and the radiometric dates are two conflicting lines of evidence, and the conflict needs an explanation.

When two lines of evidence conflict, this indicates there is something that we don't yet understand. Which is correct? Are the fossil biomolecules very ancient, in violation of the laws of chemistry that govern their half-lives today? Or are the accepted radiometric dates wrong, and the fossils are actually quite young? MN allows only one of those interpretations—the fossils must be very ancient, and we don't understand how they lasted so long. MN does not allow consideration of both possibilities—it does not allow an open-minded search for scientific truth.

Of course, if the fossils were formed within the last few thousand years (too short a time for the evolution of new types of organisms), that points ultimately to an intervening action in regard to the short time span, and science can't examine the nature of that cause. The questions here are as follows: Do we want to know what is true about the *events*, even if we can't verify their ultimate cause? Or do we allow an assumption, MN, to dictate what is true about the events?

Science can't study intervening causes, so the ideas of intervention could be described as science-stoppers. But interventionist events such as intelligent design and the creation of life or the initiation of a global catastrophic flood could have happened. If they did, will it improve our science if we pretend they did not happen? Do we want to know true answers, even if they don't fit our preferred philosophy? If the evidence indicates that a materialistic, naturalistic origin of life is not a realistic possibility, will our science be better if we ignore the evidence and insist that the only acceptable explanations are those consistent with MN? Do theory and assumptions trump evidence, as would be the case if we refuse to even consider the postulate that life may not have arisen by a naturalistic process?

We conclude that the only constructive thing MN has to offer is to remind us that science can't study *how* intervention works. It is not valid for MN to deny that some intervention could have happened in the course of origins. In some cases, the evidence (which we can study) may tell us that *events* have occurred that point back to the likelihood of miraculous or at least intelligent causes (and science can't study how those happen). Science has a definite limitation in that it cannot determine if intervention has happened in the past, and it also cannot determine if it did not happen. It seems wiser for scientists to recognize this limitation rather than to deny it. There will always be qualified, careful scientists who follow the principles of MN and some who do not. The difference is philosophical, not scientific, and we predict that those who favor interventionism, not MN, will ultimately be more successful. That may seem to be a rash prediction, but as time goes on, we will see.

Summary of This Analysis of MN

Some will object to the claim that experimental science is different from historical science, because they both involve uncertain inferences from data (interpretations) and assumptions. That is true but is not the whole story. Since it all involves inferences, a sharp dividing line can't be drawn between these two categories of science. Nevertheless, there is a dramatic and very practical difference between the study of biological or physical processes that are functioning continuously, for which the data are ultimately accessible, and on the other hand, unique historical events that cannot ever be observed. We can only know about some events if a reliable observer saw them and told us about them.

There is one factor that all, those who accept MN and those who do not accept it, can agree on: science cannot examine *how purported interventions (miracles) happen*. Since we have learned not to rely on mystical explanations of daily operations of nature, the only constructive thing MN does now is to remind us of this.

What is the difference between MN and a worldview that rejects MN? The difference, for both sides of that divide, is a religious difference. Science can't test either of these hypotheses: (1) an intervening god has been active in the history of origins or (2) no intervening god has been active in history. The choice between these hypotheses is a philosophical or religious choice, not a scientific choice. If there is an intervening god, and MN declares that he is not allowed to ever have done any intervention, will that change history? Not likely. We can see that modern processes reliably follow the laws of chemistry and physics, but what about beginnings?

MN has no ability to tell us *whether* intervention has occurred in connection with origins, nor does it have a right to dictate that to us. If an intervention did occur in the past, science can't study the intervention, but it can study any evidence that may have resulted from the intervention.

It is important to recognize the distinction between the results of *events* in history, which can be studied, and the ultimate *causes* of such events, which may not be amenable to our research. If this factor is put on the table, it can have an influence in opening up the discussion of geological and biological history and origins.

Just as it is not appropriate to assume there have been no supernatural interventions in history, we should also not *assume* that intervention has affected our research site. But our research will be more objective if we are aware of, and open to the possibility of, a different earth history than the history required by MN. In other words, we seek for our research to be evidence-based, not assumption-based.

When two lines of diligently studied evidence point in opposite directions, the contradiction is quite likely telling us there is something still to be discovered that can bring clarity and consistency to our understanding of the subject under study. We predict that this clarity will be enhanced if we are not limited in our thinking by MN.

We must return for a moment to the biggest question about the issues in this discussion of MN. Why is it so important to challenge the use of MN, especially in experimental science? We have stated that MN is not beneficial to science and also that "science has no way to explore a supernatural process." Is that an outright contradiction? Is it saying that MN is bad but we can't get along without it? The answer to those questions describes the essential reason for this discussion. MN is a problem in the modern scientific world because it is a deeply, often dogmatically held philosophy with implications that inevitably go way beyond any valid basic application. If it were only applied to experimental science, it could be fairly harmless. But the most serious problem with MN is that it inevitably spills over deeply into discussions of history, where, in practice, it tries to dictate answers about events—answers that science in some cases cannot provide.

These concepts regarding events, causes, and testable and nontestable hypotheses will be applied in the topics we will discuss in coming chapters.

More on the Supernatural and the Laws of Nature

As illustrated above with the bucket of water on a friend's head, God could act in history without breaking any physical or chemical laws. Science that follows the absolute rule of MN cannot accept that possibility. In practice, science generally will not accept supernatural action even when it appears to be required by rigorous logic. This helps explain the statement by our friend that even if creation were correct, he would have to deny it to be a scientist. This does not necessarily mean that he was a bigot. Evidently he sincerely believed 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? Has it gone from one extreme (medieval pervasive supernaturalism) to another (strict naturalism)? We can respect the right of others to believe that it is necessary to accept naturalism to be a scientist while still trying to persuade them that strict MN is not the only paradigm that can lead to effective science.

Scientific study has revealed amazing things about the laws of nature and used them to improve our health and nutrition; combat diseases; put men on the moon; and invent factories, cars, computers, air conditioners, and awesome apps for our iPads. All of these scientific and engineering advances fall in our category of experimental science—study of daily natural processes we can observe and put to practical use. The science we marvel at most is in a different category from the more uncertain study of geological and biological history, which we will discuss in later chapters.

Imagine we could bring to our day a person who had lived in A.D. 1500. 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 go home and flip a little lever on the wall and the lights come on. By now, the poor fellow may flee in terror at these supernatural manifestations. Why would he think that? It's simply the difference between his thinking and ours. He is not familiar with the laws governing the operation of cars or electricity. He thinks of these as supernatural, but in reality, he just does not understand them.

Many of the chief scientists of past centuries, those who pioneered the establishment of the framework of modern science were believers in a law-giving Creator God. Scientists of the caliber of Copernicus, Galileo Galilei, Johannes Kepler, Blaise Pascal, Isaac Newton, Robert Boyle, and many others professed belief in a God who was behind nature and its laws. The argument that successful science demands MN was not true then and cannot be true today. They already recognized that God was a God of order and that the nature He created was not capricious, so they could comfortably work in the absence of the restrictive premise of MN. The same probably applies to many of the top scientists of our day who claim to be Christians. More than 60 percent of Nobel laureates claim to be Christians. It is not likely that all the recipients completely discounted intervention. For example, Nobel laureate Werner Arber has stated: "Although a biologist, I must confess I do not understand how life came about. . . . I consider that life only starts at the level of a functional cell. The most primitive cells may require at least several hundred different specific biological macromolecules. How such already quite complex structures may have come together, remains a mystery to me. The possibility of the existence of a Creator, of God, represents to me a satisfactory solution to this problem."[15] Such evidence supports the contention that MN is not a requirement for one to be a scientist or to do good science.

Biases from Various Sources

Could a person's religious perspective cause a bias in his or her interpretation of scientific data? Certainly. Can a naturalistic philosophy bias a scientist's interpretation of data? Yes. Any worldview can introduce a bias, especially if we do not make the effort to understand different worldviews, so we can make an informed choice between them. Naturalism has a powerful biasing influence in science, steering scientific thinking and, in many cases, deciding what conclusions are to be permitted. Generally, this is not recognized, but we can only understand the scientific study of origins if we fully grasp the contemporary role of MN in mainline science.

When the discipline of geology was taking form in the eighteenth and nineteenth centuries, the geologists James Hutton[16] and Charles Lyell[17] each wrote books in which they developed a paradigm of geology that rejected the catastrophic interpretations of their day and replaced them with a theory that accepted only uniformitarian (geological processes have always been constant) and gradualistic (always slow) processes over eons of time. Lyell's book was very influential and restricted geology to a gradualistic, uniformitarian paradigm until the mid-twentieth century. Historical analysis of Lyell's work has concluded that the catastrophists in Lyell's day were the more unbiased scientists and more careful observers[18] and that Lyell's strictly gradualistic version of uniformitarianism was bad for geology because it prevented geologists from considering any hypotheses involving catastrophic interpretations of the data.[19] In recent decades, the discipline of geology has come to recognize that some catastrophic processes do occur, although geologists still interpret these processes within a time frame of billions of years.

Controlling Bias in Scientific Research

The problems a portion of Lyell's theory has caused in geology suggest that theism is not the only factor with the potential to bias the interpretation of data. This is not an informed interventionism problem; it is a human problem everyone must seek to overcome. Science has a method for dealing with this problem, which will be effective for interventionists as well as others (table 5.1).

This method is the peer-review system that helps maintain quality in science, or one might call it the critical discussion in Popper's[20] scientific method. The peer-review system is important in science, but it 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, but as it was, Lyell's gradualistic uniformitarianism was the only paradigm in use, so for a century, peer review had no effect in challenging the firm hold of Lyell's uniformitarianism. There is a parallel operating today. Since naturalism is not out on the table for open discussion, scientific peer review

Table 5.1. Components of the scientific method of bias control

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 (papers that are reviewed by several recognized peers before publication).

cannot function in analyzing whether naturalistic explanations are or are not the more correct ones.

Science will be benefited if scientists with differing philosophical views are encouraged to be active in science. Neither has anything to fear from the other as long as both are (1) active in the scientific process and engaged in quality research, (2) honest with the data, and (3) taking an active part in the scientific community, publishing their work, attending meetings and presenting papers, and talking with their peers about their work. No quality control is quite as effective as knowing that when one presents a paper, others—including some who disagree—will be ready to point out the mistakes that may have been overlooked. Also, scientists in each group are likely to recognize some types of data that the other might overlook.

Is There a Viable Alternative to Naturalism?

Science has, in many ways, been very successful before and during the reign of the philosophy of MN. But before we conclude that this success resulted from the naturalistic assumption, we must look at the issues in more detail. In the development of modern scientific thinking, there were several specific concepts that became recognized and applied:

1. Living things and physical phenomena are like machines in the sense that 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 experimentation 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 does not consider the possibility of any intervention in the history or functioning of the universe by any higher power (naturalism).

Were these six items equally essential for the progress of modern science? They were not. 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. These four concepts constitute the breakthrough that launched science on the road to its modern success. The fifth is an empirical observation, and the recognition of this concept was also an important insight that opened up large vistas for research.

The sixth item, naturalism, does not follow inevitably if the first five concepts are true. A car operates according to natural laws, and it can be interesting to study the chemical and physical 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. This is also true in study of life and its origins.

As long as we accept the first five concepts above, most of what science does would not be affected by whether we accept the sixth concept—naturalism. It is the first five items in the list above that are the secret of science's success. Living things and physical processes are like "machines" in the sense that we can figure out how they work and what laws govern their structure and function. An interventionist scientist who follows these five concepts can work and think like a naturalistic scientist with one exception: he or she does not rule out the possibility that an intelligent, superior being has, on rare occasions, intervened in biological or geological history, particularly in connection with the origin of life forms. This defines the interventionist paradigm. Within this paradigm a scientists works and generally thinks like other scientists when doing experimental study of ongoing processes (items 1 through 5 above). The difference is the acceptance of creation of the main groups of organisms and change within those created groups through time.

A story is told of a man who was on his knees under a street light. 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?" "No," he answered, "but the light is better here." Working within the accepted paradigm is indeed easier, but if the correct answer lies elsewhere it will be more productive to look elsewhere.

Intelligent Design (ID) and Evaluation of Complex Phenomena

Since Charles Darwin's day, many scientists have claimed that nature is not the result of intelligent design but that adaptations resulting from mutation and selection only look like design.[21] Some take pains to urge biologists to "constantly keep in mind that what they see was not designed, but rather evolved."[22] New efforts are being directed toward challenging the adequacy of naturalism. Is naturalism just an arbitrary assumption, or is it supported by solid evidence? If science is an open-minded search for truth, it needs to be willing to ask that question.

If we find a computer sitting in the forest, we have no trouble deciding that it resulted from intelligent design, so why should we not at least consider the same conclusion for living things with their unequaled biochemical complexity? Many scholars today believe that is a naive question, but read on. When we see design we can usually recognize it, but the problem is how to make the design argument quantitatively rigorous. This task has been tackled by William Dembski[23] and his colleagues in the ID movement. Dembski has developed a scheme for objectively determining if an event or some structure in nature cannot be explained by natural law but requires direct involvement of intelligent design. Dembski calls this the explanatory filter. The filter evaluates an object or event's degree of complexity—whether its features are defined by natural law or whether it can naturally occur in various forms and whether it meets some specification that makes it functional. For example, if a protein in an organism works—does a specific biochemical task—then it can be considered "specified." The explanatory filter provides an objective, quantitative evaluation of this intuitive recognition of design.

Figure 5.1 shows rocks on a hillside. If the pattern in A is studied carefully, it is possible to recognize the word "rocks." In B, the word "rocks" is much clearer. If we calculated the probabilities of each arrangement occurring, the pattern in B would have a far smaller probability of occurring by chance than A. If you saw the sentence in C—"These are rocks!"—on a hillside, would you have any question whether this occurred by chance or by design?

However, there is another issue to consider when we are evaluating biological systems. We know how humans make words with rocks, but we do not know of any natural process that will do this, so even the most skeptical scholar will agree that the rock sentence indicates design. On the other hand, many scientists believe there is a mechanism to produce order and complexity in living things without

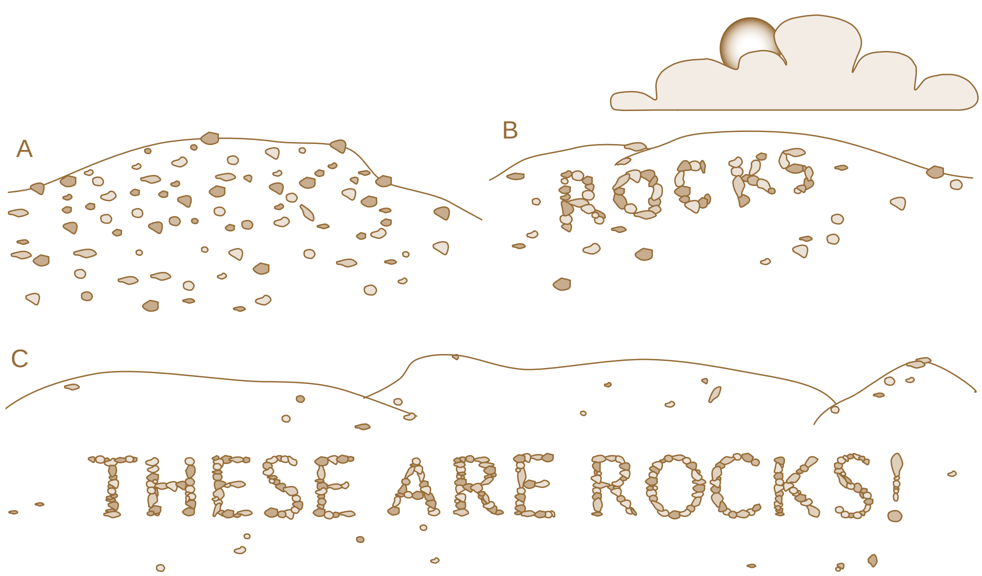


Figure 5.1. Arrangements of rocks on hillsides, for evaluation of the claim that they resulted from design (Brand 2006a).

How to make a sentence out of rocks

DATA

The arrangement of rocks gives the appearance of words in a meaningful sentence.

INTERPRETATION

Interventionism: A person made the sentence. They had a plan and a mechanism (arms and legs) to put the plan into effect.

Assumption: No assumption is necessary.

Naturalism: In this example, a person made the rock sentence. There is no natural plan and no mechanism to put a plan into effect to make this rock sentence; natural processes do not include such a mechanism. But do not apply this explanation to living things.

Assumption: Naturalism.

a designer—mutation and natural selection. The critical question is this: Do we have adequate evidence that this mechanism can produce new body plans, new organs, and new complexes of genes to specify the structure of these new features? The explanatory filter is one useful step in evaluating evidence for design, but in the study of biological systems, we still need an answer to the crucial challenge to design: Is there a demonstrated biological process that can produce new biological order without intelligent design? This question will be addressed in chapters 8 through 12.

The ID movement does not concern itself with the identity of the designer. But in this book, the discussion will go beyond intelligent design to deal with issues that are different from the questions addressed by that movement.

Evaluating the Two Paradigms

If the interventionists and persons following MN sincerely wish to understand each other's thinking, followers of either worldview must learn what it is like to think as those in the other worldview think without being judgmental.[24] Only then will they be prepared to make a fair evaluation of the internal consistency of each viewpoint and its success in dealing with the evidence. The likelihood of achieving this is highest if we all get to know each other and truly seek to understand how the other thinks.

The God who intervened in history has taken the trouble to tell humankind about unusual events that would confuse the study of history if the events were left unknown, and we can have the privilege of benefiting from this information, and it can even result in effective science, as we shall see.

Imagine a large dam built across a canyon backing up a lake as big as one of the Great Lakes. One day the dam gives way. The enormous rush of water erodes away all traces of the dam. As the water cascades through the valleys downstream, it erodes them into canyons many times larger than their original size. With time, all human memories of the dam and its destruction are lost. One ancient book tells the story, but people argue over the book's authenticity.

A geologist studying the canyons along the river rejects the validity of the old book and concludes that no natural process could have produced a flood that massive. She measures the flow of the river and the amount of sediment 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 the geologist concludes that the indicated catastrophes were isolated floods with long time periods between them.

Another geologist is willing to consider seriously that the book may be reliable. He decides that if it is correct, the insights in the book will help keep him from misinterpreting the data. Without the book and its story of such a unique event—totally different from the natural catastrophes that are part of our modern analogues—it would be difficult, if not impossible, for the geologist to have any hope of being able to think of the correct hypothesis for the origin of the canyons. More seriously, he would not even be aware of the problem.

If the book is correct, it provides a logically consistent approach to the problem: the flood was the consequence of an unusual event, someone told us about it, 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 old book might be telling the truth. If those who think the book is reliable conduct themselves as good scientists, science would be benefited more from maintaining a friendly dialogue than defining them out of science.

Interventionism can take different forms. The version of interventionism presented here concludes that the "Old Book" is a reality: the Designer communicated to us and evidence indicates the communication is reliable in describing the actual history of life. The communication is brief; it leaves many unanswered questions. But if it is a reliable account, the most productive approach will be to take it seriously and see what insights its concepts can give us in our research. Statements from the book cannot be used as evidence in science. But if those statements are true, we should be able to use some of them as a basis for defining hypotheses that lead to productive research. In chapter 19, we will present a list of other hypotheses and predictions. Of course, one must remember that the "Old Book" also contains much material that cannot be addressed with the scientific process.

A Need for Caution

One danger we must carefully avoid is the very human tendency to think that because we believe the Bible contains special insights, whatever ideas we develop based on this book are automatically correct. George McCready Price[25] 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.

At this point, we must also consider another side of the issue. Even if catastrophic geologists use their theory effectively and make discoveries others have overlooked, application of these findings has limits. Science cannot demonstrate whether God was or was not involved in influencing 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, it only would make it reasonable to believe the flood story if confidence in Scripture leads one to do so. It would not prove, scientifically, that God caused a flood.

What Should Interventionists Be Doing?

Maybe interventionism can be a basis for doing scientific research, but is that paradigm really needed? Geology did move toward correcting Lyell's mistake without any help from outside of naturalism, so why is informed intervention needed? Many bright and successful scientists are convinced that the theory of the evolution of life forms adequately explains the evidence. The rationale for their attitude is understandable, and they have a right to their opinion. Yet some dimensions to these issues are commonly overlooked. There are good reasons for taking seriously the possibility of informed intervention—not because there is proof for it or because it answers all our questions but because of a conviction that it has something important to offer science as well as religion.

The only religion worth having is one based on truth. If scientists believe their religion is truth and that it offers insights into earth history, they would be missing something important if they did not use it for generating testable scientific hypotheses. If someone gives us a map for finding a buried treasure, will we search for it? Our choice will certainly be influenced by how much we trust the person's wisdom. If we believe that God has given us true insights into earth history, the option of using these to lead us in a scientific search is irresistible!

Some critics claim that a creationist cannot function effectively as a scientist.[26] Actually a large number of interventionists are active in research and scientific publication. But in an atmosphere of unfriendly interaction between the two views, interventionists often do not make their philosophical views known.

In the long run, the beneficial approach is for interventionists to conduct themselves as genuine scientists and get actively involved in research. It is better to develop an alternate paradigm than to merely poke holes in someone else's theory. If interventionist efforts only center on disproving the prevailing evolutionary paradigm, this question will be raised: What do you have that is better?

A person's philosophy should not matter as long as he or she does quality science. That is the ideal. Both naturalists and interventionists spend too much time accusing each other. Why do we do this? We do not need to agree on everything in order to value each other's work. The ultimate test of any scientist is honesty in dealing with the data and the quality of research, not personal philosophy. For science simply to judge a person on his or her honesty and effectiveness in research should be enough. This would eliminate many unnecessary battles over philosophical issues.

In the next chapter, we will continue this discussion of the relationship between science and faith and deal more directly with Scripture and why some scientists take seriously what it says about origins and even use it as a source of scientific hypotheses.

CHAPTER 6

The Relationship of Faith and Science

Overview

What is faith and how does it relate to science? Some reasons for trusting the Bible are considered, and then two most common positions or worldviews on how to understand the Bible are compared. One of these can be described as a naturalistic perspective, comparable to naturalism in science. In this approach, the Bible is considered to be essentially human myths and legends, with no divine input or authority. Science would be considered to be our most reliable source for understanding of religious views as well as nature. The other primary perspective is the Judeo-Christian view that accepts the Bible as an inspired and trustworthy document, which is even considered reliable for understanding the history of life on earth. Since these lead in very different directions, the choices we make are important. If the second viewpoint is accepted, there is a need to develop a realistic, practical working relationship between science and religion. Such a relationship is described, designed so that seeming conflicts between them encourage us toward more careful study of both science and Scripture. It is proposed that such study can even utilize biblical insights to suggest testable scientific hypotheses and lead to improved scientific explanations. This concept will also be explored and illustrated later in the book. All of this matters only as it helps us know and trust God better.

Faith and Evidence

This chapter explores the relationship between faith and science. Science is often said to be based on evidence, while religion is based on faith. Just what is faith? How does it differ from scientific evidence? One definition of faith is confidence or belief that is not based on evidence or proof (Webster's Unabridged Dictionary). But shouldn't faith have some evidence to support it? Would we want to build our philosophy of life upon something for which we had no supporting evidence? Some see faith as a leap in the dark, and perhaps that is a valid way to define the type of faith that is not based on any evidence. How much better it seems to have some evidence to give us confidence in an idea before we put our faith in it. A Christian's faith includes confidence in unobservable events from the past and a future life eternal: "Now faith is confidence in what we hope for and assurance about what we do not see" (Heb. 11:1, NIV). Faith is exercised in all endeavors of life, including in our pursuit of knowledge through science, where we never have all the evidence. If we know and understand God, we learn that He is trustworthy, and worthy of our faith, even in issues for which we have only partial evidence. Several types of evidence can help us evaluate whether we should have faith in the reliability of the Bible.

The Reliability of the Bible

What evidence is there that the Bible should be trusted? One type of evidence is prophecy. The Bible long ago predicted that certain things would happen. When the predictions of the prophecy are fulfilled, our confidence in biblical reliability is strengthened. As a graduate student, I remember feeling the need to evaluate some of my beliefs for myself.

I took the book of Daniel, a world history book, and some other references and followed some of Daniel's predictions. The prophecy of four main world empires in the western world of ancient times had detailed information, including the subsequent division of Europe into a number of nations that would never again become united. It was fascinating to see how these predictions unfolded in world history. Prophecy, then, is a useful line of evidence because we can check whether the events occurred as the prophecy declared.

We also can look at internal consistency in all the books of the Bible written over a period of more than a thousand years. Surely the consistent message they present would provide evidence for the reliability of the entire book.

Historical accuracy is another line of evidence that can be examined. In ancient writings, secular kings wrote about the history of their nations. Their goal was not to give accurate information about previous rulers; they wanted to make themselves look good. We can compare the Bible with other ancient writings and with the known facts of history to see if the Bible is more reliable (i.e., if it presents accurate history).

Nineteenth-century archaeologists believed that the Bible provided very inaccurate history. For example, the Bible talks about the Hittite empire as a mighty, influential empire in the Mediterranean region. An active program of archaeological investigation did not find any Hittite cities. In many such cases, they thought the Bible stories were just fables and legends. When much more digging was done, however, the capital of the Hittite empire was discovered. In the long run, the Bible turned out to be vindicated.

Another supposed error concerned Nineveh, an important city in Bible history. Again, archaeologists did not believe it existed until, at last, the ruins were found. In case after case, the critics were wrong and the Bible was right. Not all archaeological questions arising from the Bible have been solved. But as more research solves additional puzzles, we have more reasons for trusting the scriptural record.

Other lines of evidence further afield from scientific thought are also important. One of these is the effect of Christianity on people. In considering any religion, we need to ask what it is like to live under that system. Here we cannot produce proof, and of course, personal testimonials can sound convincing even if based on nothing. But if we are honest and careful, we can evaluate whether Christianity has made a positive difference in our lives.

In this discussion, we have included several areas of evidence that support the biblical worldview.[1] But we must remember that the appeal to external evidence has limits. Many concepts in the Bible can never be tested—consider the stories about Jesus and the miracles that He performed. We can compare other parts of the Bible with the evidence, however; if the evidence fits, it increases our confidence in all the Scriptures.

Many scholars challenge the Bible's claims of how and when it was written. Some of the critics' claims have not stood up well to increasing knowledge of Scripture. Other claims require us to study and evaluate; do the critics seem to provide objective judgment of the Bible, or do their criticisms result from a more naturalistic perspective about life and history? Often we can only evaluate what an author is saying if we understand the nature of their data and the philosophy underlying and influencing their interpretation of the data.

Science and Religion: Their Sources

One important difference between science and the Bible is the source of their information. The Bible claims that God has seen all of earth history, has taken the responsibility to communicate to us through the Bible, and supports the trustworthiness of that communication. If the evidence has led us to have confidence in this claim, we have a strong reason to take the Christian worldview as a unit—to accept it as a whole. The more confidence (faith) we come to have in the Person—not just the book, but the Being behind the book—who is communicating to us, the more that faith carries us beyond what can be tested and gives us confidence in the parts of the worldview we cannot test. Knowing God as a personal friend may not seem pertinent to understanding science, but that individual confidence in God as a trustworthy, all-knowing, personal Being is the basis for trust in the Bible as a reliable source of information. We must continue study of the Scriptures realizing that we do not always understand the sacred documents correctly but knowing that God has taken the initiative to communicate with us.

In contrast, formulation of scientific theories is a very human process. There is no god who developed the scientific theory and has taken it upon himself to communicate it to us. Scientists would not ever want to claim that the significant aspects of a theory or paradigm must be either all right or all wrong. They would recognize that a theory may be partly right and partly wrong.

The Biblical Contribution to Origins and Early History

Because faith is built on evidence, let us apply that concept more specifically. Does any evidence lead us to take seriously the first books of the Bible, including the creation story? Tangible evidence exists in the earliest books of the Bible for intelligent, well-informed communication from a source outside the human race.

Creation/Flood Myths and the Genesis Account

In addition to the book of Genesis, other stories are found in the ancient world about creation and the flood. These include Enuma Elish, the Atra-Hasis Epic, and the Gilgamesh Epic. When these myths are compared with the Genesis account, many similar ideas appear. One of note is that a hero survives the flood. These parallel tales lead some scholars to the conclusion that the Bible account is borrowed from these other sources.

Does the evidence really point to that conclusion? If we use the same methods to compare two politicians of opposite political persuasions, we can perhaps find many similar motifs in their political philosophy. What does that tell us? In science, we must be careful to use the right logic, and it is also important here, so we won't be led astray. The two politicians both likely believe in democracy and hold other ideas in common. If we then follow the same logic that has been used in the study of creation/flood stories, we would reach the conclusion that these two politicians were from the same political mold. But there is a fundamental flaw in that logic—it only considers data that show similarities between the two. That introduces a serious bias into the study. If we want to make a valid comparison, we must also look at differences and compare them with the similarities.

Gerhard Hasel[2] and William Shea[3] have examined the creation/flood stories looking for differences as well as similarities and have found some helpful things. Genesis is monotheistic, in stark contrast to the other accounts. In Genesis, humankind was made in God's image and the earth was made for humanity's benefit. In the Babylonian creation myth (Enuma Elish), a battle is waged between the gods. Finally, the god Marduk killed the goddess Tiamat, split her body in half, and made the earth and heaven out of the two halves of her body. The god Ea then made human beings from the blood flowing from the primeval monster Kingu. In this account, the creation of life occurred after a struggle between the gods so that humanity could carry out the gods' onerous tasks.

In the Atra-Hasis Epic, the god Enlil forced the younger gods to dig rivers and canals. When they finally rebelled, the problem was solved by creating human beings to do the work. Humans were made from clay and the blood of a sacrificed god, We-ila.[4]

In these near-eastern creation stories, matter is the source of life and even the gods arise from physical matter. The principal activity is in the realm of the gods, and earthly events are merely reflections of events in the realm of the gods. In the Bible account, humans are beings with dignity created in the image of God and given dominion over the earth. God controls matter and is independent of it. In the Bible account, the activity is centered on the earth, not in the realm of the gods.

Genesis does not follow the religious themes of the other stories. Instead, it deliberately speaks out against the pagan religions of Moses's time.[5] For example, the Genesis account does not give the sun and the moon names (they are called the greater and lesser lights). This may have been done to avoid giving them any measure of respect, since other cultures worshiped them. The Bible creation story is unique and does not follow the ideas present in the other concurrent creation stories. "Genesis reveals insights that run counter to the culture and thought patterns of the ancients. . . . A document so out of keeping with surrounding culture could hardly have been created by those cultures."[6]

Important parallels between these various accounts are described by Shea.[7] The similarities support the implication that the different accounts trace back to an actual series of events. The possibility that the biblical account is more accurate should be considered.

Critics of creationism often claim that Genesis 1 and Genesis 2 give two different, conflicting accounts of creation. This is commonly cited as an argument against interpreting them as history. In Genesis 1, the plants are created, then the animals, and then humans. Genesis 2 appears to have humans created, then the plants, and then the animals. Reading the accounts may appear to support that claim, but careful study shows that the two chapters are actually a coordinated account, with Genesis 2 elaborating on one aspect of Genesis 1.[8] Study of the original usage of Hebrew words indicates that the description of the origin of plants in chapter 2 is speaking of a time before the existence of agricultural plants, weeds, rain, and farming—that is, before the fall of man into sin, not of the general creation of plants. Thus the order of events in chapter 2 does not contradict chapter 1.

Shea[9] and Hasel[10] have analyzed the literary structure of these chapters and found strong evidence pointing to a unity in their structure that argues for a single author. Genesis 2 focuses the discussion on the creation of man and woman and expands on the brief account in chapter 1. Genesis 2 can be interpreted as complementing chapter 1 rather than contradicting it. The concise list of the events of creation week in Genesis 1 provides the context for Genesis 2, which brings relationships into the creation account—the personal relationship between Adam and Eve and between them and God. These relationships are the foundation for the rest of the Bible.

Abundant flood legends are found in many cultures.[11] The differences among them tell us that each one has gone through a different history. The similarities revolve around the idea of a catastrophic flood, often focusing on a hero who survives it. Is it realistic to think that local floods in many different countries could have impacted different cultures enough to account for all of these flood legends? Some of these legends are from countries that do not experience significant floods but face other natural disasters. Yet these cultures have flood legends. The similarities in all these legends suggest that they trace their origin to an actual significant event in the distant past that found its way into the legends of all these cultures and is recorded in the Bible. The unique, elegant biblical accounts of the creation and flood stand out from the other stories and deserve consideration of the possibility that these accounts have not experienced a loss of accuracy apparent in the legends.

Moses and Laws of Health

Even though Moses was in a culture quite different from ours, he wrote many fascinating things about health in the early books of the Bible approximately 3,500 years ago, and his insights seem to go beyond the knowledge of his day. Science did not begin to understand germs and molecular biology until the nineteenth century A.D. Louis Pasteur (1822–1895) is credited with discovering bacteria that cause disease. Dr. Ignaz Semmelweis, a physician in Vienna in the 1840s, wondered if some dangerous element was possibly being carried from dead patients to living patients. He encountered strong resistance to his new requirement that physicians and interns wash their hands after performing autopsies on dead patients before going to examine living patients. But he was persistent and discovered that the death rate in his maternity ward dropped dramatically.[12] His experience graphically illustrates the ignorance of humankind toward germs prior to the modern age. In fact, Semmelweis finally lost his job because of resistance to his ideas about what we now call germs.

Moses was educated in Egypt centuries ago. Egypt had a medical textbook that included such medicines as snake oil, cow dung, and ground-up flies.[13] If Moses, who was trained by the Egyptians, had written the Pentateuch (the first five books of the Bible) based on the knowledge of his day, we might expect to find many of these same remedies in the Bible. But what do we find? Moses told the people of Israel that if they would follow the rules they were told, God would not put upon them the diseases He put upon the Egyptians. (That may sound as though God made the Egyptians sick. But probably God just chose not to explain the germ theory to the Israelites. He accepted responsibility without further explanation and just said, "If you do what I say, you will not get these diseases.")

A physician who has studied the health-related laws given to the Israelites has compared them with what we know today.[14] The Israelites were told that anyone who touched a sick or dead person was to be kept out of camp for a period of time and was to go through certain routines of washing with running water. That rule does not make sense unless we understand quarantine, the practice of keeping people with a disease separate so they do not communicate the germs to the rest of the group. The Israelites were given many other rules that would still be considered correct today, especially in a situation with no hospital available.

Could Moses have invented these health laws that just happened to be right? It is unlikely that it happened that way by chance. In our universe, there usually is a cause-and-effect relationship. The instructions given in the early books of the Bible are not based on Egyptian remedies; however, they do include things that suggest some understanding of the germ theory, which the people in Moses's day certainly did not know. This suggests that Moses had external help. Somebody knew what was going on even if it was not at that time defined and described in modern medical and scientific terms.

Some argue that the "books of Moses" were not written by Moses but written later. Even if that argument were correct, it would not change the picture since the people living two thousand years after Moses still did not have a clue as to the real cause of disease.

Jacob's Sheep

One interesting story in Genesis (chapters 30 through 32) concerns Jacob and the problem with his scheming father-in-law. Jacob took care of the sheep and agreed that his father-in-law would get all the pure white sheep, while Jacob would get all the off-colored ones that were striped and spotted. Jacob thought he was very clever and could cause the sheep to have striped or spotted young. In the centuries before modern genetic research, people believed that if a female animal saw a striped object while she was breeding, it would affect her offspring and make them striped. Jacob cut a striped pattern into pieces of wood and put these objects in front of the female sheep at their drinking troughs during the breeding season. Jacob thought this would cause the females to have striped offspring.

This story is sometimes cited as evidence that the Bible teaches erroneous ideas. Anybody who makes that claim did not read far enough—the very intriguing part of the story is in Genesis 31. After Jacob had become quite successful with his sheep, he had a dream. Before we discuss the dream, consider some basics of the genetics of sheep coloration. Modern knowledge of genetics indicates that the unusual characteristics of Jacob's sheep are recessive traits. If a sheep receives a (recessive) gene for spots from one parent and a (dominant) gene for white wool from the other parent, the sheep will be pure white because the dominant gene "overrules" the recessive one. Even though Jacob's father-in-law took all the off-colored sheep out of Jacob's initial flock, some individuals remaining with Jacob would have the recessive gene for nonwhite wool, although there would be no visible evidence of it on the sheep. Since the genes for plain white sheep were genetically dominant, Jacob should have received far fewer sheep than his father-in-law.

Jacob thought the sheep were bearing so many off-colored lambs because of his striped sticks. However, in his dream, God basically told him that he was not as clever as he thought. He was shown that the males mating with the females were striped and streaked. Remember, though, that Jacob's father-in-law had taken away all the males that had any visible evidence of stripes or other recessive traits. As far as Jacob (or anyone else before the nineteenth century A.D.) knew, none of the sheep in Jacob's flock had these characteristics. How would anybody at that time know that the recessive genes for striped coloration were lurking inside of the males doing the mating? The Bible says that God showed him that the ones that were mating were striped and streaked. Someone might argue that we cannot demonstrate that God actually did speak to Jacob or give him that dream, but it really does not matter. The point is that somebody who wrote the story of the dream knew that something invisible was inside those seemingly pure white sheep that made them not all white. Somebody knew that three thousand years before Gregor Mendel did any of the first classic genetics experiments in the late 1800s. That is evidence upon which we can base our faith. If God communicated to Moses about health laws and to Jacob about striped sheep, perhaps it is reasonable to believe He also might have communicated the other concepts found in Genesis.

How Should We Interpret the Bible?

The version of informed intervention presented here is built on the biblical account. Consequently, our study of the relationship between faith and science must consider theological methodology. How should we interpret the Bible and determine its meaning?[15] Are we justified in placing confidence in the Scriptures as a reliable communication from God? Do we believe that the Bible gives reliable information even when it addresses topics outside of theology, such as science and history?[16] These are crucial questions. We have noted some lines of evidence that point in that direction, but many modern theologians would not agree for reasons that have to do with the history of ideas and their philosophical choices. The intellectual movement that produced the philosophy of naturalism in science had a parallel influence in theology.[17] The various views on the nature of the Bible cluster around two diverse positions: the traditional Judeo-Christian view (uses the grammatical-historical method) and a more humanistic view (scientific theology, or encounter theology, which uses the historical-critical method).

In the traditional Judeo-Christian view, God transmits information to the prophet. Then, with the guidance of the Holy Spirit, the prophet communicates this information in his or her own words. The words are the prophet's, but the concepts are from God. Therefore, we can trust them as God's true communication to us. Other parts of the Bible are historical records and other nonprophetic documents, but God through the Holy Spirit has somehow exercised quality control on all of this material.

The other major position had its ultimate origin during the Enlightenment, when theology as well as science came to rely less on authority, became more inductive, and began to deny the supernatural.[18] In this view, the part that God plays was diminished. Humanity became more central in determining the content of the Bible.[19] It is a human-centered theology comparable to naturalism in science. According to this theology, a prophet is impressed in some way to write out his or her thoughts, but God does not speak or communicate ideas to the prophet. The prophet may have an impressive encounter with God or may be inspired by thoughts about God and then communicate these feelings in the form of the stories in the Bible, but the ideas in those stories are his or her own. This approach interprets the Bible as only a series of confessions of faith by its writers. The *a priori* denial of supernatural intervention in history (including the origin of the Bible) is exemplified by the theologian Rudolf Bultmann who said, "The continuum of historical happenings cannot be rent by the interference of supernatural, transcendent powers and that therefore there is no 'miracle' in this sense of the word."[20] If we accept this position, we would likely see science, not the Bible, as our best source of truth, even about religion, since the Bible only tells us that the writers had great faith in a "god." It does not contain communication of information from that god. Other views doubt whether god exists at all.

Consider an example that compares these two theological methods. According to the Bible, Moses met with God on the mountain and received the Ten Commandments. The traditional view is that they are the actual words of God, written with "the finger of God" in tables of stone (Ex. 31:18, NIV); consequently, they are as important for us as they were for Moses. In contrast, humanistic theology says that Moses met with God, opened up to God, and was deeply impressed by this experience. He then went his way and wrote something that expressed what he felt in that experience. The result was the Ten Commandments, but they were not given by God. Under this interpretation, nothing is binding to us unless we have the same experience as the Bible writers.

There is a great difference between these two points of view and where they lead us. Even in more conservative denominations, people struggle over which of these approaches should govern church belief and practice. It is important that we think these things through and understand what we believe. When we find a fork in a road, we have to decide which way to turn. The two roads initially may not look much different, but they can lead to very different places.

In logic and in theology, we also encounter forks in the road; the two theological roads may lead to two very different conclusions. The traditional Judeo-Christian view is a God-centered view. God is the standard, and the Bible is an authoritative document.[21] In the humanistic approach, God is not the standard and the Bible is not authoritative. It is only another human book containing myths, legends, and other literature.[22]

Once, a friend of mine observed that the key difference between religious conservatives and liberals is a matter of authority. The liberal says the Bible is not authoritative, while the conservative says it is. I responded that if the Bible is not authoritative, then the standard for all religious truth for a Christian is a person's own mind. His response was, "That is true, but that is all we have." This illustrates very well the naturalistic approach to theology. In this point of view, science, not the Bible, brings us truth (even in religion), and the Bible is not authoritative for religious belief and practice. On these issues, our critical thinking is needed, but it is only reliable if God's Word is taken as our guide.

A few years ago, a theologian told about his experience with his teachers in Europe. One, a prominent German theologian, was asked by his students what he thought about the resurrection of Jesus Christ. He avoided this question but, when finally pinned down, said, "The fact is, Jesus' disciples were intelligent enough to know that there is no such thing as physical resurrection. Their stories of the resurrection as told in the Bible were included to convey the thought that He is always with us."

That response implies that religion is only an emotional experience having no reliable information or inherent truth. Scripture contains some allegory and symbolism, but if the humanistic approach to theology is correct, then the basic Christian story from creation to redemption to restoration consists of stories that in reality are only fairy tales to encourage us to have the same faith in God as the writers had. But do fairy tales help us have confidence in God? What are we expected to have confidence in? If the Bible writers wrote a collection of stories that are false, are we supposed to be impressed?

The Bible writers repeatedly stated that God spoke to them. According to their own claims, they were not just inspired in an emotional sense; they were spoken to.[23] If those claims are false, then these writers were nothing more than frauds. On the other hand, if their claim that the Bible is authoritative is true, we would be wise to take it seriously. Since God is infinitely more knowledgeable than human beings, the revelation of God in the Bible is a superior source of information. The Bible is not a scientific textbook in the sense of giving exhaustive scientific information, but where the Bible does give scientific information, that information is accurate.[24] "Whenever biblical information impinges on matters of history, age of the earth, origins, etc.," as well as theology, it gives us trustworthy information.[25] The choices that we make in interpreting the Bible are of great significance.

Biblical Anchor Points

We are convinced that there are abundant reasons for accepting the Bible as an authoritative, inspired book and believing that the events in Genesis were literal events. Perhaps you will also find this a useful concept. The rest of this book will show how this view can be applied to the study of the history of life on earth. The following is our list of biblical anchor points underlying the understanding of origins presented here:

1. There was a literal creation week of seven consecutive, approximately-twenty-four-hour days. During this time, the earth's surface was prepared and living things were created.[26]
2. At the end of creation week, the earth contained a variety of plants and animals, including

invertebrates, fish, reptiles, mammals, birds, and trees, including at least some that are considered to be the more "highly evolved" types such as humans and fruit trees (angiosperms; Gen. 1).

3. The original created earth did not contain evil.[27] After humans sinned, the biological world began to change (Gen. 3:14–19). Scripture as a whole presents the picture that evil, war, destruction, lies, and disease resulted from the influence of a literal devil (Satan) who rebelled against God. Thorns and thistles began to appear, and murder and strife entered the world. God is giving Satan only enough time to demonstrate the results of his system of government so that when this cosmic conflict is over, those who have accepted God's offer of eternal life will never be fooled into rebelling again.
4. The creation week occurred only a few thousand years ago. There are uncertainties about the completeness of genealogical lists and differences between ancient biblical manuscripts.[28] But although we do not know the exact time span, Scripture clearly portrays a short history of life on this earth.[29] Many Bible writers, and Jesus, accepted the creation, the flood, and the early biblical record of human history as accurate.[30]
5. Sometime since the creation there was a literal catastrophic flood of global proportions (2 Peter 3:3–6).[31] Noah and his family and representatives of the terrestrial vertebrates survived in an ark, while the other vertebrate animals died in the flood.
6. Jesus demonstrated in His miracles that God is very capable of instantaneously creating living animal or plant tissue or restarting the biochemical processes in tissue that was no longer living. This is demonstrated in the turning of water to wine (John 2:1–10); creating food to feed several thousand people from a handful of fish and bread (Mark 6:30–44; 8:1–10); raising someone who had been dead for several days, which means

that God created him—his body was too decayed to just restart the engine (John 11:38–44); restoring sight to blind eyes (John 9:1–11); restoring tissue destroyed by leprosy (Luke 17:11–17); and restoring a withered hand (Mark 3:1–6). These demonstrate God's ability to create in the manner described in Genesis 1.

The Relationship between the Bible and Science

Now let us look at the science-and-faith question from a different perspective. If we believe that the Bible does give reliable information in theology, history, and science, which we should weigh carefully, how do science and the Bible relate to each other? If we compare the two and find things that do not seem to fit, must we accept contemporary scientific ideas and reject the Bible or vice versa? Or is there a better way? This section explores the latter question, suggests some answers, and ends with illustrative case studies showing the proper relation between science and religion.

Biblical and scientific information originate through different processes that must be kept in mind as we consider the relationship between them. The Bible claims to be a body of information communicated to us by the God

What does it take to make a living thing?

DATA

The existence of life forms. Life is so complex that it continues to defy our efforts to adequately understand it.

INTERPRETATION

Interventionism: The beginning of life requires a plan and a mechanism to put the plan into effect. We don't create life, but Jesus's miracles demonstrate that God is able—has a mechanism—to instantly create living tissue.

Naturalism: Is there a naturalistic mechanism to make life? This is the topic of future chapters.

who has acted in the history and workings of our planet and of life. This communication is in a book completed nearly two thousand years ago and written in Hebrew and Greek. Our task is to see beyond the linguistic and cultural differences expressed in the Bible and to understand its message. Then we have to decide if we are willing to trust the biblical message. Careful study of the culture and usage of words and expressions in Bible times helps us correctly understand the Bible.[32]

Because the Bible claims full inspiration by the same God for all portions of Scripture (2 Tim. 3:16), the message it contains is a unity. Thus one portion of Scripture can be better understood by comparing it to other portions that deal with the same subject—the Protestant Reformation principle of Scripture as its own interpreter. This position is the one adopted here.

Science, in contrast, is an ongoing, open-ended human search for understanding of the physical universe. It utilizes observation, experiment, and analysis to test the validity of human ideas and to help us think of new hypotheses. Science does not claim but, in fact, vigorously rejects the notion that any of its conclusions has divine authority. The Bible claims authority; science inspires confidence by its success but does not claim "authority"—its claims are always subject to revision when required by new data.

Science is a slow process. It has many human limitations, especially in study of origins, but it still is a very effective way of discovering truth. We often do not have enough data to be certain of the correct scientific explanation or theory, but even then, the data help eliminate some of the incorrect theories. Accumulating new data enables scientists to develop new theories that they had not thought of before. These new theories may be stepping stones to even better theories, or they may stand the test of time and turn out to be correct (fig. 6.1). For example, a normally graded bed of sediment is one that begins with larger particles at the bottom and grades upward to smaller particles at the top. Prior to 1950, sedimentary rocks composed of coarse-grained, graded beds (fig. 6.2) were believed to have been deposited slowly in shallow water. For instance, some Pliocene (a relatively recent geological time period) rocks in the Ventura Basin, near Ventura, California, consist of hundreds of graded beds. The evidence was interpreted to indicate that it took several to many years to deposit each layer in shallow water.[33] Then in 1950, a published paper reported the discovery of a previously unknown phenomenon—turbidity currents.[34] Turbidity currents are rapid underwater mudflows that can deposit a layer of sediment over a large area. The layers produced by turbidity currents are called turbidites, and they commonly include graded beds.

Turbidity currents provided an even more satisfactory explanation for the graded beds in the Ventura Basin, and the entire sequence of layers was reinterpreted as a series of turbidites.[35] Each graded bed was now understood to have been deposited in minutes rather than years and in deeper water. This paradigm shift (fig. 6.3) was brought about by the accumulation of new data and the discovery of previously unknown processes. It resulted in a revolutionary change in the way sedimentologists viewed such rock layers.

Many such changes have occurred in the history of science, and undoubtedly, many more will occur as new discoveries are made, some of which will be related to phenomena we have not yet dreamed of. Science is always

Figure 6.1. A diagrammatic representation of the relationship between theories and data. In this diagram and in figure 6.3, the height of the stippled area at any given date represents the amount of data available at that time. Horizontal lines represent the life span of various theories. A theory's life span ends by "collision" with accumulating evidence that contradicts the theory or by radical alteration (a scientific revolution, represented by a vertical line in fig. 6.3) into a new theory that is not contradicted by the available evidence. Figure by Leonard Brand.

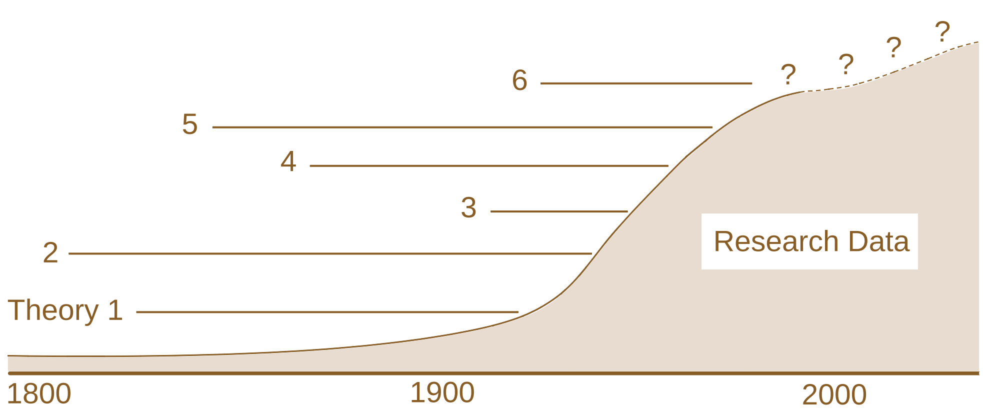


Figure 6.2. A cross-section through three graded sedimentary beds. In each bed, the larger particles are at the bottom, and the smaller particles at the top. Courtesy of Mark Ford.

a progress report on the road to truth; it is not final, absolute truth. In contrast, the Bible claims to deal with propositional truth originating with the God who has seen all and understands all of earth history and all natural laws. Each scientist must decide how much confidence to place in the Bible and to what extent science can "correct" the Bible or the Bible can shed light on science.

Some of the many possible approaches to the relationship between science and Bible-oriented religion are illustrated by the partial list in table 6.1. Models 1 and 5 represent the easiest ways to decide. They are essentially all-or-nothing approaches and do not require much careful thought on questions of the relationship between science and faith. Neither position realistically offers a way to incorporate the best of science and of religion.

Model 2, keeping science and religious faith separate, is a popular model and superficially seems attractive.[36] It even may work for a scientist whose field of inquiry does not require much thought about the history of life on earth. However, what do Bible-believing advocates of this model do when they encounter a biblical statement that contradicts the conclusions of science? When faced

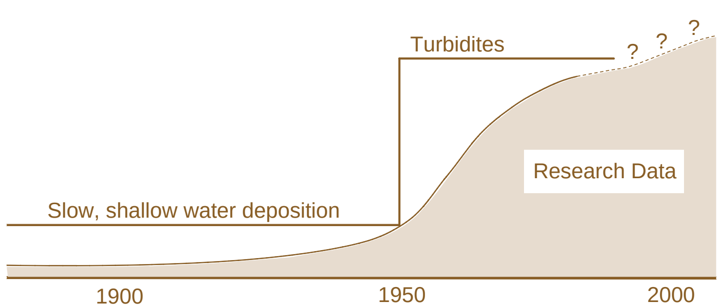


Figure 6.3. A diagrammatic representation of the change from the shallow water theory of graded bed deposition to the turbidite theory. This change occurred through a scientific revolution stimulated by the accumulation of new data. Figure by Leonard Brand.

Table 6.1. Several of the possible relationships between science and the Bible

1. Science is the only reliable source of information. The Bible may contain inspirational religious concepts, but these are only relative and allegorical. The Bible is not a source of reliable facts. The person who accepts this view reinterprets or disclaims anything in the Bible that conflicts with current scientific interpretations.
2. Science and religious faith should be kept separate. The Bible is taken more seriously than in model 1, but science and biblical faith are kept in two separate compartments, and no attempt is made to relate one to the other.
3. The dualist recognizes a type of authority in both the Bible and science and takes both sources seriously in the search for truth. Conflict between the two arises only because of human limitations in the scientific process and/or in our understanding of the Bible.
4. Science and the Bible are both taken seriously, but the Bible is granted a higher level of authority than science.
5. Only the Bible is accepted as reliable. This extreme view tends to reject all of science as a tool of the devil, designed by him to destroy faith.

Loosely adapted from Watts 1976.

with such a contradiction, Christian scientists can no longer keep the two sources in separate compartments. Then, even though they may not realize it or may even deny it, they move from model 2 to one of the other models. Consequently, model 2 has failed at the very point where we need a model to help direct our search for truth. A number of different models can work equally well in areas where science and the Bible do not conflict. It is when conflict arises that the relationship between the two sources of information becomes significant. Model 2 merely avoids the issue or pretends that it does not exist, which renders this model unworthy of further discussion.

Many authors strongly disagree with this conclusion. They maintain that science and religion should be kept separate, and/or that they do not conflict even in theories of origin—they simply deal with different aspects of these questions. Careful study of their approach convinces us that they are in fact working within model 1, not 2, and that their approach assumes that science provides facts and the Bible only provides inspirational material or some vague spiritual meaning.

Worldviews

An adequate understanding of the scientific facts and biblical spiritual meaning described above requires a comparison between worldviews.[37] A worldview is a person's way of thinking about the world; how they see the things around them. In 1990, one of us (Brand) needed a new four wheel drive vehicle. I studied car magazines and learned about a fairly new SUV—the Ford Explorer. I had never seen one, but the magazine descriptions looked promising. After more reading and a test drive, I bought an Explorer. Driving it on the highway, I saw other Explorers; they were fairly common. Why had I never seen one before? How could I have been so blind? New information and experience had changed a small part of my worldview—I saw things I had never noticed before!

There were other vehicles on the roads that I knew were called Toyotas. To me they were just objects I had to sometimes go past to get where I wanted to go, as fast as I wanted to go. But after more reading about things like quality, reliability, durability, and repair records of different makes of cars I gained a new respect for Toyotas. Watching a Toyota Forerunner on the highway I had a sense of respect and also longing—I would like to have one of those. Another small part of my worldview had changed. New insights had changed a part of my sense of values, and I saw some things different than before.

I knew about Jesus Christ since childhood, but finally, an internal longing led me to learn more about Him and discover what a wonderful friend and guide He was. That new insight and commitment changed a major part of my worldview, and now nothing was the same. My values had changed, and I saw and understood life and the world differently. I saw things I had not noticed before. It even opened my eyes to see things in science that were not noticed before.

It is often assumed that religion gives subjective, prejudiced views, while a secular scientific approach provides theories and explanations that are unbiased and neutral, not affected by religious assumptions. In other words, secular science has facts, while religion has assumptions. This has led to a two-level understanding of "truth."

Religion—personal, subjective values, emotions (heart)

Science—public, objective, reliable facts (mind)

But the two-level view of truth is unrealistic at its very core. There is no such thing as a neutral search for truth. Both secular science and religious views are based on a worldview, a set of assumptions that influences everything. A Christian worldview recognizes that the Bible is a trustworthy basis for an integrated view of the world, a "biblically informed perspective on all reality"[38] that does not separate religion from the rest of experience and knowledge.

A secular worldview introduces its own biases into the search for understanding and is no more neutral than religion. Either worldview can form a basis for the search for truth, but they will lead in very different directions. The Christian worldview is based on the truth of the central events of biblical history: creation, fall, redemption, and restoration (the Great Controversy between Christ and Satan). Commitment to this set of truths forms the foundation for an integration of all knowledge, not just religious knowledge.

The book you are now reading is the application of just such a Christian worldview in understanding origins. Of course, any worldview can use assumptions in a way that hinders an honest search for truth. A naturalistic worldview, by its very nature, disallows an objective study of origins. The goal here is to show how the Christian worldview can function effectively and objectively. We do not need to fear data and honest research. We predict that since the Christian worldview is based on truth, its careful application will ultimately lead to the most accurate scientific and biblical understanding of origins.

A debate between the leading Christian philosopher Alvin Plantinga and outspoken atheist philosopher Daniel

Dennett is written up in the book *Science and Religion: Are They Compatible?*[39] Dennett's responses to Plantinga are instructive because it is evident that he had nothing intellectually meaningful or credible to say, except to someone captivated by the naturalistic worldview. He relied on ridicule and arrogance.

The most fruitful approach to the study of origins and of earth history is found between models 3 and 4 in table 6.1, which take both the Bible and science seriously. One of the most crucial features of either model is its definition of the steps to be taken in resolving conflicts that arise between our interpretation of revelation and our interpretation of scientific data, within a fully Christian worldview. The remainder of this chapter proposes an approach to resolving such conflicts.

Science and Revelation: A Working Relationship

Within Christianity, many different attitudes are held toward the authority of the Scriptures. This study is built on the conviction that many lines of evidence indicate that the Bible writers speak for a loving and all-knowing God who can be trusted and in whose prophetic and historical messages we can have confidence. If this is true, ultimately no conflict will remain between science and revelation when we correctly understand both. Within such a framework, an effective working relationship between science and revelation can result if we utilize the following process:

1. The accumulating data from scientific research continue to suggest new ideas or hypotheses that we might not have thought of if the research had not been done. In this process, science sometimes challenges us to examine our beliefs more closely.
2. When a new idea involves a subject concerning which the Bible speaks, we must examine all relevant biblical passages, comparing Scripture with Scripture, using the Bible as its own interpreter. In

doing so, it is important to make use of all the latest information that helps us reach a correct understanding of the original meaning of the words used in the biblical manuscripts. In this way, we attempt to understand exactly what the Bible does or does not say about our new idea. Is the idea compatible with the Bible? Do the relevant Bible statements say what we think they say, or are we incorrectly reading something between the lines?

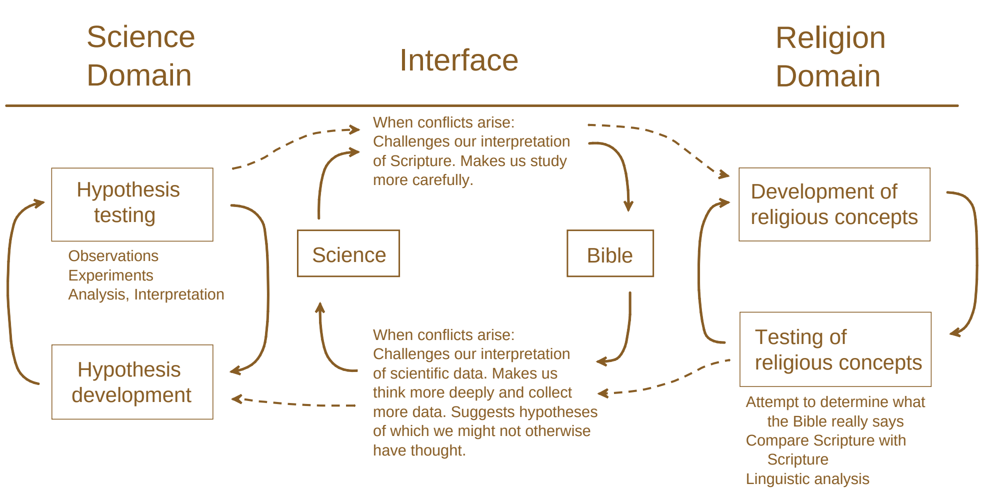
3. Next, we can make one of the following decisions or an appropriate variation of one of them:
   a. It is evident that revelation does not speak to this issue at all and does not help us in our research.
   b. Revelation addresses this topic but does not conflict with the new idea. No biblical reason indicates that we should not accept it as a valid possibility. We can then proceed with scientific research to rigorously test it. This research may give us more confidence in the idea, or it may lead to better hypotheses, which also need to be compared with the Scriptures.
   c. Our study indicates that revelation clearly contradicts the new scientific idea, thus challenging our scientific conclusions and telling us to go back and do some more research because something is wrong with our interpretation of the data.

If we follow this process, the Bible is maintained as the standard for religious doctrines and for areas for which the Bible makes claims in natural history. Yet science and the Bible continue to shed light on each other. Science suggests ideas that may help us recognize that we have been reading some preconceived ideas into the Bible. In other cases, the Bible can help us recognize incorrect scientific theories so we can turn our efforts toward developing more accurate interpretations of the data. This can result in an ongoing feedback process in the interface between science and religion that challenges us to dig deeper in both areas (fig. 6.4).

At this point, we must remind ourselves not to let our religious views twist our interpretation of scientific data (see chapter 5). A Christian does not need to fear good data. We may indeed struggle with seeming conflicts because of limits in our available data and our interpretations, but ultimately genuine truth will not contradict itself.

Still we must ask how science can be an open-ended and open-minded search for truth if we adopt the view that "whenever biblical information impinges on matters of history, age of the earth, origins, etc., the data observed must be interpreted and reconstructed in view of this superior divine revelation which is supremely embodied in the Bible."[40] Would we reject a scientific idea on scriptural grounds alone? The answer requires a correct understanding of the domains in figure 6.4. The processes occurring in the scientific and religious domains are different and cannot be interchanged. Scientific experiments are not a basis for testing divinely inspired scriptural statements. Science does not test its conclusions by linguistic analysis and "comparing scripture with scripture." The interaction between them occurs in the thinking process, called here "the interface," where we allow scripture and science to continually challenge each other and challenge us to more carefully examine our understanding of each of them.

Figure 6.4. An approach to the relationship between science and religion that provides constructive interaction between them, without inappropriate interference of one with the other. Figure by Leonard Brand.



This can be illustrated with a study of a hypothetical rock formation, the Redbluff Formation, with its abundant fossils. A careful scientific study of the Redbluff Formation might conclude that "the scientific data indicate at least a ten-million-year timeframe for the accumulation of this formation, but this time period is not correct because the Bible contradicts that conclusion." Such a statement is not scientific and, perhaps, is not even a good religious statement. It is a confusing statement! Another approach is to conclude that "the scientific data currently available are most consistent with a ten-million-year period of deposition for the Redbluff Formation (scientific domain), but study of Scripture (religion domain) leads us to predict (interface) that additional geological discoveries await us that will indicate a rapid, catastrophic origin for the Redbluff." That is an entirely valid, honest statement. It cannot be criticized for improperly mixing science and religion. The honest, probing attitude indicated by that statement, if combined with the scientific quality-control process (chapter 5), could stimulate a more careful geological restudy of the Redbluff Formation as well as more careful study of Scripture that might otherwise not have been done. In the meantime, if we truly have confidence in God's communication, we will be comfortable living with unanswered questions.

We have concluded that keeping science and religion separate is not a valid approach. That conclusion can now be refined to include the concepts in figure 6.4. There is a procedural sense in which science and religion are separate. The two use different methods. The second of the two statements about the Redbluff Formation illustrates the sense in which science and religion must be kept "separate," or at least not be confused. The thinking process, called "the interface" here (fig. 6.4), allows interaction between science and religion without confusion. As we evaluate such a challenge between science and religion, we keep clearly in mind where each idea comes from, how it can stimulate more careful study, and whether an idea is a conclusion based on mutually supportive evidence or whether it is a hypothesis or a prediction yet to be verified.

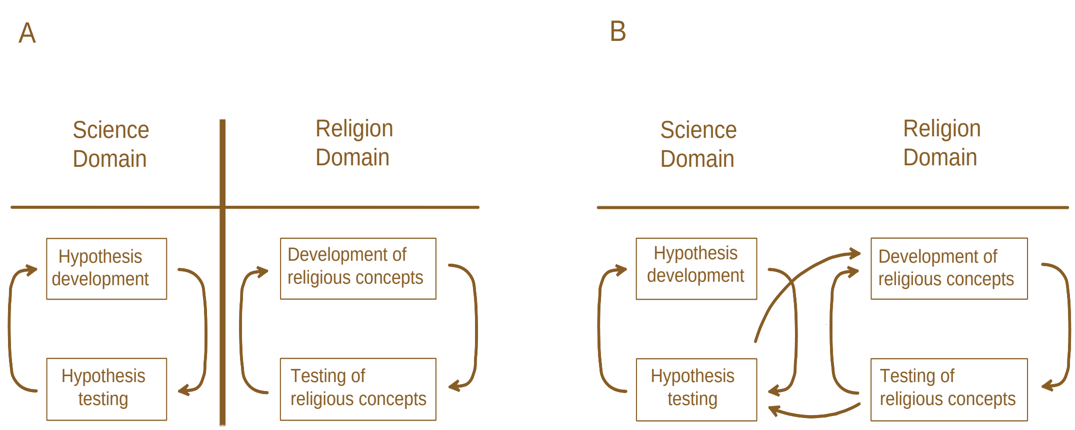
Figure 6.5 illustrates two inappropriate ways in which some individuals try to keep science and religion separate. Method A suffers the problems discussed earlier—it cannot deal with questions of origins without being schizophrenic. Method B is the same as model 1 in table 6.1. It does not actually keep science and religion separate, but tests Bible statements by external, scientific criteria.

The interface in figure 6.4 is the key to an honest and productive interaction between science and religion. It is the secret for granting science a constructive degree of autonomy, while science and religion each challenge us to study the other more carefully. Religious ideas can even lead to hypotheses that can be tested by scientific research. But neither religion nor science controls the other. This approach to the relation between science and faith is not just a theoretical idea. Some of us have been using it for years and find it both effective and practical in leading to productive scientific research (see the list of research projects in chapter 19).

Why Would God Intervene in Earth History?

Beyond the creation of life at the beginning, why might God intervene in history? According to our understanding of salvation history in the Bible, one important reason for God to take such action is to deal with difficult

Figure 6.5. Two ineffective ways to try to keep science and religion separate. (A) Keep the two in separate "compartments" and not try to analyze how they interact. (B) Science determines facts, and religion provides spiritual meaning. In this approach, science actually becomes the standard for evaluating religious concepts. Figure by Leonard Brand.



contingencies that arose because rebellious created beings abused the free will that God gave them. In other words, God has to take special actions to deal with the problem of sin and evil. When sin and violence came to dominate the lives of almost all humans in a once-perfect world, God changed the course of events with a worldwide catastrophic flood. This drastic action was the alternative to allowing Satan to dominate the entire human race. Then when the time came for a conclusive action to decide the outcome of the Great Controversy between Christ and the rebel Satan, Jesus lived on earth and daily changed the course of events as He healed the sick and raised the dead, including Himself.

Another of God's miracles has been His communication with the prophets and other messengers who provided the Scriptures. There is nothing mysterious or contrary to the laws of nature about that process. In this electronic age, we have learned many ways to communicate with someone without being there in person. Perhaps God or an angel, in a state of matter invisible to us, whispered in someone's ear. There is no need to break any natural laws for this to be possible. God just intervened in history. Humans also intervene in history as intelligent beings who can take action and change the course of events. Hitler did that with disastrous results. Martin Luther did it and strengthened the influence of Scripture. To understand God, we have to grasp the concept that He is a personal Being who loves us in the same way we can love each other, who can decide what is best for us and then acts, using His vast range of laws of nature to accomplish His will.

CHAPTER 7

The Origin of Life

Overview

The naturalistic theory of abiogenesis proposes that the first living cells were not created by an intelligent designer but resulted from random interactions between molecules over eons of time. Innumerable, highly improbable biochemical steps would be necessary in this process. The ideas and research behind the abiogenesis theory are described along with the seemingly prohibitive challenges that it faces. Two biomolecular "machines," or organelles, in the cell are described to provide insights into just how complex a cell is. Since there is so far virtually no evidence to support the theory of abiogenesis, it is necessarily intertwined with the philosophy of methodological naturalism (MN). This relationship is discussed, along with the reasons abiogenesis needs MN and MN needs abiogenesis.

The Complexity of Cells

Cells are the simplest element of living things, and they compose all complex organisms. Yet every cell is exceedingly complex. All living cells share in common many features that are fundamental to life. These include the information-rich DNA, the proteins necessary for copying the DNA and translating the DNA information into different types of RNAs, and the mechanism of protein synthesis involving the ribosome, the RNAs, the hundreds of enzymes to compose the correct amino acids into a protein following the pattern in the RNA, the cell membrane, and the metabolic machinery to accomplish all the above reactions.

Naturalists could perhaps argue that the first living cell did not need to carry out all the activities of even the simplest modern living cell. In that case, we must decide what features can be eliminated and allow the cell to still survive. We must then explain how these eliminated features arose later in the process of chemical evolution (abiogenesis) and why they are common to all cells. We will say more about this later, but for now, let us take a look at the system proposed by naturalists to have given rise to the first cell.

Chemical Evolution

In the 1920s, J. B. S. Haldane and A. I. Oparin independently suggested that life had originated spontaneously from nonliving matter on the earth's surface in the distant past and provided a scenario for its occurrence. At that time, life was viewed as nothing more than complicated chemistry, so their ideas became widely accepted among those seeking to establish a naturalistic origin for life on the earth.[1]

In 1953, Stanley Miller did his now-famous experiments using Oparin's reducing environment of methane, ammonia, water, and hydrogen gas in a glass apparatus with sparks to energize the reaction. The reducing atmosphere was essential because free oxygen will destroy any organic molecule. The reaction generated a variety of simple compounds including a few amino acids, as well as a quantity of "tar" (organic sludge incompatible with abiogenesis). Later, purines and pyrimidines, bases contained in DNA and RNA, were reported to have been made by a similar process.[2]

At present, fourteen of the twenty amino acids needed by living cells can be made under the reducing conditions proposed to exist on the "primitive earth." Unfortunately, the preponderance of the amino acids produced by these experiments is either glycine or alanine, the two simplest amino acids, and many other molecules that will interfere with any biochemical reaction. Many other problems exist, but no matter how unsatisfactory it may be, these early experiments have encouraged MN believers to think the process can explain the origin of life.

After considering the modern speculations on the origin of life, we will attempt to evaluate these speculations within the parameters the investigators have set for themselves, to see what hope they offer of achieving the end intended—that is, explaining the spontaneous origin of a living cell.

We will begin by considering the earth's early atmosphere and the likelihood that it could generate an ocean full of biologically useful molecules. Then we will consider whether the biologically important polymers needed for life could be produced, given an ocean full of small molecules. We will then ask whether it is even possible to make a living cell and investigate some significant areas of molecular biology to identify the complexity a living system entails.

Evidence for a Reducing Atmosphere

Oparin first suggested a reducing atmosphere for the "primitive earth," since the necessary biological molecules could not form in an atmosphere containing oxygen. The real question is, did such an atmosphere ever exist on the earth? A careful analysis from geological, cosmological, and chemical viewpoints reveals that such a reducing atmosphere, if it ever existed, would have been short-lived. J. C. G. Walker stated that the main reason for considering the possible existence of a reducing atmosphere is because it is required for the spontaneous origin of life.[3] But Philip Abelson[4] and J. W. Schopf[5] concluded there was no evidence for the existence of a methane-ammonia atmosphere.

Since the Apollo 16 flight, it has been recognized that UV-induced decomposition of water in the upper atmosphere is a major source of free atmospheric oxygen. It seems that this process would prevent a long-term existence of an atmosphere without free oxygen. An analysis of earliest Precambrian sedimentary rocks seems to indicate that free oxygen was present, perhaps at levels similar to ours today.[6]

These findings and others that argue against a reducing atmosphere have been accumulating over the past twenty years. It appears that the gasses in our atmosphere have come from outgassing of the mantle, and such gasses today are uniformly oxidized. Because of these issues, many who in the past considered a reducing atmosphere an absolute requirement are reconsidering this. Some propose that a neutral atmosphere (Carbon dioxide, water, nitrogen gas, and possibly a trace of hydrogen gas) is more likely,[7] but this atmosphere would soon contain oxygen. Such a prospect does not appear to have dimmed the enthusiasm of most origin of life researchers appreciably, even though the presence of free oxygen precludes virtually all scenarios thus far proposed for abiogenesis of living forms, and at present, such an atmosphere appears a virtual certainty.

Evidence for the "Chicken Soup"

The Oparin-Haldane scenario requires the production of a "dilute soup," an ocean full of small biological precursor molecules, within which life could begin. A number of careful analyses have left gaping holes in the possible existence of this "dilute soup" on the primeval earth. They[8] have all concluded that the concentration of even the most abundant amino acids would not have exceeded .0001 gram per liter, much too dilute to be involved in

Reducing atmosphere on primitive earth?

DATA

Abiogenesis requires a reducing atmosphere for the necessary chemical reactions to occur. Geological evidence indicates there probably was no reducing atmosphere.

INTERPRETATION

Abiogenesis: This assumes naturalism and concludes that life began without an intelligent designer. This conclusion is required by the assumption. Life cannot arise under present conditions on earth. We don't know how life arose; it is a mystery.

Interventionism: Inference to the best interpretation results in the conclusion that life was created by an intelligent designer.

polymeric reactions required to make proteins.[9] In the mid-Atlantic, these concentrations presently range between .00001 and .0001 grams per liter!

Numerous authors support the absence of the "hot dilute soup."[10] Although most of these scientists probably subscribe to some sort of chemical origin of life, all conclude there is no evidence the process ever occurred. In spite of this, an equal number of authors regard the origin of life scenario as so well established that it needs no justification!

Thus far, we have only dealt with the production of small molecules. We have concluded that the earth did not have a reducing atmosphere, and that even if it did, there is no chance that it could give rise to the ocean full of small molecules necessary to make the first cell by abiogenesis. But for the sake of argument, let us grant the existence of an ocean full of small molecules and see what can be done with it.

The Production of Information-Rich Molecules

Given an ocean full of small molecules, as described above, we must next approach the question of polymerization—the combining of the small molecules into macromolecules like proteins and nucleic acids (DNA and RNA). This question poses a two-edged sword: first, to demonstrate that macromolecule synthesis is possible under abiotic conditions, then to show how these molecules could become so rich in the information necessary for living cells. We shall deal with these separately.

The synthesis of proteins and nucleic acids from small molecule precursors represents one of the most difficult challenges to the model of abiogenesis, in any proposal. Polymerization is a reaction in which water is a product. Thus it will only be favored in the absence of water. The presence of small molecules in an ocean of water favors breakdown of any large molecules that might be formed. Careful experiments indicate that even in an ocean containing a 1 molar solution of each amino acid (one million times higher concentration than in the mid-Atlantic today) a protein containing just 101 amino acids would reach a concentration at equilibrium of only 10^{-338} molar.

Just to make this number meaningful, our universe may have a volume somewhere in the neighborhood of 10^{85} liters. At 10^{-338} molar, we would need an ocean with a volume equal to 10^{229} universes just to find a single molecule of any protein with one hundred peptide bonds. So we must look elsewhere for a mechanism to produce polymers. It will not happen in the ocean.

Sidney Fox, an amino acid chemist and one of my (Chadwick) professors in graduate school, recognized the problem and set about constructing an alternative in the absence of water. Fox attempted to promote peptide bond formation by melting pure crystalline amino acids and driving off water from the mix. But the result was a tarry product long before they melted. After many tries, he discovered two of the twenty amino acids, aspartic and glutamic acid, would melt to a liquid at about 200 °C. Then dissolving the other amino acids in the liquid produced a melt containing up to 50 percent of the remaining eighteen amino acids. This constituted his proteinoids, which Fox likened to cells.

Fox claimed that he had bridged the macromolecule to cell transition. He even tried to demonstrate that a piece of lava rock could substitute for the test tube in proteinoid synthesis and claimed the process took place on the primitive earth on the flanks of volcanoes. However, the proteinoids are not proteins. Proteins consist of L-amino acids connected together in specific order by alpha peptide bonds. The bonds in Fox's proteinoids are beta, gamma, and epsilon bonds joining amino acids in nonspecific order. His starting materials were purified L-amino acids in carefully constructed ratios. In the abiotic world, the best starting point one could hope for would be evaporated ocean water containing some amino acids in racemic mixtures with many other molecules that, when heated up, would form useless tar. There are other problems as well.

A number of other approaches to polymerization have been tried. One of the most promising of these is the use of clays as substrates. Clays are very thin, very highly ordered arrays of complex aluminum silicates with numerous other positively charged ions. Such layered clays catalyze the polymerization reactions. The reactants are adsorbed on the clay, which concentrates and protects them from reacting with water. This type of reaction produces polymers of up to fifty units, but only if it starts with energy-rich aminoacyl adenylates rather than amino acids. There is no evidence to indicate that an accumulation of these molecules is likely to occur in a natural environment.

Following the discovery of RNA molecules with autocatalytic properties, some chemists have suggested that life began with RNA rather than proteins. Diligent research has tried to simulate this theorized "RNA world" process, but the chemistry involved does not achieve the necessary result.[11] In addition to the problems of synthesizing the precursors and the polymerization reactions, the whole scheme depends on the ability to synthesize an RNA molecule that can make a copy of itself, a feat that so far has eluded all efforts. RNA molecules fail to perform any function vital to initiating life, and it offers no clue as to how one gets from such a scheme to the DNA-RNA-protein mechanism of all living cells. That is only the beginning of problems. So far talk of an "RNA world" remains just talk.

Investigator Interference and the Theory of the Primitive Earth

In order to be able to evaluate the credibility of various models for the origin of life on their own merits, we have ignored some very significant issues. But now we can no longer ignore these considerations.

In all experimental studies on the origin of life, the presence of the investigator makes a significant contribution to the conclusions and to the conditions of the experiment itself. When the investigator sets out to achieve a certain objective (synthesis of precursors or polymerization of precursors), he or she naturally seeks to define a system with some possibility of achieving the desired end. Thus conditions are chosen in which some of the materials are appropriate for a prebiological earth, giving the studies an air of credibility. The remaining conditions are carefully crafted to achieve the desired end. Thus the reader is left with the impression that many things would have been possible on the prebiological earth that actually have no probability whatsoever.

For example, when Fox performed his experiments to make proteinoids from amino acids using lava rock instead of a glass test tube, he gave the impression that this was a plausible model for the prebiological earth. What he was careful to avoid emphasizing was that he was carrying out the reaction on the hot lava with a mixture of purified crystalline amino acids produced by biological organisms (soy beans) and purified by another biological organism (chemist). He was also himself carefully controlling the temperature and time and exposure to water. As a chemist working in a laboratory, he carefully set up the experiment to produce the result he sought.

The same criticism can be made of every other study mentioned to date, from Miller's original classic study using a mixture of purified gases in a custom glass apparatus to studies on layered clays using purified mixtures of adenylated amino acids. Most of these studies have been designed to obtain a desired outcome, not to test the theory under the conditions that would have existed on the prebiological earth. Yet the results are used to support the validity of the abiogenesis theory they propose. After a careful review of the abiogenic research scene, J. Brooks and G. Shaw concluded, "These experiments . . . claim abiotic synthesis for what has in fact been produced and designed by highly intelligent and very much biotic man."[12]

Such candidness is refreshing, honest, and long overdue. In summary, abiogenesis experiments with a high input of intelligent design have had some success in synthesizing amino acids but consistently fail to synthesize protein, DNA, or RNA. This is not surprising when we consider how simple amino acids are in comparison with protein or DNA/RNA.

The First Living Cells

If a way could be found to make the primeval soup, if there were reactions that could produce proteins and DNA, and if a suitable primitive cell-like structure were to form to hold them together, the correct macromolecules would then have to be combined in precisely the correct structure to produce a living, metabolically active system without being destroyed by multiple natural hazards. Any such primitive cell would have to be capable of sustaining itself by transforming and utilizing energy, growing, and replicating. The process of natural selection would not assist the production of this first cell. Natural selection cannot operate until a reproducing cell is present so that the feedback process of natural selection can eliminate the less fit individuals and thus determine the characteristics that will be present in the genes of the next generation. Consequently, if the first cell formed by abiogenesis, it would have to happen by chance rather than by any form of natural selection.

The Origin of Biological Information in the Cell

The feature that distinguishes living from nonliving systems is not order but complexity of a type called "specified complexity," which will be defined below. Many inanimate structures, such as crystals, have precise order. Crystals are composed of atoms in orderly spatial arrangements—repetitive or periodic sequences of components. In contrast, the sequence of units in proteins and nucleic acids is not at all repetitive or periodic, but the units occur in complex, nonrepetitive arrangements. Just as a sentence makes sense only if the words are in a specific order, the amino acids in a protein must be in a specific order for the protein to be functional. This is an example of "specified complexity." Proteins and nucleic acids are not only nonrepetitive in their structure; they are arranged in a sequence that contains the information necessary for the construction and functioning of the entire living system.

These concepts are summarized by Charles Thaxton and colleagues (illustration used by permission).[13]

1. An ordered (periodic) and therefore specified arrangement:

   THE END THE END
   THE END THE END

   Example: nylon or crystal.

2. A complex (aperiodic) unspecified arrangement:

   AGDCBFE GBAFED ACEDFGB

   Example: random polymers (polypeptides).

3. A complex (aperiodic) specified arrangement (specified complexity):

   THIS SEQUENCE OF LETTERS CONTAINS A MESSAGE!

   Example: DNA or protein.

Any theory of the origin of life must resolve the critical problem of how to originate biological information. The DNA in a cell is like a comprehensive instruction book with all the instructions for the reproduction and functioning of an organism, including instructions for the correct sequence of amino acids in each protein. Biological cells have the machinery to read and carry out those instructions. How did the information coded in the sequence of nucleotides in DNA get there?

Think of a library as containing two fundamentally different types of entities. The first includes the omnipresent natural laws and the materials synthesized through operation of those laws. The law of gravity keeps the books from floating up from their shelves, and specific chemical bonds hold together the iron molecules in the book shelves and the paper molecules in the book pages. These laws can be described in quantitative terms, and their effects are entirely predictable. If we pick up a book and drop it, we don't have to guess whether it will fall up or down.

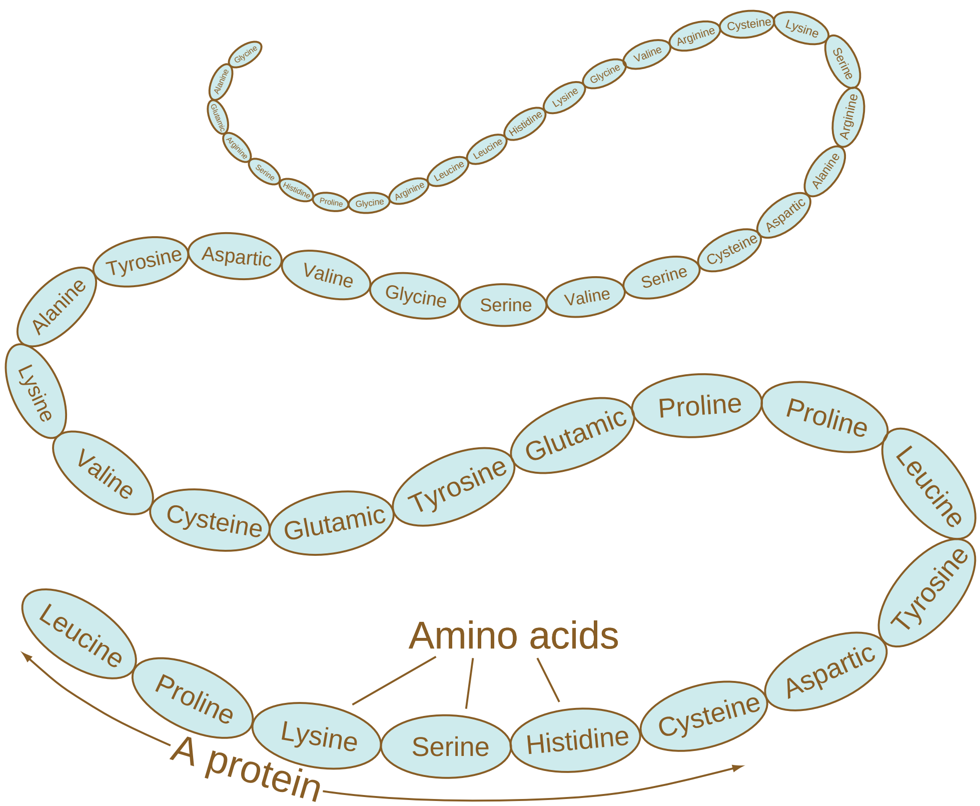
The second entity in the library is information. The sequence of letters on the book pages represent ideas, and they were generated by intelligence to convey specific messages. There are no natural laws that specify whether *n* will come before *e*, or if *t* will be followed by *h*. The sequence of letters on a page results not from natural law but only from intelligent thought and planning. Information requires a mind to invent it. In the same way, our automobiles function through the action of natural laws, but natural laws will never design an automobile. There is nothing in the laws of physics that would specify the shape of a fender or decide the size of a piston. Automobiles must be invented—designed by an intelligence who has a plan in mind and who understands how to put the laws of nature to work to ignite the gasoline and make the automobile function after its parts are designed and assembled.

Life also results from interaction of the same two entities—law and information. Much of what occurs in the universe is governed by the laws of chemistry and physics. But life is different. Even in biology the laws of chemistry are important controlling forces, up to a point. The characteristics of oxygen, carbon, and hydrogen control the possible ways they can connect together to make simple molecules, such as amino acids. We can predict that if certain elements are put together under specific conditions, amino acids will be produced. But no matter how many amino acids are mixed together, they are not alive. Life exists only if a fundamentally different entity is also present—*information*. This information is carried in two groups of molecules—nucleic acids (DNA and RNA) and proteins.

A protein is a long, linear molecule, typically consisting of hundreds or thousands of amino acids connected together like links in a chain (fig. 7.1). There are about twenty different amino acids analogous to letters in the alphabet that link together to form various proteins. Amino acids can link together in any sequence; there must be information to control the sequence of amino acids to make a useful protein. Whether a protein will catalyze the release of energy in a cell, form part of the structure of ATP synthase, or be entirely useless will be determined by its sequence of amino acids, just as the sequence of letters determines the meaning of this sentence.

Where does the information (sequence of amino acids) in the proteins come from? In a living organism, the sequence, or order of amino acids, is determined by the sequence of bases in DNA and RNA. These nucleic acids are also long molecules composed of sequences of subunits called bases. There are four bases, and combinations of these four bases make up a code that specifies the twenty amino acids and are also like letters of an alphabet (fig. 7.2). Just as with

Figure 7.1. A representative protein composed of a chain of amino acids (Brand 2006a).



proteins, there are no natural laws that specify in what order the bases will occur—the sequence contains information that has to be invented. Even the code that determines which three DNA bases specify, for example, the amino acid alanine is not inherent in the structure of alanine or DNA—it is an arbitrary code that had to be invented. It works because cells contain carrier molecules, called "transfer RNA," and each of the twenty amino acids has its own type of carrier molecule that attaches to it (fig. 7.2). Each carrier molecule (transfer RNA) is a unique and arbitrary design (like the arbitrary design of a car's fender) made to translate the

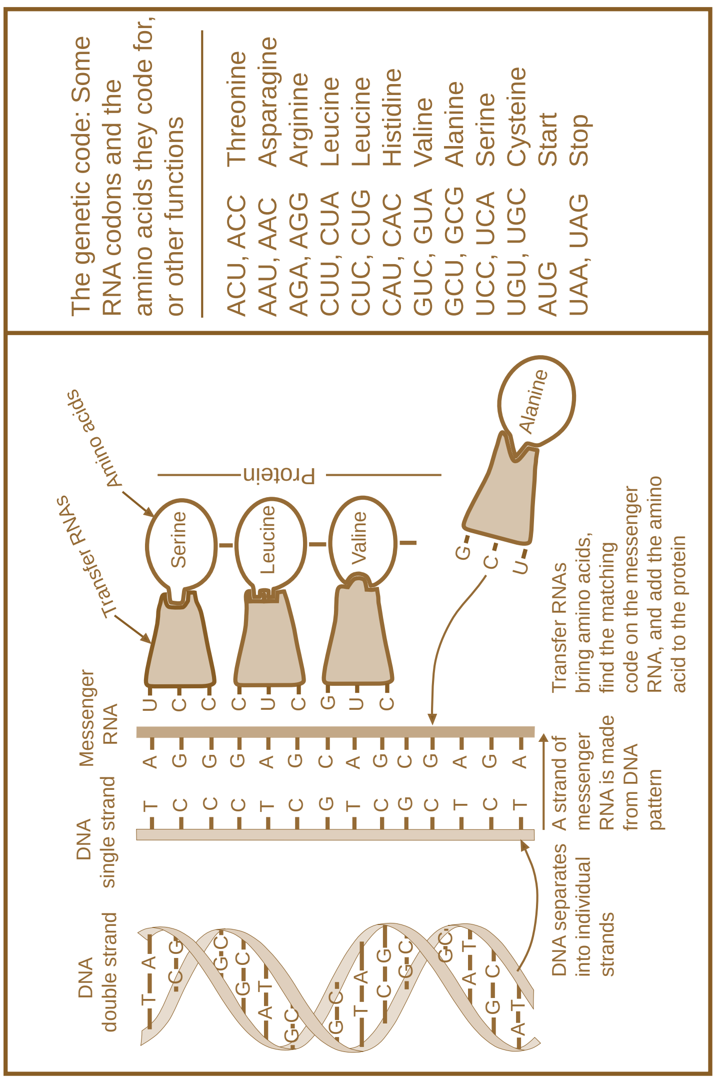


Figure 7.2. Left: The structure of DNA, with its pairs of bases (these bases are adenine [A], guanine [G], cytosine [C], and thymine [T] between the two strands of the double helix). *T* always pairs with *A*, and *C* always pairs with *G*. DNA separates to form single-stranded DNA, and a single strand of messenger RNA forms along the DNA pattern (in RNA the thymine is replaces by uracil [U]). Then transfer RNA molecules, with their attached amino acids, recognize the sequence of bases on the messenger RNA, find their proper place, and bring the amino acids into position so they can join to form a protein. Right: A sample of RNA codons (a codon is a sequence of three bases that codes for a specific amino acid or indicates starting or stopping the construction of a protein). Figure by Leonard Brand.

code into useful actions and to recognize its amino acid and where to hook that amino acid on to a new protein being synthesized in the cell's "protein factory." The structure of each of these carrier RNAs had to be invented, and the instructions for making each transfer RNA is also specified in the DNA.

The significance of this recognition that information must be invented cannot be overemphasized. Compare life with, for example, crystal growth: if the correct chemical conditions exist, a specific type of crystal will form. In contrast, the operation of natural laws is not sufficient to produce life. Life is a special, and very improbable, condition resulting only if the enormous library of necessary information is present. Life does not automatically appear because of natural law for the same reason that natural law cannot make Shakespeare's plays automatically appear. Those plays exist because of the creative efforts of a personality who thought them up and wrote that information on paper. Is there any way that the original life forms could reasonably be expected to appear other than being invented by a creative Designer who wrote the necessary information in the DNA? This question is at the center of the controversy between naturalism and intelligent design. We can only understand the gravity of the question if we get a glimpse of what is going on in a living cell.

Biomolecular Machines: The Awesome Complexity of a Living Cell

In Charles Darwin's time, the cell was thought to be a bit of protoplasm containing a nucleus and surrounded by a membrane. Something so simple could easily evolve. But the last half century of molecular biology research has utterly destroyed that simplistic concept of the living cell. Each cell in every plant and animal functions because of the united work of thousands of types of tiny protein biomolecular machines, each with its assigned work to do. To give a little glimpse into this molecular world, we will consider just two types of biomolecular machines.[14]

The first can be thought of as a donkey, programmed to carry loads to a destination in the cell. When a load of chemical is to be delivered, a molecular machine packages the load of chemicals into a container called a vesicle. It must have a delivery address, a road that goes to that address, and a donkey to carry it. The roads are called microtubules—long, slender tubes connecting different parts of the cell. A complicated molecule called kinesin serves as a molecular machine or "donkey." Kinesin (fig. 7.3) is a long protein molecule with two branches on one end that look like legs. Kinesin needs energy to do its work, and the energy is supplied by the molecule ATP. When ATP is present, the legs of kinesin alternately attach to a microtubule, then detach and move forward. The kinesin literally walks along the microtubule! The other end of the kinesin is designed to recognize the type of load it is to carry and attach to it. Kinesin attaches to the appropriate vesicle, then somehow recognizes the correct microtubule "road" and direction to go on that road, and walks along it to the designated address.

Where did that ATP molecule with its packet of energy come from? The answer is found in our second molecular machine, called "ATP synthase." which is formed of several complex proteins located in a cell membrane (fig. 7.4). Protons flow through part A, making part M rotate, just like an electric motor. An asymmetrically shaped cam is connected to the rotating part M. Part B is attached to the membrane and to part F, the factory that makes ATP. The right side of figure 7.4 is a cross-section through the middle of part F, and shows the sequence of events as the cam is rotated inside of part F, changing the shape

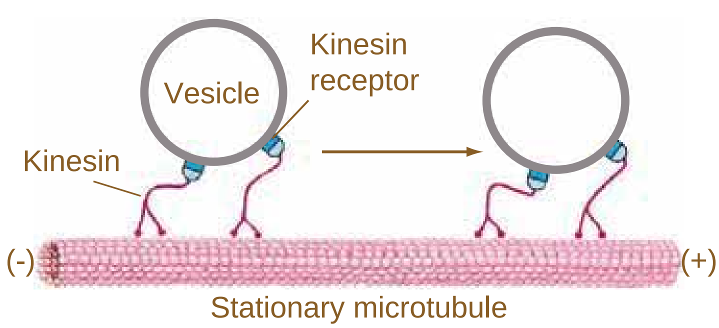


Figure 7.3. The protein kinesin, which "walks" along a microtubule, carrying a vesicle full of some chemical toward its destination (after Lodish et al. 2000). Figure by Arthur Chadwick.

of the subunits of part F. In position 1, a slot on the surface of F is opened, and ADP and inorganic phosphate attach in the slot. Then the cam rotates to position 2, the slot is reshaped by the cam, and ADP and phosphate are bound more tightly in the slot. Then in position 3, ATP is formed, and as it rotates back to position 1, the ATP is released to go and provide energy for kinesin or other machines in the cell. Of course the whole process is more complicated than this simple description, but you get the idea of what is happening as the cell carries out its incredibly complex and precise chemical operations. And these two biomolecular machines are only the tip of the iceberg of cellular machines. As molecular biology research continues, the complexity of the cell is expanding exponentially. If these machines were not present, the cell would not be alive. The theory of abiogenesis carries the heavy burden of convincing us that the origin of thousands of such machines without an intelligent inventor is realistically possible.

Alternate Theories of Abiogenesis

Various theories attempt to provide a more likely mechanism for abiogenesis. We have mentioned the "RNA world" hypothesis and the proposal that clay was involved. Another idea is that the first cells formed in

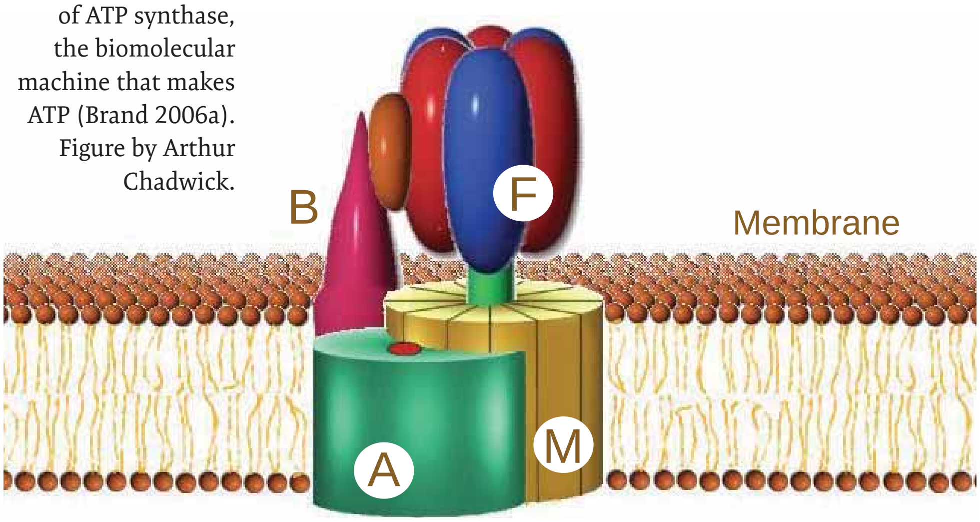


Figure 7.4A. A model of the structure of ATP synthase, the biomolecular machine that makes ATP (Brand 2006a). Figure by Arthur Chadwick.

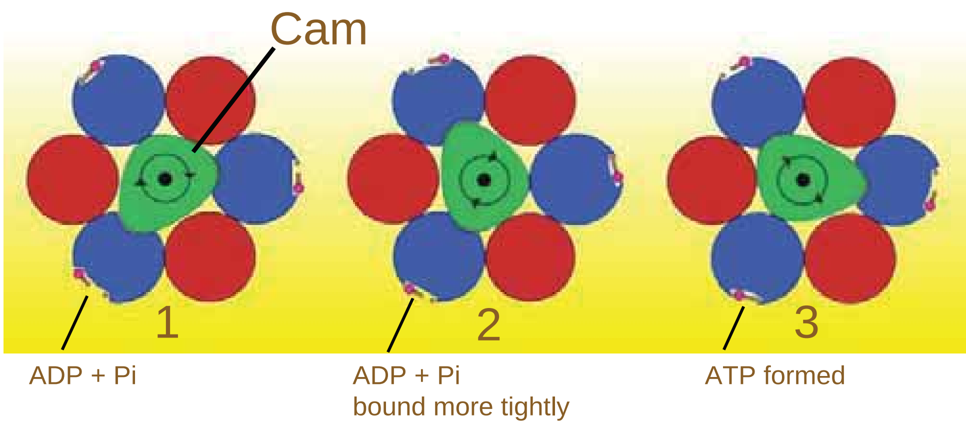


Figure 7.4B. Cross-sections through ATP synthase, showing three steps in the synthesis of ATP (after Lodish et al. 2000). Figure by Arthur Chadwick.

microscopic honeycomb minerals containing iron sulfide.[15] It has also been proposed that life evolved under very high temperature conditions, at hydrothermal vents, or deep in the earth.[16] Some of these scenarios may increase the rate of biochemical reactions, but they do not have any potential to provide a means of specifying the biological information: the sequence of subunits in proteins or nucleic acids.

In some physical systems that are far from equilibrium, ordering may appear spontaneously,[17] like the organized airflow in a tornado or the intricate structure of a snowflake. The implication is that there might be inherent self-ordering mechanisms in matter that facilitate the origin of life. But the examples given, such as the snowflakes and tornados, operate at a simple physical level and do not provide a clue how the origin of living things could be self-ordering. These physical mechanisms do not have any means to sort out the biologically useful organic molecules or to favor the effective formation of macromolecules and cause proteins and DNA to form with biologically appropriate information content.[18]

To more fully understand how serious the difficulty is of life beginning by itself, we recommend a thoughtful reading of the book *Signature in the Cell* by Stephen Meyer.[19] If you have an answer for each of the chemical challenges described there, perhaps you can put together a better theory of abiogenesis.

Origin of Life Theories and Philosophical Considerations

Since natural selection could not operate before there were living, reproducing organisms, naturalistic abiogenesis cannot escape the pervasive role of chance in the origin of life. Whichever version of the theory of abiogenesis one prefers, one ultimately must resort to an argument summarized by Richard Dawkins in *The Blind Watchmaker*: "What is the largest single event of sheer naked coincidence, sheer unadulterated miraculous luck that we are allowed to get away with in our theories and still say that we have a satisfactory explanation of life?"[20] Is there a way to get past Dawkins' grim judgment? Dawkins was not using the word "miraculous" the way a religious person might use it. He simply believes that the amount of luck needed for life's origin, even though it seems miraculous, is still within reason. He is expressing his faith and nothing more. Where else in science would that kind of thinking be tolerated? Nowhere. So why does science accept it here? How is it different from the interventionist's reliance on divine action in the beginning of life? Is one less or more scientific than the other?

If we use the principle of multiple working hypotheses, there are at least two possibilities:

1. Life arose on earth or elsewhere by some type of abiogenesis, maybe a version of it that is still unknown.
2. Life was invented and produced by intelligent intervention.

Science will not prove or disprove either option. Our most promising logical approach is to use Stephen Meyer's concept of inference-to-the-best-explanation.[21] Which of the two hypotheses best fits the evidence? But to think as scientists and still consider the second option, we will have to question the application of MN to the study of origins.

It is impossible to fully understand how science deals with questions of origins unless we comprehend the dominant role that the assumption of naturalism plays in scientific thinking today.[22] To be able to explain the origin of life without a designer is critical for naturalistic theories of origins, and abiogenesis is clearly one of the weakest links. But if it is admitted that the origin of life requires informed intervention, naturalism has been dealt a death blow. Consequently, for naturalism to survive, the theory of abiogenesis must be maintained, no matter what the evidence. The data say "no" to abiogenesis, but interpretations within MN have to say "yes, it happened by abiogenesis."

If it was admitted that naturalistic theories cannot explain the origin of life, and informed intervention might be necessary in this case, then the only remaining questions are as follows: What was the nature and boundary of the intervention? Or what are the limits of the evolution process? Those questions are incompatible with the very principle of strict MN as science understands it today. If naturalism is accepted, then one must believe in some form of biochemical evolution, *no matter what the evidence*. This means one must believe in this "sheer unadulterated miraculous luck." In other areas, where science is studying ongoing processes that can be observed and experimentally tested, that type of thinking is never accepted.

In the naturalistic worldview, the "miraculous luck" is not thought to be truly miraculous if there was enough time for such an unlikely event to happen. To use the clichéd illustration, if millions of monkeys were given typewriters and allowed to type at random for a long enough time, there is a chance that they would just happen to type Shakespeare's plays. If we determine the number of letters and spaces in all those plays we could calculate the probability of getting the right sequence by chance. This may appear to be a reasonable comparison to the possibility of abiogenesis occurring by chance, but there are other factors that we must include in our calculations.

These factors include the probability of uneducated monkeys remembering to put new paper in the typewriters at the correct time, of other monkeys filing the typed pages appropriately, and that the plays will be completed and somehow compiled before most pages are blown away by the wind, destroyed by the elements, or eaten by cockroaches. These hazards are analogous to the wide array of serious chemical and physical hazards to be expected in any primeval soup environment, ready to break down complex molecules before they could accumulate and join in the right combinations to form even the simplest part of a living cell.

In reality, you can have all the monkeys you want and give them as many millions of years as you wish, but because of those hazards, they will never type even one page of Shakespeare's plays. And we maintain that abiogenesis will never produce one living thing because there are too many natural forces working against the tidy organization, by chance, of the myriads of organic molecules needed to make life. Discussions of the probability of abiogenesis will be empty and meaningless if they do not seriously consider these hazards.

Lighting the Fire

If all the biochemical components of a cell are in place, the cell isn't automatically alive.[23] A living cell functions by a set of chemical reactions that are continuously running. A cell that has just died is the same as a living cell except that all of these reactions have stopped (reached equilibrium). How could the cell be made alive again? All the hundreds of biochemical processes would have to be restarted somehow. The same would be true of the first living cell—even if the necessary molecules are in place, somehow all the needed reactions would have to be fired up. In an automobile engine, the starter performs this function. What would do this in an evolving cell if there is no creator to "breathe into the organism the breath of life"?

Does the Second Law of Thermodynamics Make Evolution Impossible?

The second law of thermodynamics states that energy naturally moves from a more-organized state (less entropy) to a less-organized state (higher entropy). A common creationist argument is that the second law makes not only abiogenesis impossible, but also evolution of increasing complexity. That may seem like an attractive argument, but it is inadequate unless additional factors are included.

A counterargument that is used in favor of the natural increase of complexity employs mathematical calculations to make the point that with an input of energy, entropy can decrease in one realm if entropy increases somewhere else to keep the overall balance. But consider an example of two teenagers' bedrooms. If one room becomes more disorderly (higher entropy), but the doors and windows are open to let in more energy from sunshine, will that influence the other room to become more orderly? Actually there will be no increase in order unless there is a "machine"—a mechanism—to effect that increase in orderliness, perhaps an organized teenager.

Likewise a living system could only escape the implications of the second law and evolve by increasing complexity if there is some kind of mechanism to convert the energy into a useful form. The following must be available:

1. An open system (input of energy into the system—on earth the input of energy is from the sun)
2. An adequate amount of energy (there is plenty of energy)
3. An energy conversion system (a mechanism) to allow directed utilization of that energy (photosynthesis, mitochondria, and other cellular components in living things)
4. A system to control the energy conversion and utilization

Although our earth is an open system, receiving energy from the sun, complex biological energy conversion and control systems (items 3 and 4) are needed before that solar energy can be put to use in abiogenesis and evolution. Those systems do not appear to have been available on the early earth before life was present. This, then, is one of the most significant reasons the origin of life is a problem for naturalistic theories—along with the problem of the origin of biological information and biomolecular machines.

How Should Science Deal with the Origin of Life?

When no hard evidence exists for events so far in the past, science has serious handicaps, but a person may still choose to assume that life originated by naturalistic processes and then intentionally use the scientific method to determine the most likely process by which that event may have happened. The effort so far has failed, but is it worth another try? If that person is honest about the philosophical choice being made, we will defend his or her right to follow that approach even though we are convinced that the effort will not succeed.

Many individuals go further and state that any approach other than naturalism is not intellectually or scientifically valid. But when abiogenesis comes down to "miraculous luck," what fundamental difference is there between choosing to believe in the origin of life by naturalistic means in spite of the lack of supporting evidence and choosing to believe in informed intervention? Both theories are based on faith in a particular philosophy. Adherents of both views have their reasons to choose their philosophy, but neither philosophy can be verified or refuted by science. Can we be honest enough to say "the scientific process does not offer an answer for that question"? Perhaps the public would take science more seriously if the scientific community were not dogmatic on such a question as the origin of life, which is really just a philosophical choice.

We examined seven evolutionary textbooks and a book of evolution readings to see how they dealt with the origin of life. Of the eight books, three did not have any material on the origin of life. The other five,[24] to one extent or another, discussed difficulties in origins of life research. They all presented the naturalistic theory of the origin of life as a fact of history, without mentioning the serious problems discussed above.

A quote from Barton and colleagues[25] illustrates the typical approach that is taken in these books: "In the RNA world, RNA was genotype and phenotype. This was a critical step in the origin of life. However, once a translation system evolved, proteins rapidly took over most catalytical functions." This is presented as fact, as if this was a simple process. It ignores all the origin-of-life problems, is very speculative theory, and supplies no evidence that this actually happened.

We predict that in the future any theory of abiogenesis will be seen as an area of naiveté in twenty-first-century scientific thinking. This is not invoking a repeat of the god-of-the-gaps phenomenon; it is the opposite. Each new discovery in molecular biology makes the challenge to the theory of abiogenesis more serious. Two hundred years ago, the action of God was invoked to explain things not otherwise understood. As more information accumulated, it became clear that many problems could be solved by the action of natural law. But today's advances in biochemistry are not reducing the problems for abiogenesis. The more information accumulates on the nature of life, the more it indicates that natural law alone does not have the answer to the origin of life.

A few scientists concluded that biochemical evolution is unlikely to have happened on our earth and that it must have happened elsewhere, was then brought here, and proceeded to evolve into many forms of life.[26] Is this a scientifically satisfying option? This nontestable hypothesis seems to be one way to face up to the improbability of abiogenesis on planet earth but still work within the rules of MN. They just moved the problem to a different planet.

Are we willing to consider another option—the possibility that there could be a Being in the universe with the knowledge and ability to put together the first living things—and to admit, if necessary, that some questions cannot, as yet (and maybe never will), be answered within the naturalistic worldview?

We have no access to physical evidence of how life began. In contrast, when discussing microevolution, speciation, and the fossil record, evidence is abundant, though it may not always be conclusive. Once living, reproducing cells exist, does this provide the mechanism for random mutations and natural selection to evolve all the forms of life? We will return to this question in chapter 10 after considering how life forms change and adapt to their environment.

Origin of life

DATA

Awesome complexity of a living cell. Observations indicate that even the simplest cell is incomprehensively complex. Efforts to create life using the most sophisticated intelligent processes so far have not been fruitful. We can only copy/modify existing life forms.

INTERPRETATION

Abiogenesis: This assumes naturalism and concludes that how abiogenesis happened is a mystery, but it had to happen. There is no other choice.

Interventionism: Inference to the best interpretation results in the conclusion that life was created. No assumption is necessary if facts of biochemistry are taken seriously.

CHAPTER 8

Microevolution and Speciation

Overview

Since Charles Darwin's lifetime, much has been learned about the nature of life and of molecular biology. Darwin's theory was updated with the Neo-Darwinian Synthesis of the 1930s and 1940s, and that synthesis is being seriously revised with newer knowledge of molecular genetics. This chapter begins with a description of the processes of microevolution and speciation as they are understood today. Then follows an interventionist viewpoint, which begins with the creation of major life forms, and recognizes microevolution and speciation occurring within each created group. This resulted in animal and plant adaptations to changing environments during the succeeding millennia. This process that begins with creation, followed by biological changes, suggests some alterations to the conventional evolution theory. These alterations are described, and it is concluded that this interventionist theory, along with new findings of epigenetics (genetic processes outside of DNA that manage the DNA), provides a better correspondence with the available biological evidence than conventional evolution theory.

The Progress of Darwin's Theory

The belief of the Middle Ages that animals and plants did not change (fixity of species) was replaced by Darwin's theory of evolution, first published in 1859. Darwin's theory was developed long before the beginning of such fields as genetics and cell and molecular biology. The true nature of life was unknown. The accumulation of new information since Darwin's day resulted in the Neo-Darwinian Synthesis (or modern synthesis) developed in the 1930s and 1940s, combining genetics, population biology, and paleontology into what was at that time a comprehensive theory of evolution.[1] That new synthesis was based in large part upon theoretical mathematical population genetics, without much real-world data.

Since that era, the discipline of molecular biology including molecular genetics has blossomed and made dramatic changes in our understanding of the genetic system and the nature of the living cell. About the year 2000, I (Brand) listened to a prominent evolutionary scientist at an annual vertebrate paleontology meeting give a talk on the evolution process. He made the remark that "the Neo-Darwinian Synthesis has to be redone, and this time we are not going to blow it." At the time, I wondered what he meant, but since that time, advances in molecular genetics have indeed been dramatic. We will first of all describe the theory of microevolutionary change as understood in the Neo-Darwinian Synthesis and then add some modifications in the theory from modern molecular biology and from interventionist theory.

To be fair to the authors of papers cited here and in the next four chapters, it should be emphasized that most of them would not support the basic premise of these chapters. They are cited only for specific ideas or data, and we believe the reinterpretation rendered in this book is consistent with and fair to the data cited.

This presentation is simply a progress report and does not claim to answer all questions. The theory will no doubt change as more data are gathered. It will be fascinating to see how the accumulating data will affect our theories in the years to come.

Categories of Evolution

The theory of evolution can be divided conveniently into microevolution, speciation, and macroevolution (fig. 8.1). Microevolution refers to relatively small evolutionary changes within a species of organisms (species—a group of populations of organisms that interbreeds among themselves but does not interbreed with other populations).[2] Speciation is the development of a new species. Macroevolution is commonly defined as evolution above the species level.[3] However, the term is not always defined that way.[4] Some use it to refer to major phenotypic changes that result in the origin of higher taxa. In this book, we will always use the term macroevolution in that second sense—to refer to the evolution of major groups of organisms including new families and any taxonomic category above the family.

If several species of mice evolve from an ancestral mouse, the changes are generally in color, size, proportions of appendages in relation to body size, behavior, habitat preference, and minor molecular differences. All of these mice are homeothermic (warm-blooded), have hair and milk glands, and bear live young. For them to evolve from one species of mouse would not require new structures and probably no new genes. This is microevolution and speciation.

However, if mice and other mammals had evolved from a reptile ancestor, it would require the evolution of major anatomical and physiological features that did not exist in the ancestor and new complexes of genes to code for the structure and embryological development of these new features. Examples are the structures and the endocrine control mechanism for the development and birth of live young; milk glands to nourish them; a larger, more complex brain; the mechanism to maintain the mammals'

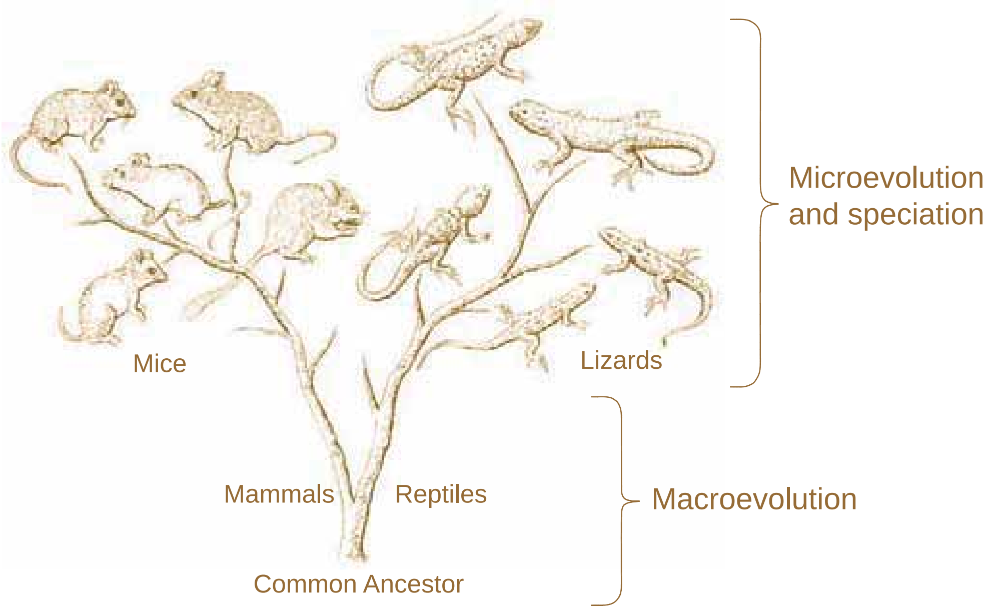


Figure 8.1. Speciation within lizards and within mice compared with megaevolution/evolution of major groups from a common ancestor. Each animal symbol represents one species. Microevolutionary changes occur within each species. Figure by Robert Knabenbauer.

higher metabolism and warm-blooded condition; and the enormous complex of regulatory genes to control all of this. This magnitude of change is macroevolution (fig. 8.1).

Microevolution

Both evolutionists and interventionists recognize that microevolutionary changes occur. Many of the processes involved in microevolution can be observed or are supported by evidence that is circumstantial, but abundant. These processes in all life forms are as follows.

Excess individuals are produced. Almost all animals produce many more eggs or young than would be necessary for a constant population size. Female field mice of some species produce an average of four litters per year, with four young per litter. If their offspring live long enough to have one full reproductive season, the offspring of just one original pair after twenty years would number 2.59×10^{18} mice, enough mice to make a pile as wide as the continental United States, 17,280 miles high. If you look out the window, you will notice there are not that many mice around. Animal population sizes, on average, are stable, which means that most offspring either do not live long or do not successfully reproduce.

Individuals are not alike. Even though the 17,280-mile heap of mice includes only one species, some variation will be evident in the characteristics of each mouse, such as differences in size, color, behavior, reproductive potential, physiology, and alertness. New variation arises through random mutations and recombinations; mutations are changes in DNA caused by various kinds of radiation, by some chemicals, or by factors within the cell. If the mutation is in an egg or sperm and is not lethal, it may be passed on to offspring and, perhaps, spread through a population of animals. Figure 8.2 illustrates a few of the numerous mutations that have been produced in fruit flies in the laboratory. These mutations and others are overwhelmingly harmful and rarely, if ever, can result in improvements in organisms.

The process of recombination, the rearrangement of the genetic traits during sexual reproduction, increases the number of different combinations of characteristics within a population of animals. Recombination is analogous to shuffling

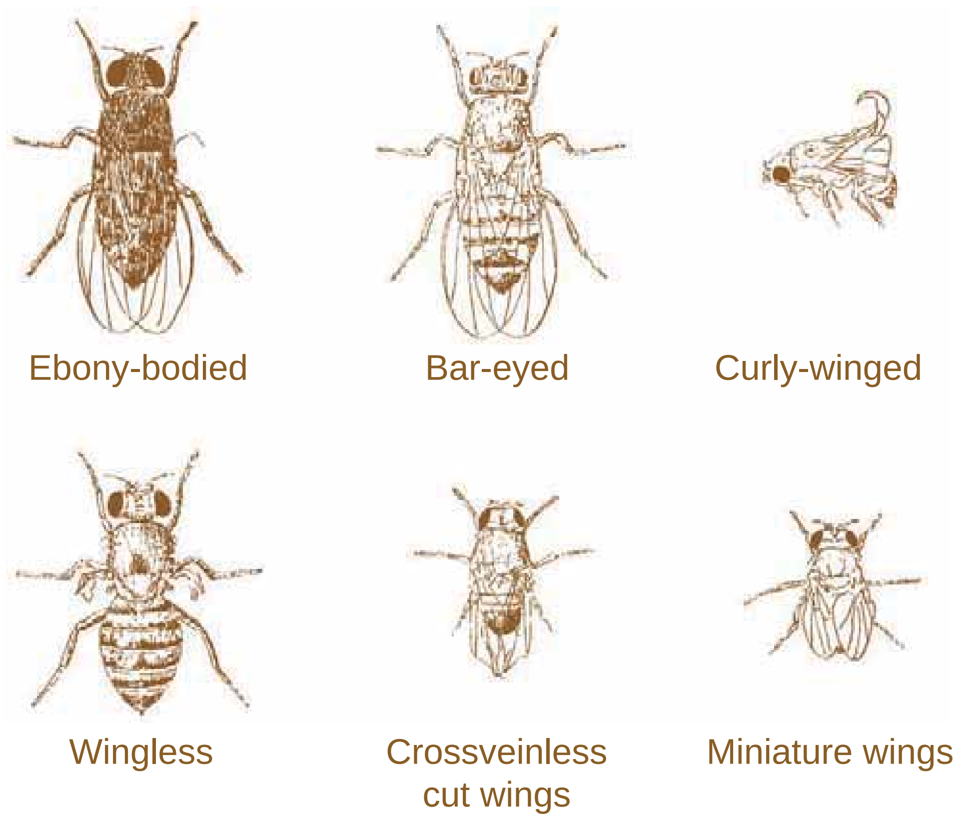


Figure 8.2. A few of the numerous mutations in fruit flies (genus *Drosophila*) that have been produced in the laboratory (after Villee 1977). Figure by Robert Knabenbauer.

a deck of cards. If a female mouse with a short tail, short ears, and light color mates with a male with a long tail, long ears, and dark color, the offspring may show all combinations of these characteristics. The variations we observe in domestic animals illustrate the amount of genetic variability that can occur through these processes (fig. 8.3).

Natural selection. Mutation and recombination are random processes. They occur strictly by chance; they cannot see what the animal will need in the future. However, another factor has been important in the development of breeds of domestic animals. An animal breeder who notices an individual with a highly desirable combination of characteristics makes this desirable animal an important part of the breeding stock to assure its characteristics are passed on to as many offspring as possible.

This process has resulted in faster horses, collie dogs with longer muzzles, cows that produce more milk, and a breed of show chickens with twelve-foot-long tail feathers. The short legs of dachshunds, flat muzzles of bulldogs,

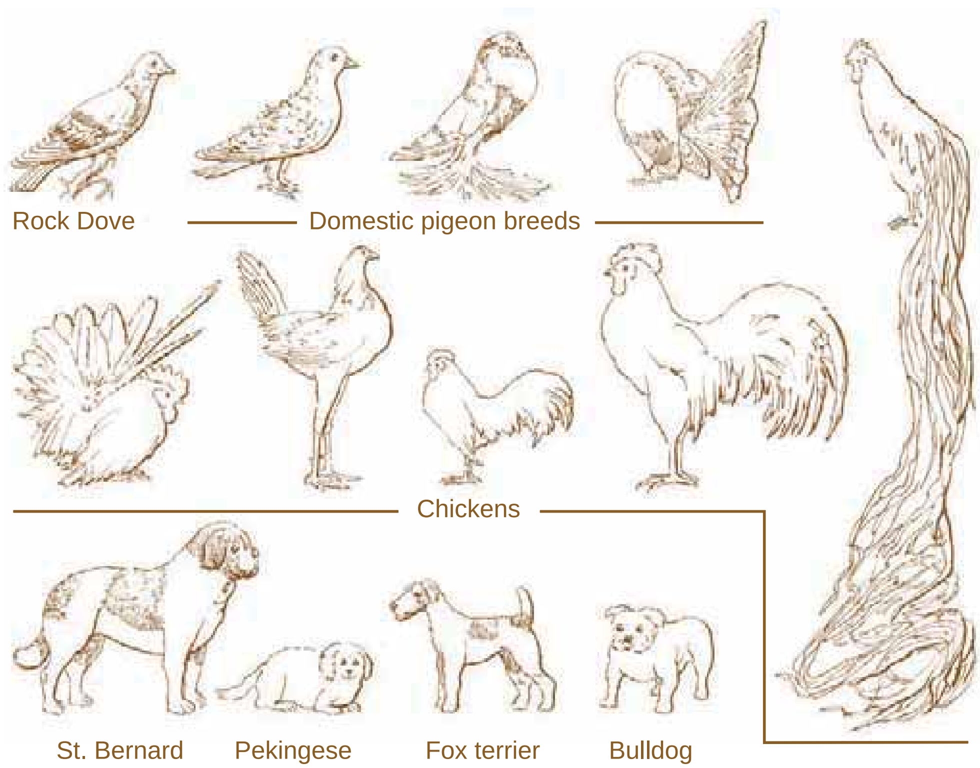


Figure 8.3. A few of the many varieties of domestic animals. The rock dove is a wild species. All the other varieties of pigeons, chickens, and dogs shown here have been produced by selective breeding (after Clark 1979; Moore 1964). Figure by Robert Knabenbauer.

curly hair of poodles, and tumbling flight of some show pigeons (actually a nervous disorder) are examples of mutations. These mutations are not constructive evolutionary adaptations because such animals would likely not survive in nature, but they have been artificially preserved through selective breeding and human protection.

Darwin and others wondered if there might be natural processes that would result in selective breeding. Indeed, we do find that some individuals have a greater natural likelihood of surviving and producing offspring. This process, called natural selection, is defined as "differential reproduction of genetically diverse organisms."[5] Those individuals with characteristics adapted to their environment have the best chance of surviving and successfully reproducing.

Wolves in Alaskan valleys like to eat caribou, but a wolf can capture only those that are sick, slow, or not very alert. Even a very young caribou with normal health and vigor can outrun a wolf. The Eskimos have a saying: "The wolf keeps the caribou strong." This is natural selection in action. The wolves' ability to catch only the weaker caribou selectively eliminates those individuals from the reproductive population.

The operation of natural selection is usually not as dramatic as a race between a caribou and a wolf. The results of natural selection are expressed in evolutionary studies as changes in gene frequency. Genes occur in different forms called alleles. For example, in a gene that affects eye color, some individuals have the allele for blue eyes, some have the allele for brown eyes, and others have both (in this case, since brown is dominant, their eyes are brown). Each individual in a species has a different combination of gene alleles in its chromosomes that determine its characteristics. If any factor (selection pressure) makes individuals with one particular characteristic more likely to survive and successfully reproduce, the allele for this characteristic becomes more common in the population. Pocket gophers in the southwestern United States live in a wide variety of habitats. In desert areas with very light-colored sand, their fur is the color of the sand. In more vegetated areas with darker soil, their fur is darker and matches the hue of the ground. A gopher with the wrong color of fur would be conspicuous and more easily seen by a predator. This is natural selection. It is a straightforward process that clearly does occur.

Now we are ready to put together the major components of the process of microevolution. In a given species of animal or plant, an excess number of offspring is produced and many or indeed most of them die before reproducing. Since there is also variation in the characteristics of these offspring, some have combinations of characteristics that give them a better chance of surviving the natural selection process than others. Hence these survivors produce more offspring and make the greatest contribution to the genetic makeup of the next generation.

There are other factors that affect the microevolution process, like random shifts in gene frequency called genetic drift. Also, if a small number of larger than average individuals become isolated and found a new population, that population may be larger than their relatives (the founder effect). Not all evolutionary scientists agree that genetic drift or the founder effect have a significant role in microevolution and speciation.[6]

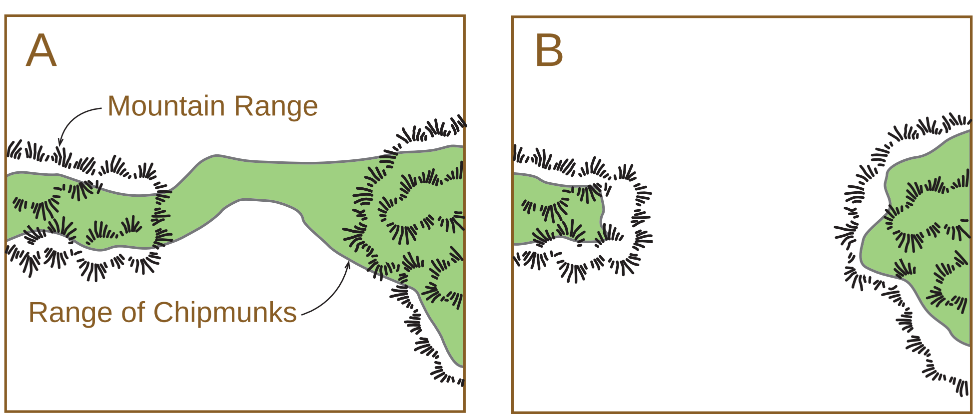
An increasing number of scientists doubt that the microevolution process extrapolated over time is adequate to produce more significant changes. They suggest that larger-scale evolution must involve a different mechanism other than microevolution and that it happens rapidly.[7] Abundant evidence shows that the process of natural selection does occur.[8] To most scientists, there is no question that micro- and macroevolution evolution occurred; the only question is by which naturalistic process or mechanism it occurred. There are plenty of questions and lively discussions over that issue. Now we will turn our attention to the relationship between microevolution and the development of new species.

Speciation

Evolution theory proposes that evolution not only causes pocket gopher fur to become more like the soil color in their habitat but also produces new species under the right circumstances. The many diverse breeds of domestic dogs freely interbreed. By definition, this makes all domestic dogs members of one species. On the other hand, many similar species of wild animals live side-by-side in nature with no evidence of hybrids. The differences between these wild species may be small, but they are consistent, and they include features that prevent them from interbreeding. The development of new species often seems to begin with geographic isolation, then adaptation to new environments, with changes that lead to reproductive isolation.

Geographic isolation—how important is it? Differences of opinion exist about the details of the speciation process.[9] But according to the best understood concept of speciation, two populations of animals first become geographically separated before speciation occurs. For example, if chipmunks live on two mountain ranges and also through the forests between the two ranges, they remain as one species. Even though the chipmunks on one mountain range may look a little different from those on the other range, the interbreeding throughout the species may cause enough mixing and sharing of genes, or gene flow, to prevent them from separating into two distinct species (fig. 8.4). However, if a change in climate results in a strip of desert between the mountains and the chipmunks do not enter the desert, they are geographically isolated. The two groups have no opportunity to interbreed, and thus

Figure 8.4. Geographic ranges of chipmunks, (A) without geographic isolation and (B) with geographic isolation. Figure by Leonard Brand.



there is no gene flow between them. However, in some situations, speciation occurs without geographic isolation. For example, in some large lakes, cichlid fish divide into many species without geographic isolation.[10]

Adaptation and reproductive isolation. If the environments on the two mountain ranges are different, natural selection may cause the two groups of chipmunks to become different. If their differences prevent them from interbreeding, they have become separate species.

A variety of mechanisms produces this reproductive isolation. In some cases, the species are so genetically different that even if they do mate, they can produce only infertile offspring (like the mule) or perhaps no offspring at all. Often reproductive isolation mechanisms are more subtle. My (Brand) wife is Korean, but it didn't bother her that I was a little different. But I suspect that if a California chipmunk tried to flirt with a Korean chipmunk, he would be rebuffed, even though Korean chipmunks are almost identical to some California species (fig. 8.5). Her reaction is likely to be, "Get lost; I don't know you and you smell funny." This example illustrates that wild animal species are very specific in their choices of mates, and this usually, but not always, prevents hybridization. Some species that may be able to cross and produce viable, fertile hybrids in the laboratory do not hybridize in nature because of differences in habitat or behavior. For example, in some cases, two species of chipmunks live on the same mountain range, but one species lives in low-elevation pinyon pine forests and the other lives only in high-elevation lodgepole pine forests. Consequently, they have no opportunity to interbreed.

Two species of fruit flies may live in the same areas and breed at the same time of year, but one species limits its breeding to the morning hours and the other breeds only in the evening. In many animals, reproductive isolation is maintained by their courtship rituals that are unique to each species. For example, part of the courtship of songbirds, frogs, toads, and some insects is the courtship song

Figure 8.5. An interracial human family (top), a California chipmunk species (left), and a Korean chipmunk photographed on Seoraksan (right). Figure by Leonard Brand.

or call given by the males. The song is different for each species, and the females respond only to the song of their own species.

Advances in Molecular Biology and Their Implications for Evolution

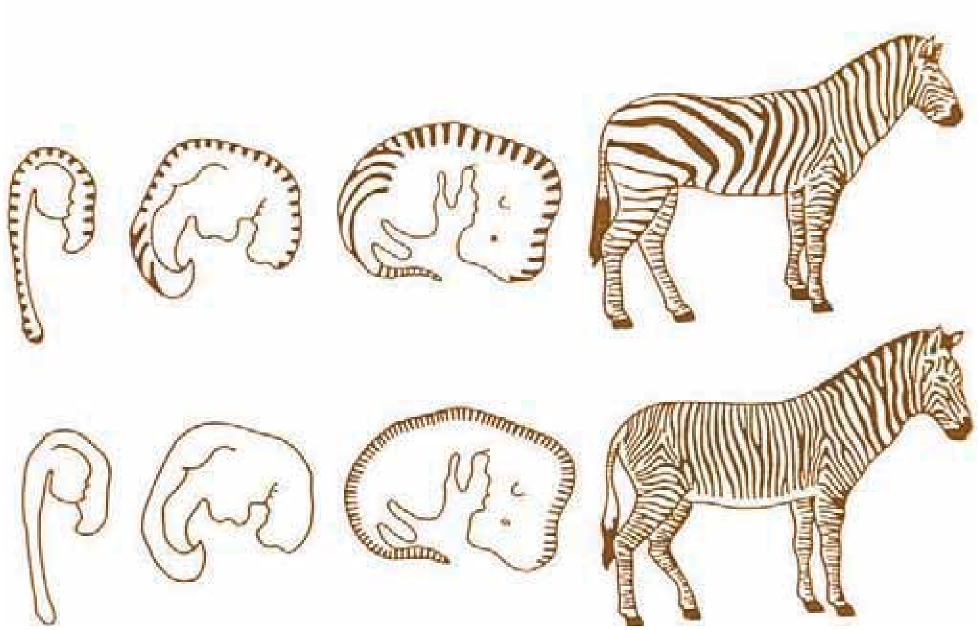
The section above presents the standard Neo-Darwinian understanding of microevolution and speciation. We will now consider the findings of molecular biologists in recent decades, which have significant implications for evolution theory. In this chapter, we only consider the changes *within* major groups of organisms (microevolution and speciation). Science is just beginning to understand the complexity and sophistication of the genetic system. The possibility of that genetic system and the major groups of organisms arising by evolution in the first place is discussed in chapter 10.

Regulatory Genes and Epigenetics

Increased understanding of regulatory genes has revealed their influence on coding genes and on animal structure and development. Small changes in regulatory genes can result in large changes in an animal. For example, timing of embryonic events apparently controls the stripe pattern in some zebras. The stripes on the lower back of the zebra *Equus quagga* (formerly *Equus burchelli*) are widely and irregularly spaced. This results because the back part of the embryo grows faster than the rest of the embryo after the stripe pattern is established. The stripe pattern in *Equus grevyi* is not established in the embryo until that differential growth is completed. Consequently, the stripes in the adult of this species are more equally spaced (fig. 8.6).[11] It is possible that future research will modify this explanation for differences in zebra stripe patterns because of epigenetics, our next topic.

The blossoming field of epigenetics is revolutionizing genetics. Epigenetics is the study of inheritable traits arising from outside of the DNA, involving processes that control the *expression* of genes without changing the DNA.

Figure 8.6. Embryonic development and stripe patterns of the zebras *Equus quagga* and *Equus grevyi* (after Futuyma 1986). Figure by Carole Stanton.



It is now known that, important as DNA is, there are layers of additional control systems that manage and control how the DNA is expressed. DNA by itself cannot do anything. DNA is like a hard drive with a massive amount of information, but this information is managed by the epigenetic system. Millions of tiny molecules in each cell, including methyl and acetyl groups, are attached to specific sites on DNA and associated molecules and serve as chemical tags or markers that turn genes on or off, controlling how, when, and whether each gene will be active. Genes are not always completely on or off, but the tags also act like dimmer switches, varying the amount of activity of genes. Additional levels of intracellular management control where and when these tags will be associated with the DNA. This management system involves RNA, hormones, other proteins, and the central nervous system.[12] The control of development and the processes of adaptation are managed by a vastly more complex system than was previously imagined.

This complexity is especially significant in multicelled organisms because their genetic system must not only determine the order of amino acids in proteins, but also manage the arrangement of billions of cells in the body, of many different types, from conception to adulthood.

Environmental signals may initiate these epigenetic changes, and the resulting genetic alterations can last for several or many generations with distinct influence on microevolutionary modifications in physiology, anatomy, or even behavior of animals.[13]

Stress, nutrition, and other aspects of a mother's experiences during pregnancy can affect her young, and the results last a lifetime and can even affect several succeeding generations.[14] This brings to mind a Bible statement: the sins of the fathers will be "upon the children to the third and fourth generations" (Ex. 20:5, NKJV). A recent paper on epigenetics in the prestigious scientific journal *Nature* was titled "Epigenetics: The Sins of the Father."[15]

Examples of these epigenetic alterations include changes in the size of beaks of Galapagos finches resulting

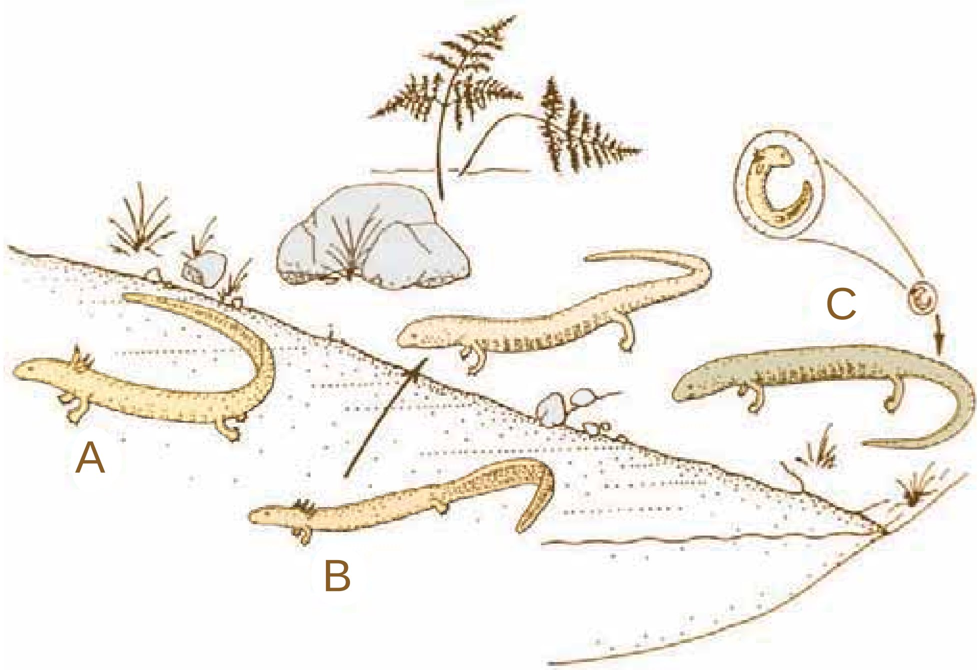


Figure 8.7. Three salamander life cycles: (A) a species with gills and a tail fin retained into an aquatic adult life, (B) a species with an aquatic larva that loses its gills and fin in the transition to a terrestrial adult form, and (C) a fully terrestrial type that loses its gills and fin when it hatches from the egg. Figure by Carole Stanton.

from changes in food source.[16] Some salamanders live their entire life in the water and have gills all through their lives (fig. 8.7). Other species have gills in their larval stage but lose those gills before they reach the terrestrial adult form. The DNA in a salamander species is apparently the same whether or not they keep their gills throughout life. Their genes are the same; the difference is not from mutations but is in the epigenetic control system. Environmental stress apparently induces this change in their breathing apparatus if they adapt to an environmental change by altering their life cycle.[17]

Blind cave-dwelling species, such as blind cave fish, do not become blind because of gene mutations, since all their eye genes are unchanged. They become blind because of epigenetic alterations in the expression of those genes.[18]

John Cairns and colleagues[19] demonstrated that some types of mutations in bacteria occur only when there is selective pressure for the phenotypic characteristics provided by those specific mutations. Their evidence indicated that these are not random mutations but are consistent with the action of the epigenetic system, activating genes in response to new conditions. This means that the bacteria have the information to detect what is needed and to switch on the appropriate stored genes to deal with the challenge.

Rarely, dolphins have been found with small rear flippers in addition to the normal front flippers.[20] This also seems to indicate that these animals have genes for structures that do not normally develop because the genes are usually turned off. Horses occasionally are born with extra toes, indicating that the genes for these toes are present but not normally active. This perhaps tells us something about fossil horses that also had extra toes. It seems highly likely that if the genes for these flippers or horse toes had been unused for millions of years, they would have been seriously damaged by negative mutations. Epigenetic control of unaltered genes seems much more realistic, turning them on or off as appropriate and, in rare, situations turning them on unexpectedly.

Many more examples can be given of features in organisms for which epigenetic explanations are far more realistic than Neo-Darwinist explanation by random mutation and selection.[21] In fact, "one century of studies on mutations has not provided a single verified example of a gene mutation that led to an adaptive morphological change in metazoans."[22]

A difficulty this all poses for the naturalistic theory of Neo-Darwinism is the clear implication that environmental stresses detected by organisms can result in the induction of nonrandom beneficial heritable changes—environmentally directed microevolution. This is anathema to any naturalistic theory of origins because it sounds like Lamarckism—inheritance of characters acquired by an organism *because* they will benefit the organism. In Darwinian theory, all new features must arise by random processes that do not know the needs of the organism. If the environment initiates beneficial features that enable the organism to deal with environmental changes, this implies some kind of genetic/epigenetic foresight—the process "knows" what will be needed. Such foresight implies an intelligent designer.

At present there is a controversy within the ranks of evolutionary scientists. There are always some controversies in challenging topics like these. But the controversy now is more significant because of its deeper implications for Neo-Darwinism. We speak of the controversy between those committed to the Neo-Darwinian Synthesis (with its central claim that all new biological information arises through random mutations and natural selection) and molecular biologists who recognize that intracellular processes are now known to be so sophisticated that there is little room in that process for random mutations.[23]

We examined seven standard evolution textbooks and a book of evolution readings to see how they dealt with epigenetics and related concepts. One textbook had one noncommittal sentence on this topic.[24] Douglas Futuyma included about three-fourths of a page on epigenetics and assured readers that mutations are random and "there is no evidence that epigenetic 'mutations' are induced by environments in which the mutation would be adaptive."[25] One other book includes a couple of pages on epigenetic concepts but concludes that "environmentally induced changes in phenotype are not transmitted to future generations."[26] Neither provided evidence to verify these claims. A book titled *Macroevolution*[27] included a chapter by Futuyma with three pages on nongenetic inheritance (epigenetics). He concludes that epigenetic processes cannot play a significant role in evolution. He concurs with the conclusion that seeming directed adaptiveness must actually arise by some other process, and "the only known candidate process is the 'neo-Darwinian' action of natural selection" on random variation. He rejects epigenetics because it is not consistent with the accepted naturalistic theory. The other books had no reference to this subject.[28] Concepts now known as epigenetics have been published since the 1980s, but most scientists committed to the Neo-Darwinian Synthesis are ignoring the findings of several decades of molecular biology research.[29]

Four other books by authors who also hold the naturalistic evolution worldview take a very different position on this issue, fueling the controversy. All four propose that evolution occurs through this process of epigenetic decisions by cells and organisms, rather than by the Neo-Darwinian process of random variation, but they do not deal with the question of how this incredibly sophisticated system originated.[30] One says that how this system evolved is a mystery,[31] and another simply says that the system must have evolved in the Early Cambrian.[32] The book *Evolution: The Extended Synthesis* develops a theory of microevolution and macroevolution incorporating principles of epigenetics, presented above, in their extended synthesis.[33] We will discuss their theory and its broader implications for macroevolution in chapter 10.

Interventionist Modifications to the Theory of Microevolution and Speciation

Interventionist understanding of earth history includes some differences in the factors influencing the microevolution and speciation processes, compared to conventional theory. These interventionist concepts, we suggest, along with the new epigenetic insights can generate a much more realistic theory of how this process works.

Origin and Direction of Adaptive Changes

Naturalistic evolution. The genetic information for new variants within species ultimately arose by random mutations producing altered genes. As we have mentioned, mutations are random in relation to the needs of the organism, and most are deleterious and lower the individual's fitness or adaptation to its environment.[34] Natural selection eliminates the deleterious changes and preserves the available combinations that are best adapted in the organism's environment.[35] This would be a very slow process.

Interventionism. Complexity in plants and animals was the result of intelligent design. The high point of the complexity of life on earth was at the very beginning.

Organisms were designed with a genetic and epigenetic system capable of generating or turning on variability for physiological adaptations to changing conditions. It was designed to produce new species that are variations on existing, created themes. We suggest the first populations within each original species already had considerable variation, and the genetic/epigenetic system was capable of generating additional diversity when needed, to improve the adaptation of the species and to branch off into new species that are adapted to different habitats.

As a result of changes precipitated by the fall of mankind (Gen. 3), environmental changes resulted in cosmic radiation and other mechanisms that produced random mutations—actually random genetic damage. Since these random mutations are almost all deleterious, the damage must be controlled to prevent life from going extinct. Natural selection is the agent to eliminate the less fit individuals and assure that, on average, those which reproduce are the healthiest and best adapted to the environment in which they live.

Within each group of organisms, the microevolutionary origin of new morphological or behavioral variation has involved two basic components. **First** is selection of those individuals with alleles best suited to the environment, resulting in adaptation to changing conditions by the process of microevolution, as seen in the development of a dark coat by a rodent living on dark soil.[36]

The adaptation process described here involves not necessarily either an increase or a decrease in complexity of any species but just improved adaptation to the environment. This would involve the epigenetic turning on or off of existing genes, as triggered by environmental signals. New species characteristics might be generated by activation of formerly inactive genes.

Loss of Genetic Information

A **second** component involved in the origin of variation is the tendency toward loss of genetic information in organisms since their origin. Examples are loss of flight by some birds and insects and loss of sight by cave organisms.

Naturalistic evolution. An animal species has a certain amount of genetic material, some of which is absolutely vital for survival. Another portion of the genetic information is optional, including behavioral and physical traits that the species can lose or turn off and still be viable (fig. 8.8).[37] Which features fall in this latter category will be influenced by the environment.

Loss of flight would probably doom many birds to extinction. However, on an island with no predators, losing the ability to fly might not be a problem and could even be an advantage in a tropical storm that can blow flying birds out to sea. A number of species of flightless birds are known and most of these inhabit islands.[38] In this situation, flight is optional, illustrating how a certain amount of genetic loss is possible. Other possible examples of genetic loss and/or epigenetic inactivation are blind cave animals and parasites that lack a digestive system.

Interventionism. Interventionism accepts the explanations given above for flightless birds, cave-dwelling animals, and at least some parasites. We propose that loss of genetic information not only has been involved in these extreme cases but has been a subtle, pervasive part of the genetic/epigenetic change in animals and plants since their original creation. The following example of possible loss of information is probably more typical than the type of loss experienced by some parasites.

William Dilger studied the behavior of African lovebirds of the genus *Agapornis*, which are in the parrot family.[39] He arranged the species of lovebirds in an evolutionary sequence. At one end are species that do not have the specialized features of some

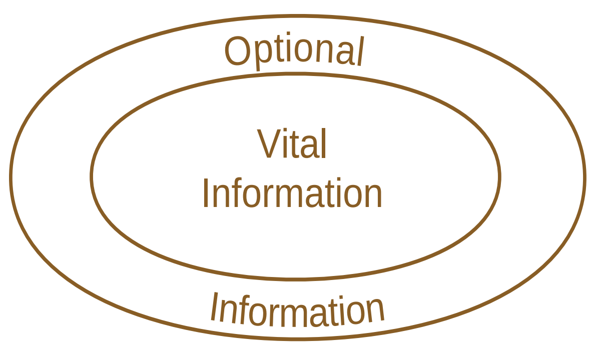


Figure 8.8. A representation of the total genome of a species and the core of vital genetic information necessary for life. Figure by Leonard Brand.

other lovebirds. They are plainly colored, have simple courtship rituals, and make a crude nest. The species at the other end of the family tree are more colorful birds that carry on a more complex courtship and build elaborate, covered nests.

If lovebirds originated by evolution from related birds, Neo-Darwinian principles require that the plain lovebird species, with fewer unique lovebird characteristics, were near the beginning of the family tree. The more specialized species were the most highly evolved. But how can we be so sure that the changes did not go the other direction (fig. 8.9)?

If we do not assume that all creatures have evolved progressively (in this instance, from another kind of bird), we also can consider the option that their evolution went the other way, starting with the created species having the most unique lovebird characters. As time has passed, varying amounts of genetic information has been genetically/epigenetically disabled in some of the other lovebird species, depending on the environment to which each population has been exposed. What has been inactivated

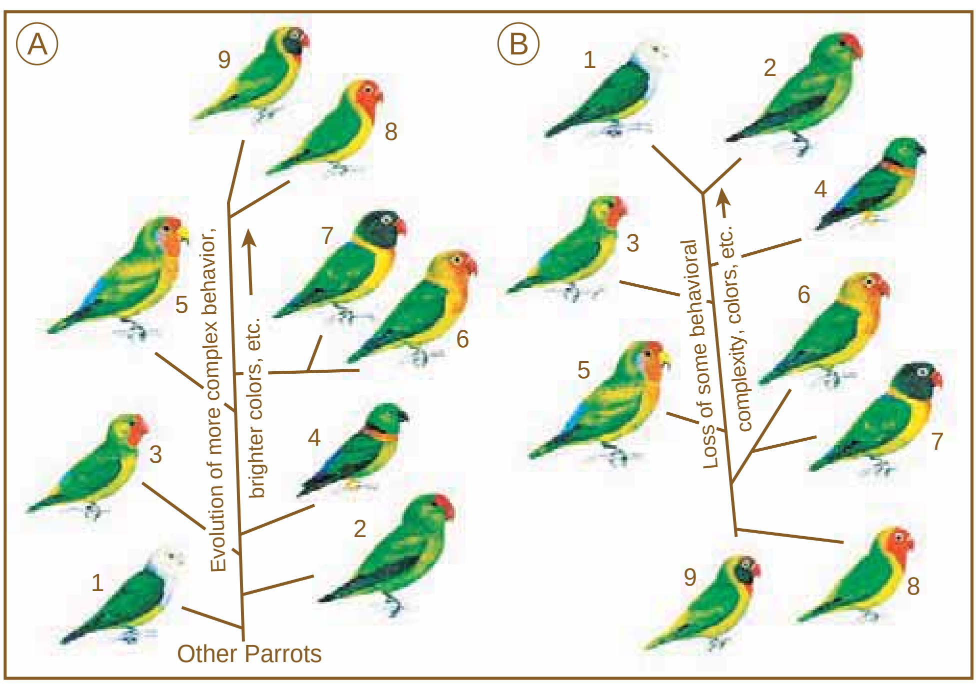


Figure 8.9. Two lovebird phylogenetic trees: (A) a conventional Darwinian tree and (B) a tree based on microevolution and speciation beginning with the most genetically advanced species (partly after Dilger 1962). Figure by Leonard Brand.

was some of the optional features not required for a viable lovebird.

Another example comes from many years of research on bacteria by microbiologists. There is a vast complex of bacterial species, and it has become evident that genetic changes known to have occurred in bacteria are primarily from loss of genetic information or a degradation of the genome or, to a lesser degree, from horizontal transfer of genes from other bacteria rather than from development of new genes by evolution.[40]

We argue that organisms today are, on the whole, less complex and less adaptable, and interactions between organisms in ecosystems are less finely tuned than at the beginning of life on earth. In most cases, natural selection tends to slow down the loss of information that results from damaging mutations.

The result of the above-postulated process of genetic loss is that while lovebirds may have been divided into many more species, the tendency is still toward reduction of functional information. Many species are highly specialized (less adaptable) and live only in a narrowly defined ecological niche. This specialization may be accompanied by loss of features or abilities that are needed by more generalist species. Ralph Hinegardner indicates that species with lower amounts of DNA tend to be more specialized.[41] Exceptions to this trend occur, which may indicate that some genes are turned off, not lost.

Since the original creation of organisms, populations that were originally adaptable with a high level of genetic information have often divided into a number of highly specialized species, possibly with less functional or active genetic information per species.

This multiplication of specialized species is not just the latest minor episode in the history of life but a major part of the change that has occurred since life began on this earth. Figure 8.10 illustrates the basic differences between the two theories.

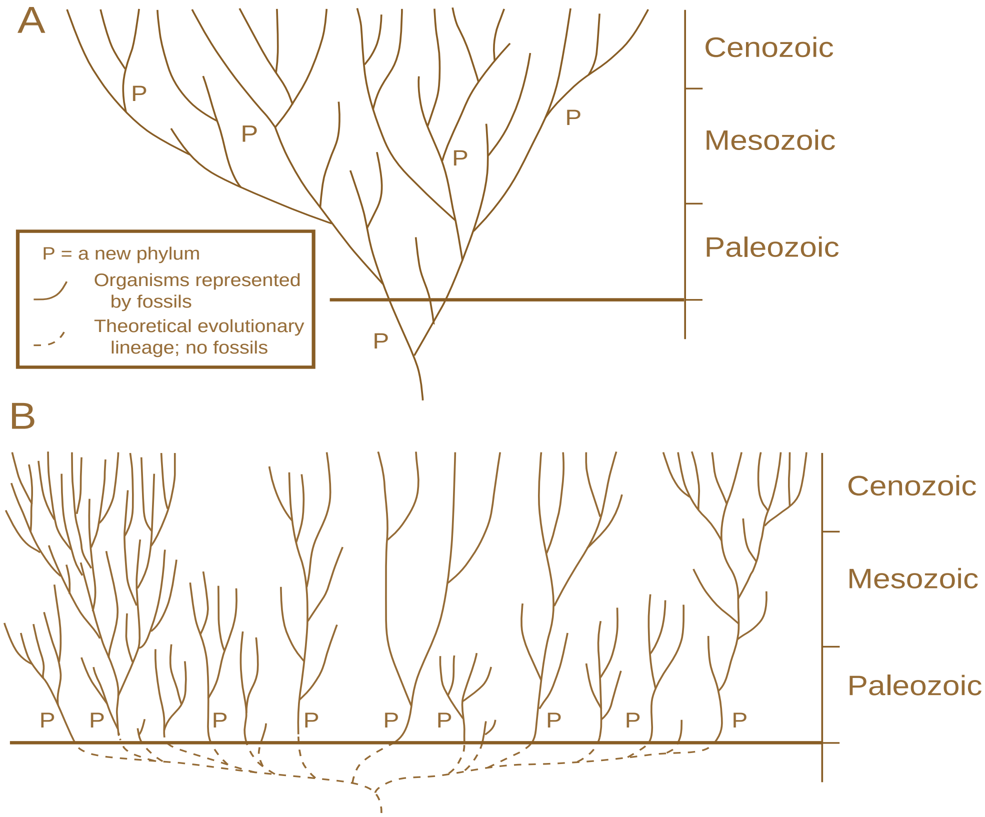


Figure 8.10. (A) A reasonable expectation for the pattern of evolution, with small changes gradually resulting, through time, in the origin of new phyla. (B) The pattern seen in the fossil record, with virtually all phyla present in Early Cambrian sediments. The diversity of phyla is highest at the beginning of the fossil record. This is compatible with independent origins of major groups, followed by speciation within groups (Brand 2006a).

Natural Selection

Both naturalistic evolution and informed intervention recognize natural selection as an important factor in the microevolution process, but the specific role of natural selection differs in the two theories.

Naturalistic evolution. The naturalistic, Neo-Darwinian theory of evolutionary change begins with the random raw materials provided by mutation and recombination. Natural selection is the key process that rises above the randomness of mutation and selects the appropriate features to improve the adaptiveness of species. Even though most mutations are harmful, natural selection is effective in eliminating most destructive mutations and preserving beneficial ones. Consequently, the proposed net effect is upwards toward improved adaptation to the environment and the eventual evolution toward macroevolution of new genes, new structures, and fundamentally new organisms.

Interventionism. The interventionist theory recognizes natural selection but suggests that the balance of forces is different. Edward Blyth anticipated Charles Darwin's theory of natural selection, but Blyth was not an evolutionist. He viewed natural selection as a conserving force, maintaining the species by eliminating the weak individuals.[42] Lane Lester and Raymond Bohlin have suggested that Blyth was more correct than Darwin and that evolutionary change occurs only within limits.[43] Interventionism suggests that mutation and natural selection are not able to produce an increase in complexity by generating new genes and organs. The epigenetic system facilitates adaptation in response to environmental cues, within the constraints of their original genetic potential. Natural selection acts as a brake to slow down the slide toward oblivion that would occur if the accumulation of harmful mutations were not held in check. The net evolutionary change is slightly downward.[44]

This theory of natural selection is not a new or radical idea. It does not seem to go against the data that are available. There are noninterventionist scientists who question whether natural selection can actually do some of the things that the Neo-Darwinian Synthesis maintains that it does.[45] They are not suggesting that animals were created but that the traditional process of random point mutation and natural selection is not the process that generates significant evolutionary change. Interventionist theory takes the conclusion further. It recognizes that microevolution does occur but questions whether mutation and natural selection are able to generate any significant new structures and complex life. We will pursue this issue in chapter 10.

Evolution Rate

How rapidly do microevolution and speciation occur? There have been differences between creationists and noncreationists in understanding how fast microevolution can occur, but the differences are disappearing because of new data.

Naturalistic evolution. For Darwin and his followers, all new variability must ultimately be the result of random genetic changes. If that is true, evolution will be a very slow process. However, in the last decade or two it has become evident that microevolution actually happens rapidly.[46] Introductions of monkeys, birds, copepods, and moths to new geographic areas have produced change equivalent to new subspecies or species in time spans of thirty to one thousand years.[47] Experimental studies show that rapid change can occur in animals introduced into a new environment.[48]

Interventionism. Rates of evolution observed today (microevolution and speciation) are from seven to ten orders of magnitude faster than the rates calculated from the fossil record as dated by radiometric dating methods (fig. 8.11). Acceptance of the radiometric time scale would require one to conclude that observed modern evolutionary rates do not reflect reality.[49] However, acceptance of a geology theory with time since creation of only thousands of years means that rates of microevolution and

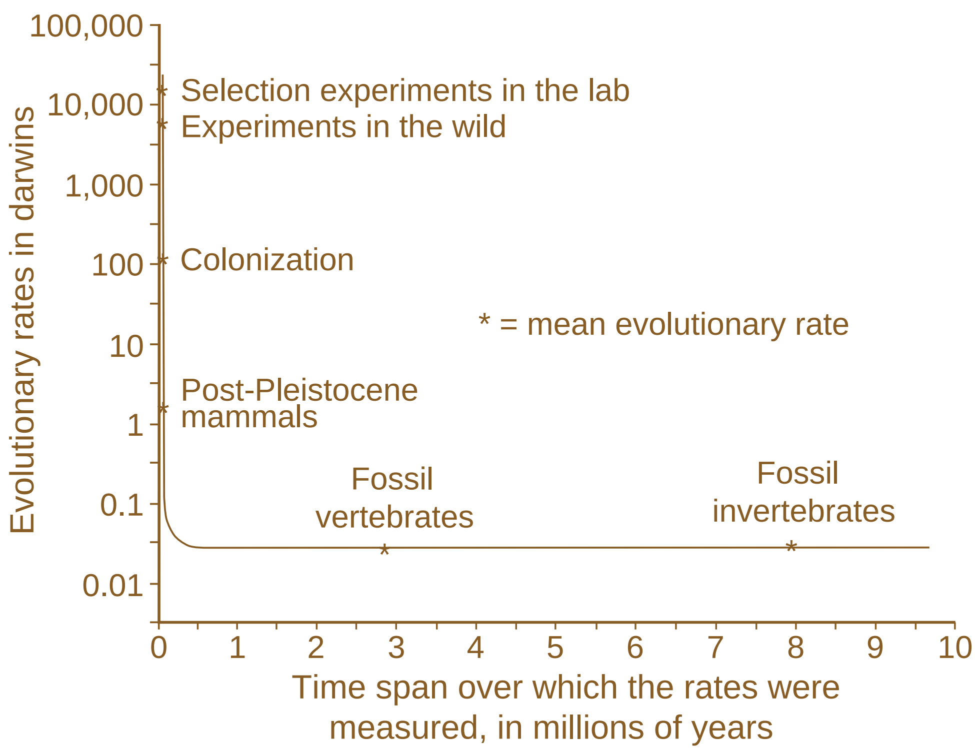


Figure 8.11. Comparison of rates of evolutionary change, expressed in units called Darwins. The rates of change seen in modern experiments and rates of change seen after animals colonize new islands are orders of magnitude faster than rates of evolution calculated from the fossil record (dependent on radiometric dates). Data from Gingerich 1983; Reznick et al. 1997.

speciation in the past may have been as fast, and quite possibly much faster on average, than the rates measured today.[50]

Even though interventionists are often thought of as antievolutionists, the fact is that short-age interventionists believe in a far more effective and rapid process of morphological change than noninterventionists. They have a shorter time period for the evolution of a large number of species and genera of organisms. We propose that this is realistic. First of all, the major taxa were in existence from the beginning. All that is required is a process of diversification and changing adaptations within each taxon. These changes do not depend on novel traits evolving through random mutation and natural selection. Rather, change begins from the high level of genetic potential that was created in the beginning, followed by some loss of information, differential gene expression, and epigenetic changes in response to the environment. The created complex of DNA and the epigenetic system respond to the environment by activating the appropriate combination of traits that are available in the organism's created genome. This scenario results in much more rapid microevolution and evolution than Darwin could have ever imagined.

Geological Catastrophe, Microevolution, and Speciation

According to the theory presented here, much of our current taxonomic diversity has been the result of limited evolutionary change after a global catastrophe. The original groups of plants and animals have diversified into multitudes of species as they adapted to fill specific niches in the seriously changed conditions after the catastrophe. If we consider such conditions and compare them with factors that are known to favor rapid genetic change, we find that they would be ideally favorable for rapid change (table 8.1).

Table 8.1. Factors suggested to result in rapid microevolution and speciation after the global flood catastrophe

1. *An abundance of potential unoccupied niches to which organisms could adapt*. Animals that have successfully colonized islands, especially groups of islands, have often developed a large number of species. Examples include the numerous species of fruit flies and honeycreepers of Hawaii. Apparently this speciation is facilitated by open niches and the resulting lack of competition (Ford 1964, chap. 2).
2. *Before the development of mature, balanced ecosystems, population dynamics would be unstable*. This situation would result in flush/crash population dynamics: Populations of animals expand, with all genotypes surviving, until they use up their food supply or until expanding predator populations catch up with them. The resulting population crashes produce the population bottlenecks (a time with few individuals in the population) favorable to speciation. Those individuals best adapted to particular niches have the best chance to survive the crash. Several, or many, species could be created simultaneously by a series of such cycles (Carson 1975; Mettler et al. 1988, p. 295).
3. *Rapid geologic and environmental changes would favor the separation of organisms into isolated populations, facilitating speciation* (Mayr 1970). This might have been particularly important for aquatic organisms, plants, and terrestrial invertebrates, which would likely have survived the global catastrophe in many scattered, isolated pockets. As the animals moved out over an empty world after the catastrophe, almost limitless opportunities would open up to occupy available new niches and to speciate. In this situation, ecosystems initially would have been simple and relatively unstable. Until mature ecosystems developed, many population fluctuations would likely occur. These, along with rapid geologic changes in the recovery period after the catastrophe, would divide animals into smaller populations. The result would be a potential for very rapid rates of biological change after the global catastrophe (perhaps the most favorable situation for speciation we could imagine). The amount and rate of change would slow down as environments and population dynamics stabilized, available niches were filled with increasingly specialized species, and ecosystems became more complex and balanced.

One result of such a global flood is the introduction of population bottlenecks into some groups of animals. This is a possible challenge for the theory of postcatastrophe evolution because of the expected loss of genetic variability in those species with small numbers of individuals surviving the catastrophe. This leads to the suggestion that some mechanisms (perhaps part of the epigenetic system) must exist that rapidly increase genetic variability after a population bottleneck. Observations of much higher genetic variability than expected after experimental or natural bottlenecks provide some evidence for the existence of such mechanisms.[51] Environmental or genetic stress apparently produces genetic instability with increased rates of recombination and modification.[52]

We suggest that most of the numerous modern (Holocene) species of animals may have evolved very rapidly after the global catastrophe.[53] For the reasons given above, we propose that interventionist theory is more effective in explaining the evidence than any conventional naturalistic evolution theory and is especially effective in explaining the recent evidence that microevolution can occur rapidly, within a few years.

CHAPTER 9

Can a Creationist Accept the Process of Evolution?

Overview

Can a Christian fit microevolution and speciation with belief in the biblical account of creation and earth history? This chapter evaluates this in light of what the Bible says and what we see in the biological evidence. We conclude that these biological concepts are compatible with Scripture. The evidence suggests that the amount of change has included microevolutionary adaptations to the environment, new species and genera, and possibly some new families.

Microevolution and Speciation since Creation?

At the end of creation week as described in the book of Genesis, there was a balanced ecosystem in existence, with fish; birds; reptiles; creeping things (invertebrates); mammals, including humans; and the plant world, including fruit trees (angiosperms or flowering plants). These organisms did not arise by macroevolution but were invented and brought into being by instantaneous creation. Do we have biblical reason to believe God can do this? The Bible claims He does, and when Jesus was on earth, He healed people instantly and raised the dead. This involved instant creation of live tissue, including healthy nerve pathways and information processing centers for a person born blind. God is well able to do what He claimed. But what about microevolution and speciation? Does this really occur?

Charles Darwin saw evidence for microevolutionary changes in animals and plants. This led him to reject the rigid creationism of his time, with its fixity of species. He also believed new species form, but his theory didn't discuss how that happens. The interventionist of today believes Darwin and some of his contemporaries made a mistake in equating belief in creation with a belief in the fixity of species. Several lines of reasoning lead us to reject the idea that all species were created as they now exist. The variation we observe in domestic animals tells us the genetic system is capable of considerable change. Selective breeding has produced dogs ranging from Pekingese to Saint Bernards, chickens with twelve-foot-long tail feathers, and horses varying from the impressive Clydesdale and other working breeds to a dog-sized miniature. This evidence, by itself, does not demonstrate that the same thing would happen in nature, but it does show that the genetic potential for a lot of microevolution is present. We have seen microbes develop immunity to antibiotics, by the process of microevolution, resulting in consternation of medical practice.

The interventionist also must explain another type of evidence—the origin of parasites and other destructive forces in nature. Many parasites are highly modified in their anatomy and physiology for their dependence on parasitism as a way of life. The idea that a benevolent God would create these repulsive, destructive things in nature greatly bothered Charles Darwin, and rightly so.[1] The old concept of the fixity of species made God responsible for everything in nature, both good and bad. A more consistent interventionist approach suggests that God designed

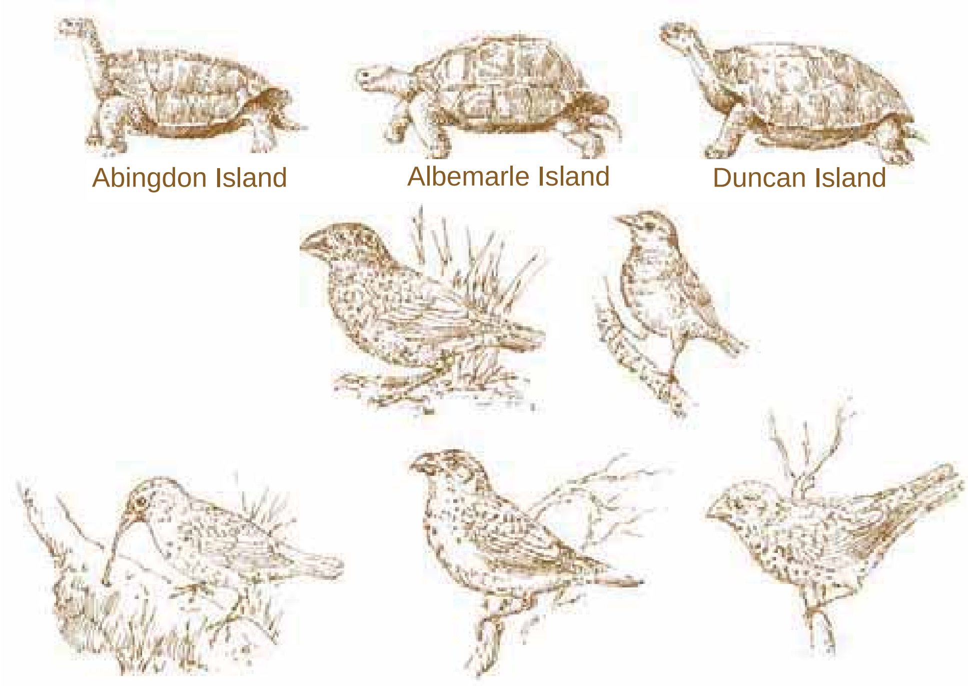


Figure 9.1. Several species of Darwin's finches and giant tortoises from the Galapagos Islands (after Stebbins 1971). Figure by Robert Knabenbauer.

nature to operate harmoniously and that some features of the biological world have developed through evolution after creation.

After Darwin returned from his visit to the Galapagos Islands, he realized that the finches and the giant tortoises were somewhat different on each island (fig. 9.1).[2] This and other cases like it led him to propose that God didn't make a different species on each island, but each species developed by evolution. Research since his time supports this concept.

Of the twenty-two species of chipmunks in the United States, thirteen appear in California. The differences between them (fig. 9.2) are quite small, involving variations in color patterns, size, behavior, ecology, and bone proportions. Some have white tips on their tail hairs, and others have yellow tips. Some have bright and contrasting stripes, while others are less contrasting. Their chipping calls are different enough that, after some practice, one can identify them by their calls alone.[3] Some live in open forest, while others prefer dense brush or forest with considerable brush and logs. Certainly the differences

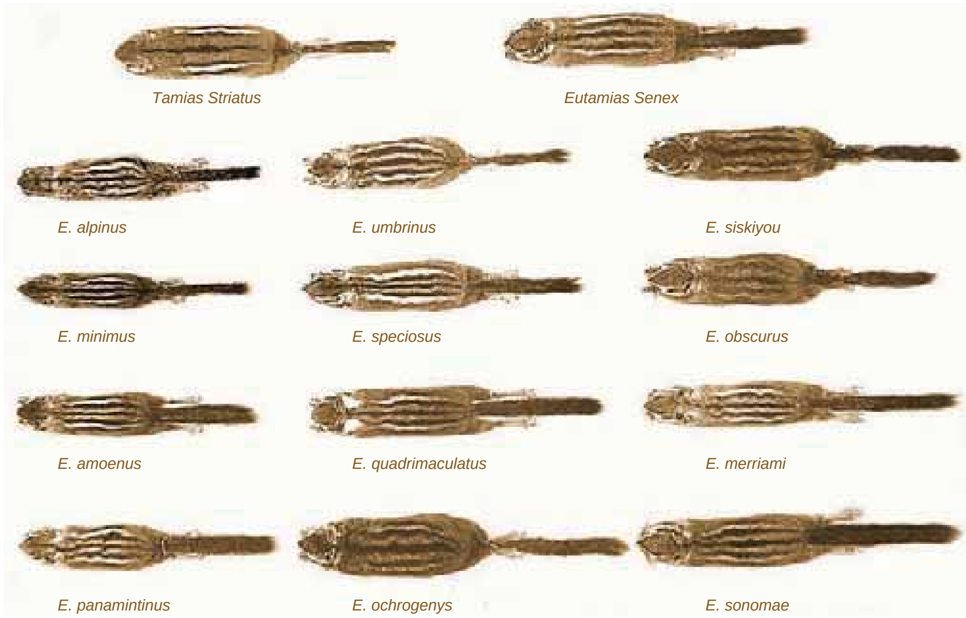


Figure 9.2. The thirteen species of chipmunks from California and the eastern chipmunk, *Tamias striatus*. Courtesy of Mark Ford.

between these chipmunk species are much less than the differences between many breeds of dogs. But since the different chipmunk populations do not interbreed, they are different species.

We also find that each species has its own geographic range (fig. 9.3). *Eutamias sonomae (note: some biologists now put all western chipmunks in the genus* Tamias*)* appears only in the chaparral brush of northwestern California. *E. panamintinus* is found only in the semidesert pinyon pine forest east of the Sierra Nevada Mountains, and *E. alpinus* is limited to rocky mountain meadows above the nine-thousand-foot elevation in the Sierra Nevadas.

Did God make these chipmunk species and put them where they are? Certainly He could have done so, but the evidence seems to imply otherwise—that He made each group of animals with a defined potential for genetic variability: the ability to adapt, through microevolution and speciation, to new habitats and climatic changes they would encounter after they were created. This is reinforced even more if we take seriously the possibility of a global geological catastrophe and recognize that the mountain ranges and climatic conditions that determine chipmunk

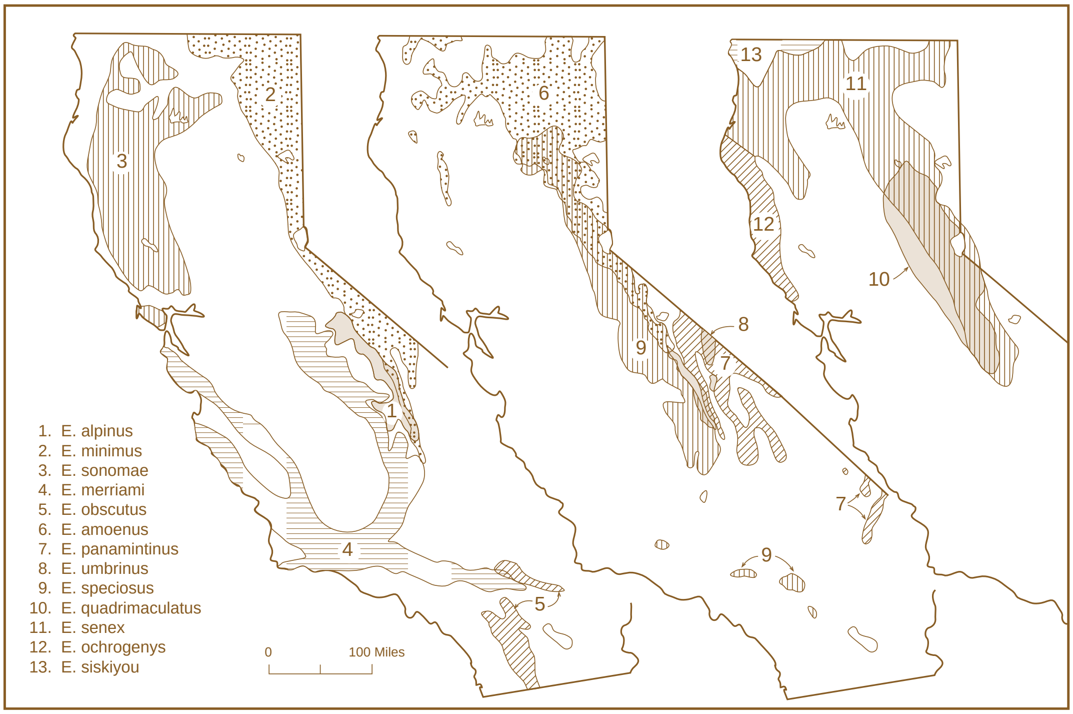


Figure 9.3. Geographic ranges of chipmunks in California (after Hall 1981; Johnson 1943). Figure by Carole Stanton.

distribution and adaptations did not even exist in their present form until after the catastrophe. Perhaps, after the catastrophe, the original chipmunks spread through Asia (one species does exist there) and into North America where groups of chipmunks colonized many different areas and these groups simultaneously adapted to their local conditions to produce the twenty-two species. When one species, such as the ancestral chipmunk species, gives rise to several new species as different populations adapt to different ecological niches, the process is called adaptive radiation.

The word "evolution" (from the Latin *evolution*, meaning "to unroll or unfold") as used here means change. Good evidence indicates this genetic process of evolution (or some variation of it) does occur and produces new varieties and new species. Of the many similar examples we could examine, let's look briefly at just one more—the meadow mice, or voles. These little, short-eared mice exist worldwide and live predominantly in grassy areas in systems of tunnels they chew through the vegetation.

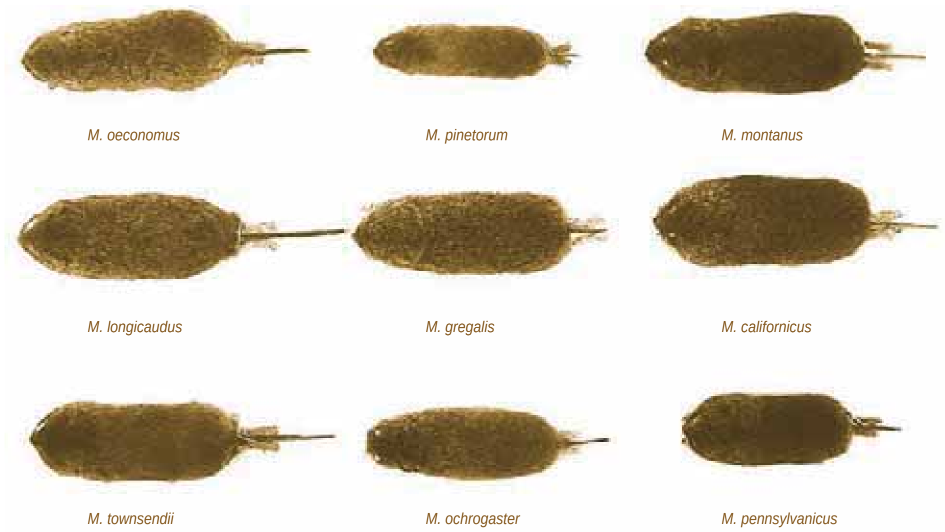


Figure 9.4. Several species of voles in the genus *Microtus*. Courtesy of Mark Ford.

Figure 9.5. Several genera of voles. The genera *Lemmus* and *Dicrostonyx* are lemmings from the arctic region. Courtesy of Mark Ford.

The most famous voles are the lemmings in the Arctic. A few of the many species of voles in the genus *Microtus* are shown in figure 9.4. They are all quite similar—as similar as the species of chipmunks. Further investigation reveals a number of genera of voles not much different from *Microtus* (fig. 9.5). They are classified in different genera because each has certain characteristics consistently different from *Microtus* and from each other, but these differences are still relatively minor. They include variations in the cusp patterns on the grinding surfaces of the teeth, differences in the characteristics of toes and

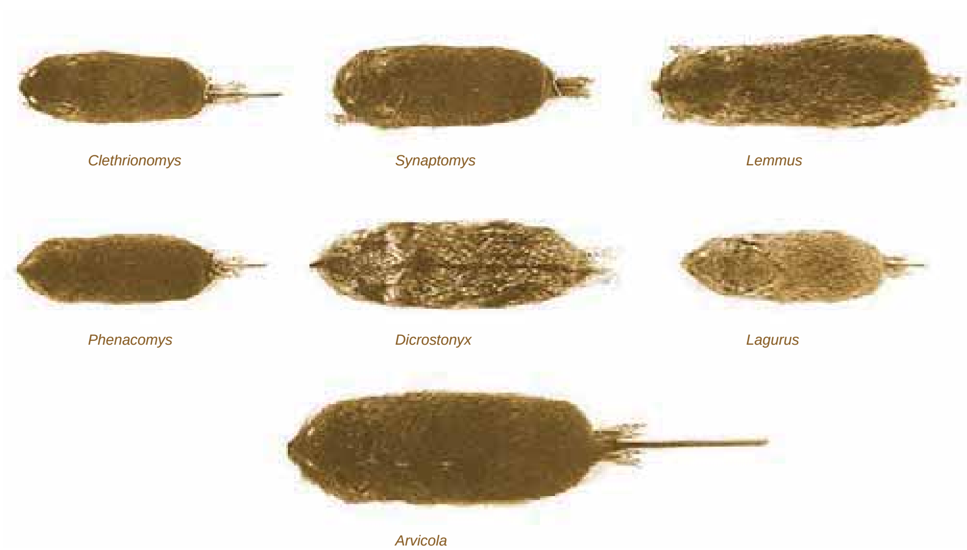


Figure 9.6. Relatives of the voles, the round-tailed muskrat (*Neofiber alleni*) and the muskrat (*Ondatra zibethicus*). Courtesy of Mark Ford.

claws, minor differences in the proportions of anatomical features, and some differences in their molecular biology. It is conceivable that all of these genera developed from one created ancestor, especially considering the new insights from study of epigenetics. Even the muskrat and the round-tailed muskrat are in the same subfamily as the voles. They are different mainly in size and in a few adaptations for life in the water (fig. 9.6). Could they have originated from the same created ancestor as the voles? Perhaps so.

But Didn't Moses Say . . . ?

Some may raise the objection that the Bible says God created the animal species as they are now. The only Bible statements that might be interpreted that way are the "after his kind" expressions in some Bible translations. But one cannot demonstrate that the phrase "after his kind" was intended as a technical genetic statement meaning that every species would be unchanged. It more likely indicated that offspring would be similar to their parents. Also, the phrase "after his kind" is used only once in connection with the order to multiply, and it is interpreted that way only in some translations (Gen. 1:11–12, KJV).

The rest of the time it is used in connection with the statement that something was created or in reference to the types of animals entering the ark.[4] The original Hebrew phrase can be translated in more than one way. Some modern English translations use the more easily understood statement “God made the various kinds of wild beasts of the earth” (Gen. 1:25, AAT) rather than the somewhat awkward “God made the beast of the earth after his kind” (Gen. 1:25, KJV).

The fact that the major groups of organisms were present at the end of creation week, including supposedly highly evolved types like flowering plants (fruit trees) and human beings, indicates that macroevolution is not compatible with biblical interventionism. However, Genesis does not seem to have anything to say against microevolution and, perhaps, even some aspects of macroevolution, at least to the development of new genera. Such is certainly implied in the words God spoke to Adam after the fall: “Then to Adam He said, ‘Because you have heeded the voice of your wife, and have eaten from the tree of which I commanded you, saying, “You shall not eat of it”’: ‘Cursed is the ground for your sake; In toil you shall eat of it All the days of your life. Both thorns and thistles it shall bring forth for you, And you shall eat the herb of the field. In the sweat of your face you shall eat bread’” (Gen. 3:17–19, NKJV). Scientific evidence is strong in favor of microevolution and speciation, and the Bible does not speak against them. Interventionists today have no reason to doubt their validity. They are incorporated as a part of “intervention theory.”

One can only wonder what would have happened in biology during the last century if Darwin had read his Bible more carefully and learned that the Bible does not rule out the evolution of new species. If he had developed a theory of evolution within the limits of the created groups, would science have been as successful as it has been? Probably so, or perhaps even more successful.

Interventionists and other scientists can agree on microevolution, speciation, and some macroevolution.

Thus research in these areas would be unaffected by the researcher's philosophical preferences. The interventionist disagrees on the question of macroevolution and proposes limits to the changes that evolution can produce. Some researchers are asking, "What are the limits of evolutionary change?" "What were the limits of the original independent groups?"[5] The naturalistic evolution theory does not ask such questions. It assumes that all plant and animal groups could have arisen and did arise by evolution.

The limits of evolutionary change are not easy to define due to the uncertainty we encounter in the study of things that happened in the more distant past. Still, it is a question worth trying to answer. The Bible does not give much specific information to help us determine how much evolutionary change has occurred since creation. On this topic, like many others, the Bible only gives the important principles to guide our thinking and leaves the details to challenge our curiosity.

Some claim that if we accept microevolution, we have no reason to question macroevolution—the evolution of major groups of organisms. Is that true? If we accept microevolution, does that lead to acceptance of the evolution of everything? Not necessarily. How much change can be produced by the Darwinian process (mutation and natural selection)? These questions will be discussed in chapter 10.

Persons who write anticreation literature often assume that creationists still believe in fixity of species, but this is based on their lack of acquaintance with the thinking of educated interventionists. We do not sneak microevolution and speciation into our thinking because of ignorance but consciously accept it from careful analysis of the strength of, or weakness of, evidence for different parts of the theory of evolution. Anticreation writings would be more credible if the authors made a meaningful effort to understand the thinking of educated creationists.

How Much Change Does the Evidence Suggest?

The evidence suggests that quite a bit of speciation and morphological adaptation has occurred within created groups. The reinterpretation of evolutionary genetics presented in this book is proposed as a step toward understanding the process of change that brought life from the original created state to its present adaptation to modern conditions. We propose that these created genetic mechanisms are adequate only to diversify and adapt life within the original created taxa.

It appears that the limits of these changes are not at the species level. Because of the subjectivity involved in defining higher categories in different groups of organisms, it is not possible to consistently define the limits of the original groups of animals and plants in terms of one specific taxonomic level such as family or genus. The distinction between a genus and a family of squirrels and between a genus and a family of beetles, for example, may not be equivalent. Preliminary analysis suggests that, on average, almost all modern species, probably most modern genera, and perhaps some families have resulted from modifications of the originally created species.

Frank Marsh proposed that a created group, which he called a "basic type" or "baramin," would include all individuals or species that are able to hybridize.[6] Scherer edited a volume summarizing the available hybridization data, and fourteen basic types that seem to emerge from these data, if we accept Marsh's proposal.[7] These basic types are at the tribe, subfamily, or family levels. Some representative examples of these basic types are the family Canidae (dogs, wolves, foxes, jackals; 15 genera and 34 species), the family Equidae (horses; 6 species), the family Anatidae (ducks, geese, and swans; 148 species), the family Estrildidae (estrildid finches; 49 genera and 131 species), and the family Phasianidae (quail, turkeys, pheasants; 34 genera and 203 species). Hybridization data are available for only a small portion of the animal and plant families, and much more research could be done.

Interventionists are also developing other approaches in the study of biochemical and other systematic evidence to analyze the probable boundaries of the original, independently created groups.[8]

A study of foxes begun in the 1950s at an experimental fox farm in Siberia has yielded fascinating results and contributed to a new theory of the evolution of domestic dogs from wolves.[9] Foxes are bred for their fur on fox farms, but the foxes' aggressive dispositions made them difficult to work with. Professor Dmitry Belyaev began an experiment, selecting foxes for only one feature—tameness. Using a consistent procedure to test their reaction to humans, he selected the individuals that were tolerant or curious in response to his close approach. Only these individuals were allowed to breed. Within about a decade this resulted in a population of tame foxes, and the tameness was inherited by each generation. The unexpected result was that even though they were only selected for one feature, tameness, they not only became tame, but they also changed physically. New coat colors appeared, including mottled and black and white patterns. Their ears became droopy like many dogs, they began to bark like dogs, and they changed from an annual reproduction cycle to breeding twice a year. It appears there is genetic linkage between such features as adrenaline and melanin and others. Epigenetic research suggests that these changes involved heritable, nongenetic (epigenetic) activation of genes controlling color.[10] Epigenetic processes would help explain why the changes occurred so rapidly.

This result supported Raymond Coppinger's theory on the origin of dogs.[11] Based on his career of research on dogs and wolves, he doubted that ancient people caught baby wolves and tamed them. Doing this with many wolves for many generations would be a daunting, if even possible, task given the persistent natural genetic wildness, intelligence, and independent spirit of wolves. In addition to that problem, people who had never seen a dog would have no insight into what possibilities could result from taming wolves. Coppinger's theory is that when humans settled in villages this would result in garbage dumps, a potential new source of nutrition for animals, including wolves. But the wolves' natural fear and tendency to quickly run far away when people appear would minimize their ability to utilize garbage dumps. If some individual wolves had a shorter flight distance and were more tolerant of a human presence, they would have a very strong selective advantage that could naturally, in time, result in a population of genetically tame wolves without the people doing anything to bring this about. Coppinger suggests that this process, comparable to the changes in the foxes, could have resulted in the origin of dogs in a single human lifetime.

These changes within created groups involved epigenetic processes, mutations and natural selection, loss (or turning off) of some genetic information, and resulting adaptation to changing environments. Epigenetics and changes in regulatory genes have probably been an important factor in making rapid change possible. Could even the series of fossil horses have resulted from these processes?

This interventionist theory has a number of implications for the genetic system, along with suggestions for future research. An obvious implication is that with adequate genetic variability and changing environments, morphological change and speciation can occur rapidly—even orders of magnitude faster than has been commonly believed, but within limits. Animal populations that are well adapted to their environment would not be expected to change, but rapid evolution within limits is seen as the normal expectation under some environmental conditions.

The Hawaiian Islands are the longest and most isolated island group in the world, a chain of volcanoes, rising from the floor of the Pacific Ocean, more than 3,500 kilometers from the nearest land mass. Even more so than the Galapagos Islands, these islands are an ideal laboratory for consideration of the processes of evolutionary change. For example, there are more than five hundred species of fruit fly in the Hawaiian Islands, all in the genus *Drosophila*, the common fruit fly that can be seen hovering over ripe bananas in homes today. These fruit flies are all endemic to the islands (not found anywhere else). Where did all of these diverse forms come from? How did they get to the Hawaiian Islands? Why are they found only there?

It is presumed that a single gravid female *Drosophila* arrived there by chance, perhaps being carried aloft by a storm, or arriving on floating vegetation and finding a rich environment with many unexploited niches. Generations of offspring adapted rapidly to fill those niches, producing over time the hundreds of different kinds of *Drosophila* that are found there today. There are no known examples of fruit flies that have become other kinds of flies or insects. Fruit flies have also been the subject of decades of laboratory mutation studies, and they are all still clearly fruit flies. So with fruit flies, the genus appears to be the stable element, with change occurring only within the genus. But within this genus is an enormous variability displayed in the many different species found there. Fruit fly evolution all falls within the category of microevolution and speciation.

Similarly, a relative of the California tarweed, a weedy composite, must have floated to Hawaii, perhaps as a seed or a raft of seeds. It has likewise diversified in the uncrowded Hawaiian environment to form a variety of genera, in this case, that look very different today. *Argyroxiphium*, the silversword is a well-known genus found principally on the rim of the Haleakala Volcano in eastern Maui. It has the appearance of a yucca, with a tall flowering spike, but with sunflower type composite blooms. *Wilkesia* is a related genus found in western Kauai. In appearance, it is much like the silversword but is green and appears more fragile than the silversword. *Dubautia* is a related genus, also with sunflower-type blooms, that grows with the habit of a vine. For these plants, the family is the coherent element. All of these genera are in the family Asteraceae, and no genus outside of that family is believed to have been derived from the speciation of this group. Many other examples occur in the Hawaiian Islands that record speciation, but all such changes have been within the limits of a family.

All of this evidence leads us to the conclusion that microevolution and speciation are very real processes in nature, and the data are readily interpreted within interventionist theory. They are also consistent with the interpretation that Genesis is a factual account of earth history.

Are microevolution and speciation real processes?

DATA

There are groups with very numerous species, apparently a response to specific modern environmental situations. There is evidence of broad genetic potential as seen in domestic animals, observations of microevolutionary changes as observed in development of immunity of microbes to antibiotics and in many other examples.

INTERPRETATION

Assumptions: None required.

Both interventionism and naturalism conclude that microevolution and speciation are supported by abundant evidence; there is a mechanism to accomplish these changes.

CHAPTER 10

Challenges to Macroevolution

Overview

How well does the existing biological evidence support the Darwinian theory of macroevolution—the naturalistic origin of major taxonomic groups of organisms like classes and phyla? There is solid evidence available in evolution publications that supports microevolution and change within families. Concepts of origin of major groups by evolution are much more theoretical and dependent on the assumption of naturalism. Macroevolution theory faces many serious challenges, especially with the rapid growth of knowledge of biochemistry and molecular biology in recent decades. The challenges come not just from interventionists but from within the ranks of more conventional scientists. A growing number who accept the general concepts of evolution from common ancestors challenge the ability of Darwinian random mutations and natural selection to account for origins of new animals and body plans. A successful theory of macroevolution will need a different process. A few simply say that how the genetic system evolved and how life began is a mystery. Study of epigenetics (genetic processes outside of the DNA that manage the DNA) is providing new insights and challenges to Neo-Darwinism.

What Is Macroevolution?

In chapter 8, we defined microevolution and macroevolution, but we will define further what we see as the difference between them. Microevolutionary adaptations and the origin of a new species within an existing genus do not involve any new structures or physiological systems and probably do not require evolving any new genes. It is just variation within the existing genome. In contrast, macroevolution, the evolution of a new body plan, a new class or phylum of organisms, involves new genes and new body structures. Our question here is whether this level of evolutionary change is supported by the evidence.

Evidence for Macroevolution? Claims and Critique

We have described an interventionist theory of limited genetic change. Now we must return to the question of whether the genetic evidence provides an adequate theory to show that macroevolution can happen. If microevolution occurs, does this demonstrate that macroevolution also occurs? What types of evidence provide support for, or pose a challenge to, the proposal that there is an adequate process of macroevolution that can explain the origin of phyla and classes of organisms?

One possible answer is that the fossil record shows a sequence of appearance of organisms that is consistent with the theory of macroevolution—there are only invertebrates and fish-like vertebrates at the bottom of the Cambrian, and then fish, amphibians, reptiles, mammals, and birds appear in that order, just as might be expected from a pattern of increasing complexity, giving support to the macroevolutionary origin of life forms. But it can also be argued that this answer is not adequate to eliminate the alternate explanation—separate creation of different body plans.

The fossil sequence (fig. 10.1) might be explainable by other processes besides evolution. Marine animals are common all through the fossil record. As we examine the higher Paleozoic strata, there is a shift in the ecological settings

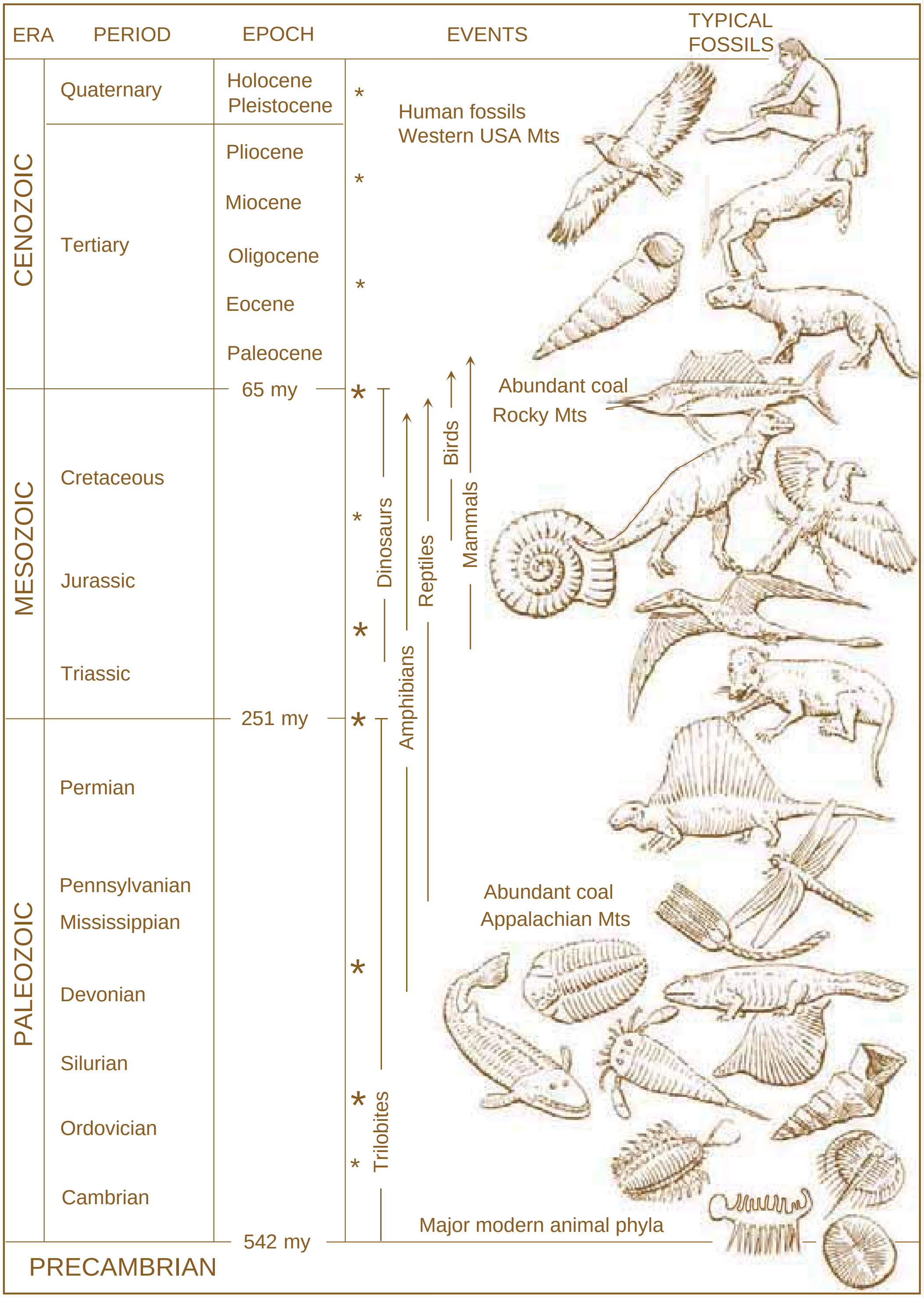


Figure 10.1. The geologic column and the standard geologic time scale. Large and small asterisks indicate major and minor mass extinctions in the fossil record. Figure by Robert Knabenbauer.

represented by the fossils; the marine animals are joined by progressively more land-dwelling animals. Also as we go up through the fossil record toward the more recent fossils, there are animals with increasing intelligence and adaptability. In a geological catastrophe, for example, these factors could possibly influence the order in which the vertebrates are killed and buried. In addition, there is always the possibility that the Creator interacted with nature in some unique way that produced this sequence. The point is that if we are willing to pursue an open search for truth, and are at least willing to consider the possibility that there might be a Creator, we have to consider the option of a nonevolutionary explanation for the fossil sequence. Consequently the sequence of fossils by itself cannot demonstrate whether Darwinian mutation and natural selection can and did evolve genuine biological novelties (new structures or body plans). Some other evidence besides the fossils is needed to tell us how much change resulted from evolution—preferably genetic evidence.

The multiple working hypotheses that seem to be under consideration at this time include at least the options listed in table 10.1.

Table 10.1. Multiple working hypotheses for the nature of evolutionary change

1. All major groups of animals and plants arose from a common ancestor by the Darwinian evolution process: modification by random mutation and natural selection. We can call this traditional Darwinism.
2. All life has descended from a common ancestor, but not by the Darwinian process of random mutation and natural selection. Some other genetic process is needed to explain macroevolution and maybe even microevolution.
3. Macroevolution does not occur. The various phyla or body plans originated by creation. Microevolution and speciation has been occurring by Darwinian random mutation and natural selection after the creation event. This applies traditional Darwinism at the level of microevolution.
4. Macroevolution does not occur. The various phyla or body plans originated by creation. Microevolution and speciation has been occurring since the creation event. Random mutations do happen, but microevolution requires a more sophisticated genetic process than Darwinian random mutation and selection.

The rest of this chapter will discuss the available data and interpretations as understood by interventionists (hypotheses 3 and 4 in table 10.1) and also as presented by conventional evolutionary scientists (hypotheses 1 and 2). The growing body of evidence is generating constructive controversies over how to explain the evidence.

If there is sufficient genetic evidence to help us evaluate the hypothesis of macroevolution, we might expect it to be described in a good evolution textbook. In two well-respected evolution textbooks, there is abundant evidence supporting the reality of microevolution and speciation.[1] They also discuss patterns in the fossil record, biological adaptations, and a large amount of other material they incorporate in explanations of macroevolution processes. However, careful analysis of these explanations reveals that they are dependent on the *assumption* that life is the result of macroevolution. One example will illustrate this. Certain types of crustaceans have two types of thoracic appendages, and it is suggested that the morphological evolution resulting in this difference between the appendages was the result of changes in expression of two *Hox* genes.[2] The data in this case are the existence of two types of appendages. The evolutionary explanation is their interpretation, based on the *assumption* that such differences result from naturalistic macroevolution. Without that assumption, the evidence could be explained by an interventionist theory that the two types of crustaceans were designed with different expressions of the *Hox* genes. For another example, gene differences between humans and other primates are also believed to have arisen from duplication of portions of primate genes, resulting in many new genes.[3] This interpretation is based on the *assumption* that these "new" genes resulted from evolution rather than from design.

It is often claimed that the development of resistance to insecticides or to antibiotics, or the adaptation of bacteria to new culture media, demonstrates the evolution of new biological features. But when the molecular details of these cases are examined, it is evident they only involve adjustment of existing genes and enzymes, often with loss of genetic information. Nothing new was evolved.[4] There is evidence that resistance to antibiotics is driven by epigenetic processes, rather than by gene mutation.[5]

The eyes of vertebrates are fantastically complex. Octopuses have eyes that rival the vertebrate eye for complexity. Vertebrates and octopuses obviously did not get their eyes from a common ancestor with complex eyes.[6] Could these two types of sophisticated eyes have evolved independently? One can find animals with eyes of many different levels of complexity, line them up in a sequence of increasing complexity,[7] and argue that this sequence demonstrates the origin of complex eyes from simple eye spots by evolution. But since there are still huge biochemical and structural differences between the types of eyes in this sequence, the question remains: Do we actually have evidence that the more complex eyes could and did arise by evolution, or is that an untested assumption? Other, much larger, structural differences also need an explanation. For example, arthropods have a skeleton on the outside with joints that bend, and humans have an internal skeleton. Does current knowledge of genetics give us any reason to believe these different body plans could arise by the process of evolution?

Artificial selection by agriculturalists may give us some clues. Much progress has been made in attempts to improve food crops. Careful, selective breeding has increased production. Is this an example of the process that produces unlimited change? Wheat with small heads has given rise to domestic wheat with much larger heads. The same is true of corn and other crops. Small, sweet wild strawberries have been altered to our large domestic berries. But evidence shows that intensive selection for a trait in these food crops does not continue indefinitely. The amount of change levels off and reaches a plateau indicating the limit of the organism's genetic potential.[8] So the known genetic processes do not produce unlimited change. Does this have a wider application in evolution theory? Are there limits to natural evolutionary change?

Perhaps, but evolution theory predicts that given enough time there are no limits.

The plants described above have a specific range of genetic potential, and by intensive selective breeding, we have "used up" the genetic variability of the species. If we wait millions of years, will more beneficial mutations occur? If new mutations accumulate as new variation in the population, then we could select again for more increases in production (fig. 10.2). But what we need to know is whether that second rise in the curve in figure 10.2 will really happen. Will occasional beneficial mutations actually build up the genetic potential for increased productivity, or is this a false hope? These are critical questions for the theory of macroevolution. The data indicate a limit to the genetic potential. Whether the genetic potential resulted from random mutations and can keep on increasing by additional mutations over long time is an interpretation—an assumption.

The Proposed Mechanism for Generating New Genes

The fundamental hypothesis of macroevolution is that natural selection is a creative process generating new genes, new structures, and, ultimately, new body plans. Natural selection must produce protein coding genes (genes that define the amino acid sequence in proteins) that did not exist before, or alter genes systematically to the point where their protein products acquire a new function. Such a process would also have to produce additional genes to recognize and regulate the functioning of the new coding genes and repeat the process for all the new genes needed to form a new structure or body plan that did not exist before.

The proposed process for naturalistic evolution of new genes begins with mutational

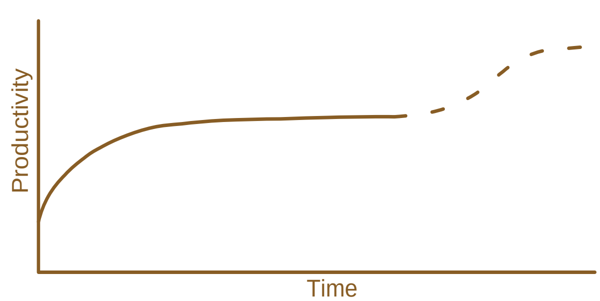


Figure 10.2. Increase in plant production that levels off as genetic limits are reached. Dotted line is hypothesized increase that would be possible after an additional time period for more accumulation of mutations. Figure by Leonard Brand.

duplication of genes. When this happens, the original gene continues its normal function and the duplicate gene is free to be modified by additional mutations. If the right mutations occur, the theory assumes that eventually the duplicate gene can become a new gene coding for a new protein (fig. 10.3). Is there evidence that this will work?

We would look for the duplicate genes in what is called "silent DNA." This silent, noncoding DNA (including pseudogenes[9]), comprising the vast majority of the chromosomes of higher organisms, was believed to have no function and was interpreted as "junk DNA." If junk DNA has no function, it could include the nonfunctional, duplicated genes that can evolve into new genes.

But in recent years, regions of DNA formerly thought to be junk DNA have been recognized as regulatory genes.[10] This change in thinking came to a head in September of 2012 at the completion of the massive ENCODE genetics research project. Thirty papers were published at the same time, recognizing that all or most of the "junk DNA," including the pseudogenes, are functional and have regulatory function.[11] Even before that event, a massive

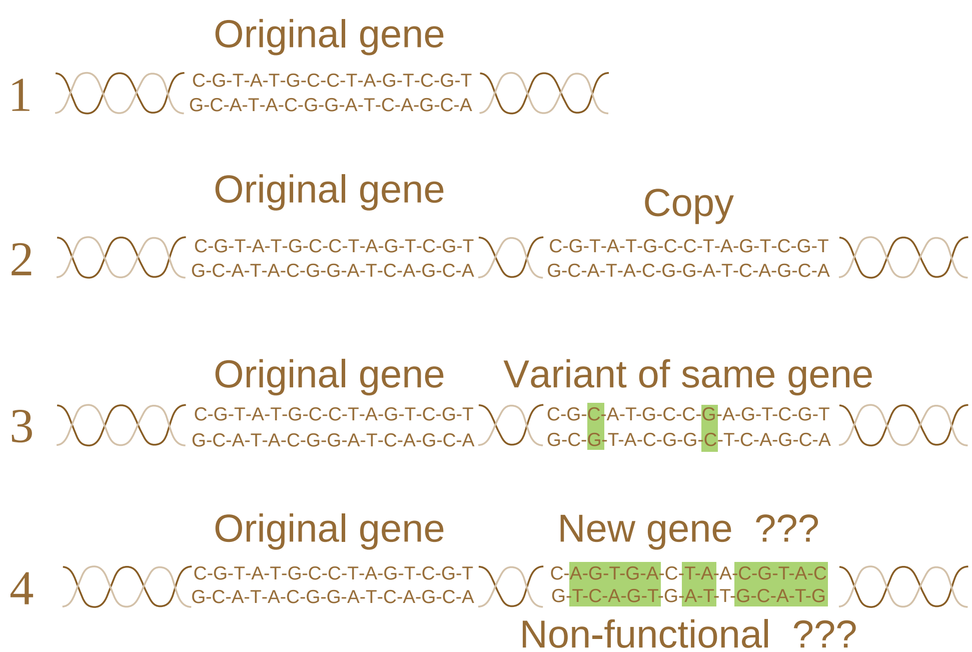


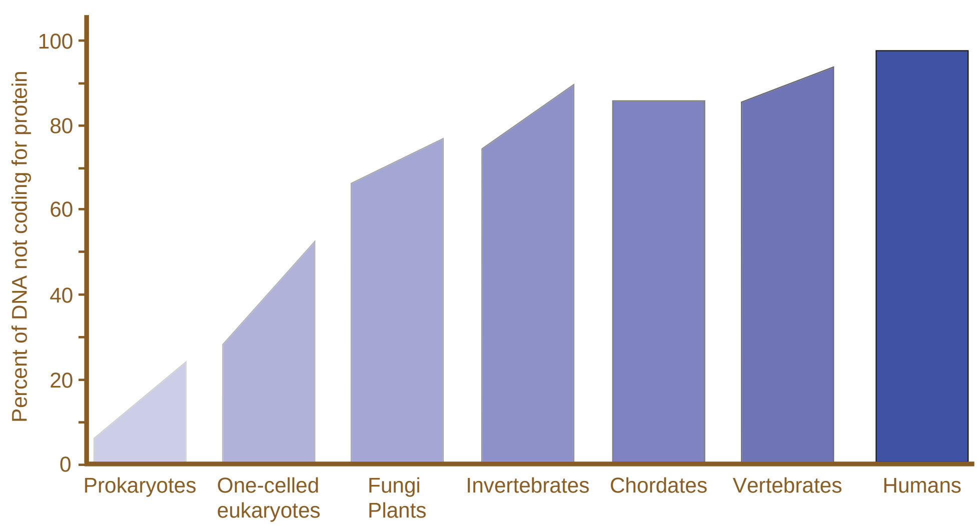
Figure 10.3. The theory of genetic evolution by gene duplication. Figure by Leonard Brand.

literature review of noncoding DNA revealed a direct relationship between the percentage of the genome that is noncoding and the structural complexity of the organism. This implies that the noncoding DNA has a function in generating that complexity (fig. 10.4).[12] "Junk DNA" is no longer even a useful concept.

This does not demonstrate that there are no duplicated genes. However, it is clear that there is a vast complex of genes involved in regulating when and where each protein will be made and in what quantity, the embryological development of each different organ and its integration with other organs, the functioning of the tremendously complex biochemical systems in each cell, and the controlling of such things as how long your fingers will be. Without those regulatory genes, we would all be very dead. Apparently few, if any, of the duplicated genes needed for macroevolution actually exist. Convinced Darwinists realize the significance of this development and have tried to downplay the results of the ENCODE project.[13]

Even if some of those duplicate genes do exist, the critical question of whether there is a mechanism to generate new biological information must still be answered. In all naturalistic theories, any genetic information new to the living world can enter that living world only through

Figure 10.4. The relationship between the amount of "junk DNA" (noncoding DNA) and the structural complexity of organisms (after Mattick 2004). Figure by Leonard Brand.



random mutations. If these mutations were not random, that implies an intelligent plan—someone knows what is needed.

The usual response is that although mutations are random, natural selection is not a random process. It selects beneficial features and rejects detrimental ones. This is true, but selection can act only on the raw material that mutation provides for it, and mutation is a random process in the sense that it does not know the needs of the organism or what those needs will be in the future. It does not know what mutations it should provide. In other words, natural selection affects the *survival* of mutations, but it does nothing to influence the *arrival* of any specific mutation.

This brings us to the core of the critical issue in this whole discussion. If new information is to enter the genome, the needed mutations or sets of mutations (1) must *occur by chance by the time they are needed* (if they occur too soon, they will likely be reversed or damaged by more mutations) and (2) *must result in some selective advantage for the organism at each step along the way,* or they can be eliminated by selection. Unless these two critical conditions are met, natural selection is powerless to make *anything* new or useful.

Figure 10.5 illustrates this point. If a gene that produces a protein is duplicated, and the duplicate gene is to change until it produces a new protein with a different function, new to the organism, a series of mutations will be needed to alter it to the new form. Figure 10.5B shows a sequence of truly random mutations in a protein if the process is governed by chance. In this process, the chance that needed mutations will be the ones to be preserved is far lower than the chance that mutations will cause the nucleotide sequence to wander randomly through time and make nothing useful (fig. 10.5B). Figure 10.5A shows the successful evolution of the new gene *if* each step is favored by natural selection. In that case, selection will determine, at each step, which form will be most common in the next generation. But at this point, the theory faces a serious problem. Selection does not and cannot know anything about the future new function, so it has no ability to recognize and preserve the mutations that will be needed for the new function. These problems will come into play at every step of any proposed evolution of new genes, new proteins, and new structures that did not exist before (as in every step in the presumed evolution of different types of eyes). Figure 10.5 only represents one protein. The problem is compounded many times over if we also consider many proteins and the needed complexes of regulatory genes to control each protein's role in the cell. Without these regulatory genes, it is quite certain that even if a new coding gene happens to appear it could not become functional.

This lack of a demonstrated process for generating truly new, functional genetic information is the major challenge faced by naturalistic macroevolution theory—the critical question referred to here. So far, we are not aware of any evidence to support the theory of duplicate genes evolving into new genes with a new function under the guidance of natural selection. The theory is conjectural interpretation, without data to support it.

If complexes of new structural and regulatory genes are to originate through mutation, recombination, and natural selection, this requires that duplicated DNA, if it does exist, gradually accumulates beneficial mutations that can be selected and that this process produces a new gene and

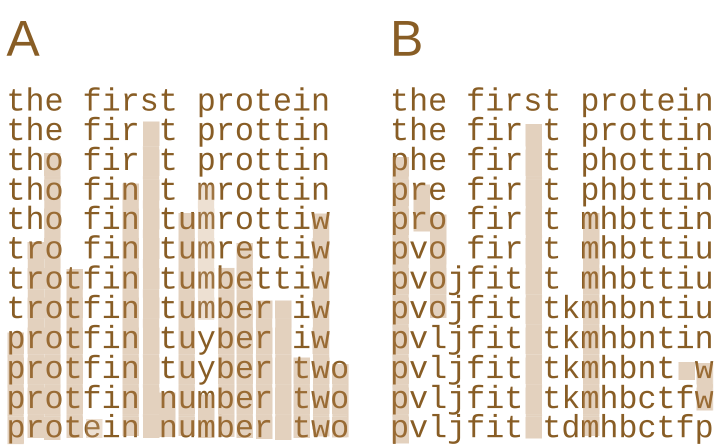


Figure 10.5. Two series of mutations, using letters to symbolize nucleotides in DNA, with a meaningful phrase representing a functional protein. There are two mutations in each step, except in the last step in (A), where there is only one mutation. In (A), a series of mutations converts one gene into a new gene producing a protein with a different function. Almost all mutations make a positive alteration toward the new gene. Example (B) is a series of truly random mutations. Some mutations are constructive changes toward the new gene, but unless the new gene is already functional and selected for, those constructive changes are just as likely to change again—away from the "goal." Evolution of a new gene and protein would involve many more mutations, but the principle would be the same: example (B) is a far more probable series of events. Figure by Leonard Brand.

its protein with a new function. Is it possible for this to occur with no intelligent input, producing not only a new structural gene but also the complex of regulatory genes that recognize and control it? Based on current evidence, we predict that the answer is no. Until that prediction can be falsified, the theory of naturalistic macroevolution of higher categories from a common ancestor stands on a weak and shaky foundation. Both informed intervention and macroevolution rest on a foundation of faith—faith that naturalism is or is not a valid philosophical assumption. The evidence for a genetic mechanism adequate to produce increased complexity and new body plans does not seem to exist at this time.[14]

Other Options for New Information

However, other possible sources of new information have been proposed. Watson takes us through extensive theoretical discussion of the combining of genetic information from different entities in various ways to make something new.[15] This can involve transfer of genes from one organism to another, a process called lateral gene transfer. This transfer is mediated by viruses that carry portions of genetic information between different types of organism. An organism could certainly gain new information by lateral gene transfer, but this does nothing to explain how that genetic information originated in the organism that first contained the information. It has only explained how the information, once it exists, can be shared with another species.

Another suggestion is that two organisms could combine into one. A hypothetical example is the proposal that early in the history of life two bacteria combined into a symbiotic relationship. The DNA from one grew into the nuclear DNA to form a eukaryote, while the DNA from the other was reduced to form mitochondrial DNA.[16] This is a very speculative theory, and what is missing is evidence that the complex merger occurred and evidence of a mechanism to evolve the new genetic information to support this merger.

Other proposed mechanisms for facilitating the origin of new information suggest that simple proteins (protein domains) or biochemical structures could evolve for one purpose and then be combined with other such components to make new, more complex structures. This is referred to as co-option or exaptation.[17] The problems with this theory of co-option of parts for new functions can be illustrated by comparison to Lego building blocks. A few simple Lego parts can be put together to make a great variety of complex structures. This is possible because the blocks were carefully, intelligently engineered with this goal in mind. Proteins are orders of magnitude more complex than Lego structures. If protein domains show the engineering that allows them to combine into a wide variety of proteins or biomolecular machines with differing functions, this ability increases, rather than decreases, the magnitude of the problem for evolution. Natural selection cannot foresee what will be needed for complex functions that will arise in the course of evolution millions of years in the future. Thus it cannot be expected to design protein domains with the engineering to combine in many novel ways and make the proteins needed for those future applications.

The Achilles' Heel of Macroevolution

Evolutionary science assumes there is a genetic process that can evolve new structures or gene complexes, but there appears to be no convincing evidence for such a process. This point is key to the entire question of whether it is even possible for the living world to result from unguided evolution, so we will summarize it once more. The entire paradigm of macroevolution depends on the unlikely assumption that the series of specific random mutations needed for any new adaptation will be available when needed. Yet this is only an assumption and has no tangible evidence to support it. If the needed series of mutations cannot be counted on to be available *when needed*, then the entire edifice of Darwinian macroevolution collapses. This is the Achilles' heel of Darwinism—a biochemical grand canyon separating microevolution from macroevolution. Without significant evidence for the regularly occurring evolution of those new genes with their regulatory genes, there is no reason to say that acceptance of microevolution naturally leads to macroevolution. Our interpretation is that the only evolution that will occur is evolution within an intelligently designed genetic system, and the amount of change will be governed by the evolutionary potential built into that genetic system by design.

To evolve, a new functional protein faces a second level of difficulty on top of what is discussed above. Most proteins do not function independently from other proteins but are part of a larger molecular complex, such as a flagellum or ATP synthase. They must be able to perform their own functional role (such as a catalyst or binding to a substrate) and also be able to recognize and bind to the other proteins in the molecular complex. This is a very

Does microevolution over time naturally lead to macroevolutionary change?

DATA

Different body plans exist, and their origin requires an explanation. Very different types of organisms succeed one another in the fossil record in a predictable sequence (e.g., reptiles followed by mammals). The accumulating evidence summarized in this book bears on this issue.

INTERPRETATION

Conventional science: There is a lack of agreement. A traditional view is that microevolution over time adds up to macroevolutionary origin of new higher taxa. Other evolutionary scientists maintain that macroevolution requires a different process than microevolution but do not know what that process might be. The order of fossils is a record of macroevolution.

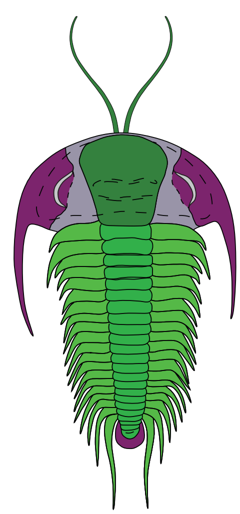
Interventionism: Microevolution generates variation within the genetic potential created in each group of organisms. There is no satisfactory evidence-based process of macroevolution. Interventionism predicts that efforts to find such a process will not succeed. The sequence of fossils of major groups resulted from some process other than macroevolution.

large challenge for macroevolution, but there is also an additional problem.

A greater difficulty for evolution comes when we recognize the unity of intracellular biochemistry across the spectrum of organisms. Because of that biochemical uniformity, virtually all of these macromolecular intracellular machines, factories, and motors must have already been present in the first multicellular organisms we find in the Lower Cambrian strata. Evolution is faced with its inability to explain the origin of a single functional protein by random processes, but on top of that, the evidence indicates that all those molecular machines were present in the first organisms present in the fossil record.

An example of this claim is the trilobite (fig. 10.6).[18] The claim is based on very abundant data on the molecular intricacies of the cells of organisms from plants to insects to humans, combined with basic accepted principles of the theory of evolution. According to evolution theory, complex structures found in different types of animals were present in the common ancestor of these different animal groups. This is especially true of molecular features inside all living cells. Exceptions to this principle, such as the analogous structure of the wings of birds and bats (explained by convergent evolution) certainly exist, but facile application of convergence undercuts the credibility of macroevolution.

Figure 10.6. A Lower Cambrian trilobite in the order Redlichiida, family Paradoxididae. Antennae added from another trilobite. Conjectural color scheme patterned after the living mantis shrimp. Figure by Leonard Brand.



There are no living trilobites, but they are in the phylum Arthropoda along with insects. The intracellular structure of insects and humans is virtually identical. To describe these molecular similarities would require a whole book[19] and more. For now, it is sufficient to recognize that according to basic principles of evolution, if humans, insects, and their relatives the trilobites evolved from a common ancestor, then all the molecular features of humans and insects were present in the oldest trilobites. Trilobites are among the first fossil forms to appear in the lowest Cambrian sediments, in the Cambrian explosion. So when did these shared structures evolve?

The belief that humans and trilobites trace their origin back to a common ancestor is not based on physical evidence. It is based on the requirements of the worldview of methodological naturalism (MN). The data are the similarities in structure and function among humans, insects, and trilobites. Differing interpretations of those data derive from the assumptions of different worldviews—the similarities arose by evolution (MN) or by design by an intelligent Creator (interventionism).

So far, we have described some serious challenges to Darwinism, but there is much more, and we will summarize what has been well described by Stephen Meyer and others.

The Conflict within Science

Through the last few decades, an increasing number of eminent evolutionary scientists who are not creationists have doubted that the Neo-Darwinian process can do the job beyond microevolution. Their growing mass of contrary evidence is undermining the rationality of believing that new organisms can form by the evolution process. Meyer has well summarized this work,[20] and some of the issues are briefly described below.

Mathematical Challenges

In the 1960s, a group of mathematicians, computer scientists, engineers, and biologists met for a symposium called Mathematical Challenges to the Neo-Darwinian Interpretation of Evolution. They determined that to make one functional protein, random mutations have to search through all the possible amino acid sequences to find the right sequence for most of the hundreds or thousands of amino acids in the protein. The chance of doing this for one average protein, they concluded, is about one chance in 10^{390} tries (for context, the number of atoms in the Milky Way galaxy is only 10^{63}). Their original calculations may have numbers that are too high, since proteins may still be functional if there are variations in which amino acid fills some specific amino acid positions. But their error doesn't make any practical difference. The probability for generating a functional molecule of cytochrome c (a small protein with about one hundred amino acids), taking into account all known functional substitutions, has been precisely calculated.[21] The chance of getting the correct amino acids by random search is one chance in 2×10^{75} tries. To accomplish this would still take ten trillion times as long as the presumed age of the universe if 110 amino acids are combined and tested 10^{44} times per second!

What is the meaning of such big numbers? William Dembski has calculated the maximum number of molecular events that can happen in the entire thirteen billion years that the universe is supposed to have been here. There are 10^{16} seconds in thirteen billion years, and the number of possible changes of state per second (events) is 10^{45} (the inverse of Max Planck's time). Thus the total number of events that can have happened in the entire posited age of the universe is about 10^{141}. Any number in the range we are discussing for Darwinian random mutations to "search" and find the right combination of amino acids to make one new functional protein would require many orders of magnitude more tries than the time allows. To any reasonable person, such events are effectively impossible. Not only that, but such random changes in a computer program inevitably degrade or kill the program and this would be analogous to the Darwinian process.

ORFan Genes

Geneticists have recently become aware of a new challenge to evolutionary origins. With increased availability of the DNA sequences of many organisms, investigators have discovered that hundreds of thousands of genes are unique to particular taxa, called ORFan (Open Reading Frame, which means protein coding) genes, commonly referred to as orphan genes. They have been found throughout the plant and animal kingdoms, sometimes, many of them in a given species. Ten to twenty percent of genes are orphan genes in all taxonomic groups so far studied.[22] Orphan genes have been shown to be especially important in specialized adaptations of specific organisms. For example, orphan genes found only in honey bees are important in all aspects of the social behavior and diet unique to honey bees.[23]

Because they are unique, they cannot have been inherited from a progenitor. They cannot have formed spontaneously out of nothing, and we have seen already that they cannot realistically be formed by mutation and natural selection. In spite of that, some evolutionary biologists have suggested that these did form "de novo" (i.e., from scratch). That sounds a lot like intelligent creation (intervention) or like the mystical explanations commonly used in past centuries. At our present level of understanding of these phenomena, they appear to render evolutionary origin of these groups impossible.[24] Orphan genes were not mentioned in any of the twelve evolution books reviewed in chapter 8 of this volume.

Irreducible Complexity

Michael Behe and David Snoke have argued that many molecular structures are irreducibly complex. In other words, several complex parts must all be present before the structure can function. This seems incompatible with Darwinism. Charles Darwin stated correctly that if any biological structure was found that could not be built up step-by-step, his theory would break down.[25] Behe argues that such irreducibly complex biochemical organelles or systems do exist. He uses a mousetrap to illustrate the concept. A mousetrap is composed of five main parts, and all five parts must be present at once or the trap will not work. If a part is missing, it does not make the trap less efficient—the trap will not work, and the local mice are very safe. Some biochemical systems can be readily argued to be irreducibly complex. Behe cites the bacterial flagellum as such a structure, containing what is essentially an electric motor that rotates the flagellar tail.[26]

Behe's critics argue that flagella occur in various forms and can evolve from "simple" parts co-opted from other organelles.[27] However, even the simplest flagellum has a number of complex parts that must all be functional and integrated before the machine will work.[28] Critics of Behe and Intelligent Design (ID) in general skirt these central questions and only address peripheral issues.[29]

The Edge of Evolution

Behe has now published additional insights that aim to determine the power of random mutation and natural selection. His analysis of the changes in malaria resistance, in bacteria, and in the HIV virus gives insights into the power of natural selection. Selection is capable of destroying or reducing the functioning of some genes, which in a bad situation may be better than the alternative (sickle cell disease is not as bad as malaria). It can also make slight positive changes, but only in small creatures, like bacteria, with their very rapid reproduction rates.[30] This evidence strengthens our conclusion above that the required series of mutations is unlikely to happen when needed for the evolution process.

Developmental Biology

Developmental biology poses one of the most serious challenges to Darwinism. Some genes that control embryological development act early in the process and establish the body plan of the organism (analogous to defining the body and engine of a car). Other genes act late and control the finer details of an organism (like paint on the car). The early acting genes are the only ones that, by mutating, could produce a new body plan, but mutations to the early acting genes are invariably lethal. The late acting genes may survive mutations, but they do not affect the body plan.[31] Thus it seems that mutations cannot produce a new body plan.

Epigenetics, Regulatory Genes, and Natural Genetic Engineering

The role of the enormous complex of regulatory genes in controlling the activities of coding genes and their proteins has been highlighted by the recognition that silent DNA is not junk but part of the regulatory gene system.

Then in recent years, the problems for any proposed naturalistic origin of our genetic system with its complexity of information-bearing molecules have become vastly more difficult because of the discovery of epigenetics. The complexity and details of this system are just coming to light. Epigenetic processes have the amazing quality of allowing environmental cues to influence changes in cells and organisms without any permanent change in the DNA sequence.

The molecular process in the cell that makes decisions about how to use the DNA information is called by Arthur Shapiro natural genetic engineering.[32] He argues that random mutations and natural selection can play a partial role in microevolution, but they cannot be the mechanism of macroevolution: the genetic/epigenetic system is too sophisticated for random mutations to be effective. Convinced traditional Neo-Darwinians criticize him, but he says their criticisms are philosophical, not scientific, and are not supported by empirical evidence. Although Shapiro is a committed evolutionary scientist, he concludes that how this system evolved is a mystery, as is the origin of life. This new understanding of the level of biochemical complexity is represented in figure 10.7.

Some evolutionary scientists are developing a new evolutionary synthesis based on the concept that epigenetic processes are the mechanism for macroevolution. They point out that "soft inheritance," changes induced by the environment, exists and "is found in every type of organism and seems to be common."[33] They state further that "the mechanism that allows soft inheritance during microevolution, and the epigenetic mechanisms that lead to macrovariations and instances of rapid evolutionary change need to be incorporated into the emerging extended evolutionary synthesis."[34]

They point out that the modern synthesis only explains how existing traits diversify. They state that *origination* of significant new structural features like arthropod limbs, the vertebrate skeleton, insect wings, and many others cannot happen by "standard variation." "They require a distinct explanation." These features are true novelties—structures that have no "homologous counterpart in the

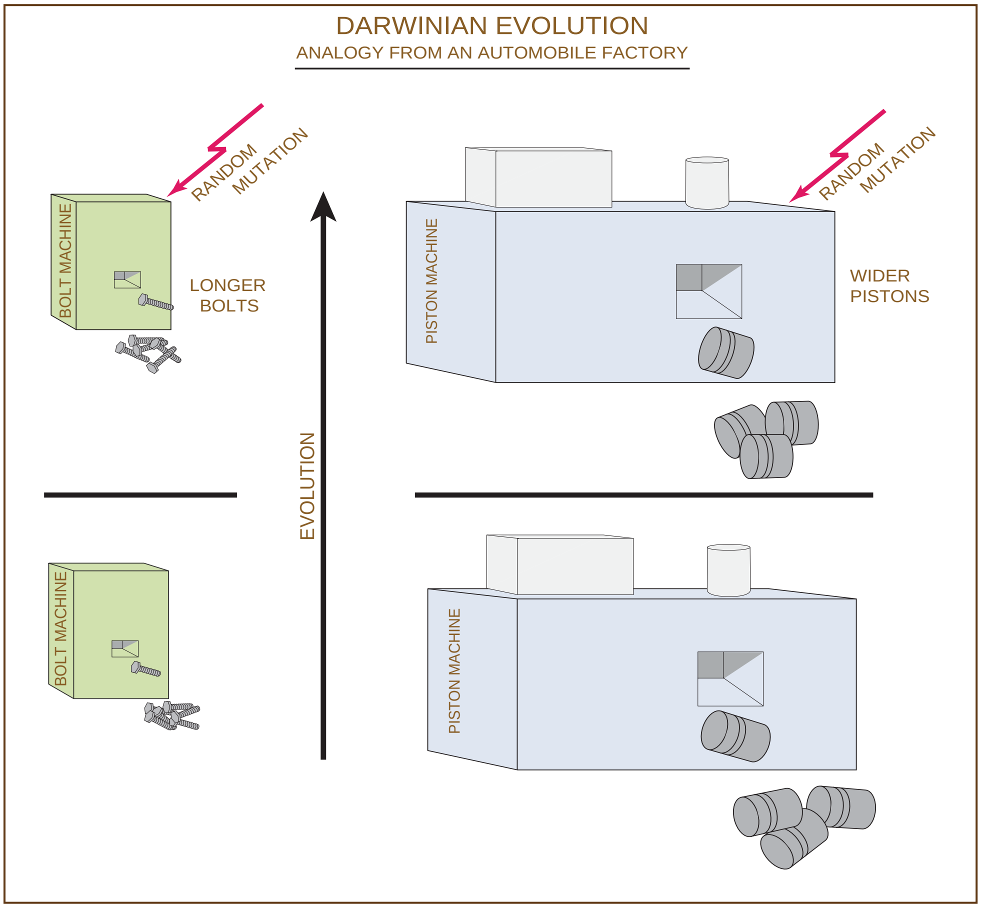
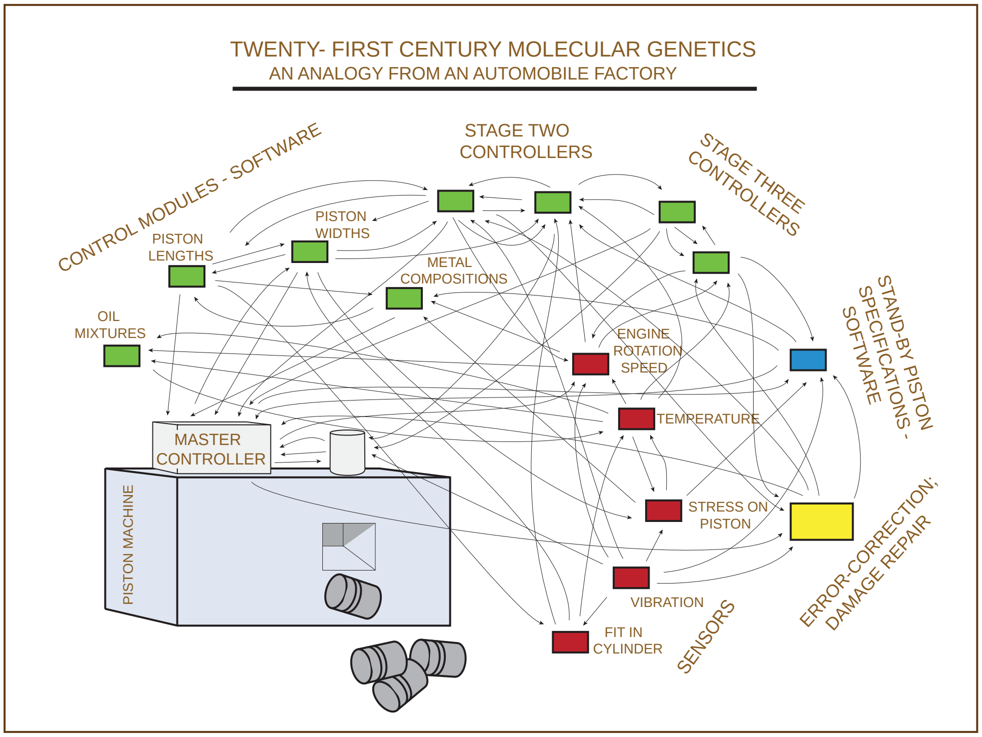


Figure 10.7. An analogy from an automobile factory. Above: The Darwinian process of random mutations (the red spark) that change some instruction in the computer, changing the size of the product. Next page: A complex control system, analogous to the twenty-first century understanding of the genetic system with its multiple layers of genetic control and response to the environment. Figure by Leonard Brand.

ancestral species."[35] Their extended synthesis attempts to explain the origin of these novelties.

They recognize that the modern synthesis objects to epigenetic inheritance because it seems to imply a Lamarckian mechanism. They propose a very speculative theory of macroevolution attempting to explain that it actually doesn't involve transmission of acquired traits. Part of their proposed process involves behavioral changes, leading to epigenetic modifications that are later incorporated into the genome.[36] But their theory depends entirely on their *assumption* that the genetic/epigenetic system did arise by evolution.

Whether epigenetic modifications do persist as long-term genetic changes remains to be verified. In its observed, short-term effects, epigenetics is a system that suggests a degree of biological foresight, facilitating efficient and adaptive microevolutionary modifications



in response to environmental conditions. This poses a significant challenge to a naturalistic theory, which still requires that *all new biological information* must initially arise by random, nondirected processes with no foresight of what the organism needs.

Epigenetics poses another level of challenge to naturalism. The same epigenetic system seems to be a prominent part of all organisms. This means that if life was the result of evolution, the entire genetic/epigenetic system had to be already present in the first eukaryote. DNA plus this intricate, multilevel genetic management system had to evolve *before* all organisms more complex than bacteria were in existence. This system, from its single-celled beginning, had to be sophisticated enough to efficiently manage the genetics of fish, reptiles, whales, apple trees, and human concert violinists that would arise many millions of years in the future. Is that anywhere near believable? One response that will be given is, "Isn't it amazing what evolution can do?"

One other example illustrates the same concept along with the evidence discussed above in regard to the biochemical processes shared between humans and trilobites. All organisms have biochemical switches that turn genes on and off. It was recently documented that the DNA code, the language used by these switches, is the same from flies to humans.[37] This means that the specific codes used in these switches was either created by the same intelligent designer or they evolved at the very beginning, before the ancestors of flies and vertebrates diverged and probably before many of these instructions were in use. We can again ask, is this anywhere near realistic?

Microevolution and speciation are well supported by the evidence, but we suggest that epigenetics and the other evidence we have discussed is coming as a karate chop across the dreary, broader Darwinian worldview.

Alternate Hypotheses

We should not claim at this point that we have disproved macroevolution; on the other hand, the shortage of

A sample of the logic in Müller's extended synthesis of evolution

DATA

- Animal taxa and a description of any anatomical structures not present in related taxa
- A description of genes present in these taxa but not present in related taxa that do not have these structures

INTERPRETATION

Müller's conventional science theory: Interpretation is based on the assumption that the added structures arose by evolution. Gene duplication is the hypothesis for the origin of the added genes; the hypothetical duplicated genes are interpreted to have evolved into the genes for the added structures. There is no evidence to indicate that this is how it happened.

Interventionism: Since we didn't see the origin of these structures, our interpretation will, by necessity, involve an assumption. We assume they were created or were part of the created epigenetic potential. Interpreting by inference-to-the-best-explanation, that fits the evidence best. The added (novel) structures and the genes to specify them were designed and created as a coordinated unit.

evidence for a genetic mechanism for evolution of truly new biological features leaves the door wide open for an open-minded look at an alternate hypothesis—that mutation, as a process generating random changes in the DNA, only produces increasing chaos if not held in check by selection, and thus mutation and natural selection are incapable of any creative role. If the genetic evidence does not provide a mechanism for evolving truly novel organisms or structures, it appears that a process other than macroevolution is needed to explain the sequence in the fossil record and to test the hypothesis that all life is related by common descent.

This suggests that we consider the possibility that the major life forms were created by intelligent intervention, and the fossil sequence resulted from some process other than macroevolution. The possibility for rigorous testing of scientific hypotheses such as these may continue to increase as science advances in its understanding of the molecular processes behind the biological features seen in nature.

Although both concepts, design and naturalism, are based on faith, the contest between them is not an even match in the long run. We know that intelligent, informed scientists can manipulate elements and simple molecules to fabricate or modify complex biological molecules. The only additional step required is a willingness to accept that there could be a Being in the universe with the superior intelligence and ability to do this on a much grander scale than we can. But naturalism asks us to believe that unguided chemical and physical processes can do the same by chance, even though the biochemical evidence to demonstrate this process does not exist, and the sheer enormity of such an assumption, if we are honest, is staggering. Naturalism carries the heavy burden of convincing us that life does not need a designer.

A common response to this reasoning is represented by Dawkins who says "invoking a supernatural Designer is to explain precisely nothing, for it leaves unexplained the origin of the Designer."[38] In other words, "who designed the designer?" Since none of us can answer this question, it may seem that theists or intelligent design advocates have lost the argument. But not so. If there is no intelligent Creator, then where did matter and energy come from? Where did the exquisite set of natural laws come from that make the universe and life possible? Why is there anything at all, and how is it that all those chemical and physical laws just happen to work so well?

When we look back toward the ultimate beginning, theists, atheists, intelligent design advocates and detractors alike face questions that are equally serious and unanswerable from a human perspective. To claim otherwise is a refusal to candidly face reality. Figuring out a theory of how life could have evolved without a Designer may be intellectually satisfying to some, but if that theory is not true, it is ultimately meaningless. And to claim that matter, energy, and the laws of nature have always been here explains precisely nothing. It is part of the nature of the Designer described in the Bible that He is timeless and that He has always existed. So the question "Who designed the designer?" is easily answerable: "Nobody. He has always been there" is the only answer that can be given. We may not understand what that means, but that is our limitation, not His.

What about Theistic Evolution?

What if the Creator set up the laws of the universe to surmount the above problems? Perhaps He started the universe on its way and set it up so that life, including complex life, would inevitably emerge. Genetic research shows that in at least some cases the genetic system even controls which mutations will occur to meet the needs of an organism as its environment changes.[39] It could be proposed that this is evidence of the Creator's grand design to let life "make itself" through macroevolution. But if the genetic system can determine what mutations will be beneficial, this means all the information is already there to deal with new challenges, in addition to just maintaining normal life. Where did this information come from? Is there any evidence that this information for making all forms of life—including bacteria, mice, cockroaches, starfish, and humans—is present somewhere in the laws of chemistry and physics, or even in some original microbe? Science cannot study supernatural processes, but it can evaluate whether the needed information is there to govern the evolution of all life without new information needing to arise from random mutations. There is evidence that creatures have been made with the genetic information to support microevolutionary adaptations, but this is vastly different from the claim that the information for the evolution of the living world was present in some initial form. Another option is that a Creator has tinkered with the evolution process at every step—a mother of all god-of-the-gaps explanations, not compatible with science or the Bible.

Until the source of that primordial information is found, this is one more philosophical position that is based entirely on faith. It does not appear that the evidence supports it. It seems to us that interventionism has much greater explanatory power for the origin of cellular complexity than has any theory of macroevolution process.

Conclusion

How does this relate to what is really happening in science? Thousands of scientists are doing evolutionary research. How can all this science be so successful if the basic biological concepts in the study of macroevolution are not on a more solid foundation? This is interesting to ponder when attending annual meetings of organizations such as the American Society of Mammalogists or the Geological Society of America. Most of the scientists at these meetings would reject interventionism, and most would probably assume that interventionists could not be effective scientists. Yet perhaps 80 or 90 percent of the research reported could be done by any interventionist trained in the same area. Acceptance or nonacceptance of naturalism and Darwinism has little influence on most modern biological research.[40]

Even in the field of evolution, most of what is being studied is microevolution, speciation, and the aspects of macroevolution that interventionists also believe are real evolution processes that have occurred. The same is true for most aspects of earth science, especially those areas that lend themselves to experimental research or comparison with modern processes. These topics of science lend themselves to collecting good data and effectively testing hypotheses, irrespective of personal philosophy.

The study of macroevolution is where interventionists disagree in a fundamental way with other scientists, and macroevolution is all about events that are presumed to have happened in the distant past and consequently can never be a precise, testable science with the same level of confidence as many other areas.

Macroevolution is also the area in which evolutionary science is searching for better mechanisms. Interventionists should have no interest in preventing anyone from trying to develop a new theory of macroevolutionary mechanisms. But intervention theory suggests that no theory of macroevolution will ever work adequately because the origin of basic new types of organisms will not happen without informed intervention by an intelligent designer. Consequently, interventionists also suggest that perhaps it would be scientifically productive for at least some scientists to pursue the questions, Are there limits to the evolution process, and what are they?

If space would allow, there is more evidence that we could present. New publications regularly appear, and we also recommend Illustra Media videos (*Metamorphosis, Flight, Unlocking the Mystery of Life, Darwin's Dilemma, The Privileged Planet*, and *Living Waters*).

Early in this chapter (table 10.1), we presented four examples of multiple working hypotheses for this topic. Which of these hypotheses best qualifies as the inference-to-the-best-explanation? Some evolutionary scientists, especially molecular biologists, don't see traditional Darwinian theory as a viable option. They seem to be on the right track. If we accept their judgment, this raises doubt about options one and three. The remaining choices are options two and four, and the biggest question is whether any theory of macroevolution is realistic.

The evidence against a viable mechanism for macroevolution seems overwhelming, but have we missed something in this chapter? Have we presented a biased story? We think we have presented, fairly, the existing evidence and the difficulties it poses for macroevolution. The other side of this story consists of theory, assumption (naturalism), and "just-so stories" of how macroevolution could, perhaps, happen. The data underlying those stories are the similarities and differences in anatomy, physiology, and molecular systems in living and fossil creatures. Did those similarities originate from common ancestry or from the work of a common designer? Those are the possible interpretations or working hypotheses. Let's now consider the logical approaches that are often used in response to these questions:

1. Assume that naturalism is true and that the origin of living forms did not involve any intelligent planning and apply this assumption in explaining the history of life. If this option is chosen, it requires that the living world arose by chance and selection—there is no other choice. It is often stated that those of us who doubt naturalism are not creative enough to think of naturalistic explanations, and we are just not willing to wait for the expected new discoveries that will show how life arose. According to this view, devising a story to explain how a process *might happen* is sufficient to eliminate the need for intelligent intervention. This is stated explicitly by Victor Stenger in reference to intelligent design in biology and in cosmological fine-tuning (the author defines these as "God of the gaps"): "As long as science can provide plausible scenarios for a fully material universe,

even if those scenarios cannot currently be tested, they are sufficient to refute the God of the gaps."[41]

2. If we are willing to at least consider seriously the option that life was created by intelligent intervention, we then appeal to the inference-to-the-best-explanation as we interpret the evidence. In cases of seemingly conflicting evidence (e.g., fossil record vs. biochemistry), then follow options 3 and/or 4 below.
3. Assume that life was created and proceed to explain biological processes in this framework. This approach seems to currently have the highest success rate in interpreting the evidence. Among those who believe this is the right approach, some of us have such strong confidence in it that we find option 2, above, to be a sufficient approach.
4. We don't know the answer, so it is best to wait and see. This approach doesn't contribute directly to finding answers to our questions, but it has the virtue of avoiding dogmatism and leaving the options open. Neither naturalism nor intervention can prove its point with "scenarios," or "just-so stories," so rather than depending on an assumption, which Stenger's statement does, just admit that science doesn't have a solid answer for the question.

This chapter has dealt with the mechanics of life—the biochemical assembly line for making living organisms. But someone may suggest (using logical option 1 above) that perhaps there is a branch of the assembly line that hasn't been discovered yet. The branch that performs macroevolution? The accumulating evidence so far is rapidly going the other way; every biochemical advance moves further in dismantling the story that Darwin so diligently put together.

But such complicated issues are seldom entirely black and white, so rather than just dismiss a theory that we think is a loser, we will proceed to dig deeper into the evidence. We don't see how new body plans could evolve, but if it happened, has the process left evidence in our bodies and in the rest of nature that tell the story? A wounded arm may heal but leave a scar that tells the story of what happened. Did eons of evolution leave telltale scars, like vestigial remnants of old body parts, poorly designed organs, or a genetic trail from our ancestors? The next two chapters will pursue these questions.

CHAPTER 11

The Case for Macroevolution and Its Scars

Overview

The previous chapter found many serious challenges to the concept that macroevolution could even happen. But if it did happen, perhaps the protracted evolution process would have left some "scars" in animal bodies to tell us about the evolutionary journey. We will summarize the lines of evidence most commonly cited as support for this theory and will seek to present as strong a case as possible for macroevolution. Concepts discussed include embryological remnants of evolution, vestigial organs, homologous body parts or biochemical systems, mistakes and imperfect designs that don't look like the work of a wise designer, biogeographical evidence, and the fossil record.

Introduction to Naturalistic and Interventionist Theories

Naturalistic theory and interventionist theory differ most significantly on the question of the origin of major groups of organisms. Evolution to the level of a new class or phylum (macroevolution) would require that many new genes and new structures evolve. The evidence covered in chapter 10 raised serious, maybe even unanswerable, doubts about the possibility of evolving new types of organisms. But for those who accept the naturalistic assumption, that assumption dictates that macroevolution has somehow occurred and has produced the entire living world. On the other hand, interventionists ask, "What are the natural limits to the evolution process? How much change can evolution actually accomplish?" In this chapter, we summarize the most common lines of evidence that are used to support the evolution theory and present as strong a case as possible for macroevolution. In chapter 12, we will review the same evidence and present the case for an alternate interpretation.

In evaluating the data, we attempt to determine into which of the following categories each type of evidence fits:

1. Data compatible with both theories are of minimal help in determining which theory is more correct.
2. Data that are compatible with one theory but contradict the other are helpful in evaluating which theory is more likely correct.

The strength of each line of evidence must be evaluated separately. If, in comparing these two paradigms, we conclude, for example, that since evidence A and B fit macroevolution best, we should seek to explain evidence C by macroevolution, this can be circular reasoning. If evidence C does not independently support macroevolution, it should be acknowledged that C is contrary or is not helpful in deciding which theory is more correct.

The Theory of Macroevolution

The theory of macroevolution maintains that over billions of years of earth history, evolution processes have produced all existing and extinct kinds of plants and animals from the first single-celled ancestors. These changes, it is assumed, occurred by the processes of microevolution and speciation and/or by some other natural process, and all new biological information ultimately arose through mutation and natural selection. Such changes accumulated through the ages to produce organisms different enough that biologists call them different families, orders, classes, or phyla. A number of lines of evidence support the concept that the diversity of life has resulted from macroevolution. The items described below are the scars left behind by our evolutionary history.

Homology

Homology is a key line of evidence used to determine evolutionary relations between organisms and in developing phylogenies—theories of the evolutionary pathways by which these organisms arose.[1] Let's consider two ways of defining homology and related terms. The definitions commonly used are already an interpretation, so we use a functional definition first and then introduce the standard (or interpretive) definition later.

> Homology: Parts of different organisms that may serve different functions but have the same internal structure and develop from the same embryological pathways.
>
> Analogy: Parts that serve the same function but have different internal structures and develop along different embryological pathways.

The principle of homology can be illustrated by the front limb structure of four kinds of mammals (fig. 11.1). A human hand and arm are adapted for fine manipulations, a seal's flipper is designed for swimming, a bat's wing for flying, and a dog's leg for fast running but not for delicate maneuvers. The front limbs look different and have different functions, but in their internal anatomy, they have the same basic features. All have the same bones: a shoulder blade; a humerus, radius, and ulna; and the wrist and hand bones. Proportions of the bones are different, but the muscle attachments and articulations are the same. In the bat, the radius is reduced, or vestigial.

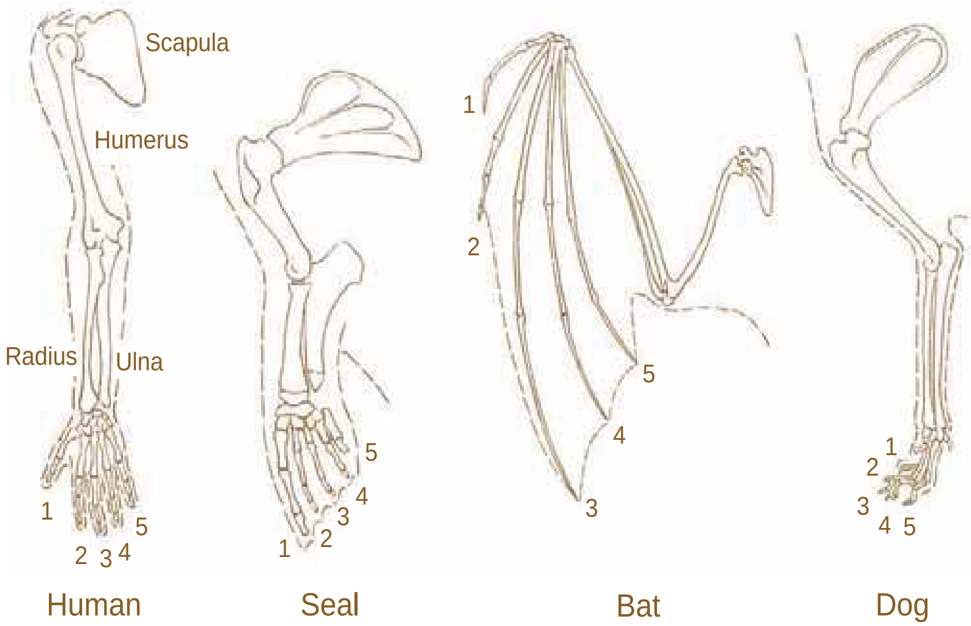


Figure 11.1. Homologous limb bones in four kinds of mammals (after Dunbar 1961). Figure by Robert Knabenbauer.

Even the "hand" has the same bones in these four very different limbs. A bat's wing has the same bones as a human hand, and the wing is supported by four fingers with very elongated finger bones. This is the meaning of homology: functions may be different, but the internal structure is the same.

Mammals have these homologies because the four types of front limbs evolved from a common ancestor that had the same basic limb bone arrangement. They inherited the bone structure from the common ancestor and evolved modifications to adapt the limb to the needs of each. In contrast, when different animal groups have analogous structures, such as wings, these structures did not evolve from a common ancestor. Several groups of animals have wings, and each group independently evolved wings to serve the same purpose. Because they evolved independently, they have different structural features.

Four different kinds of wings will illustrate this concept of analogy: butterfly, bird, bat, and pterosaur (an extinct flying reptile; fig. 11.2). In bird wings, the finger bones are quite reduced, and feathers make up the main flight surface. In a pterosaur wing, the fourth finger alone supports the wing membrane. Insect wings have no bones at all.

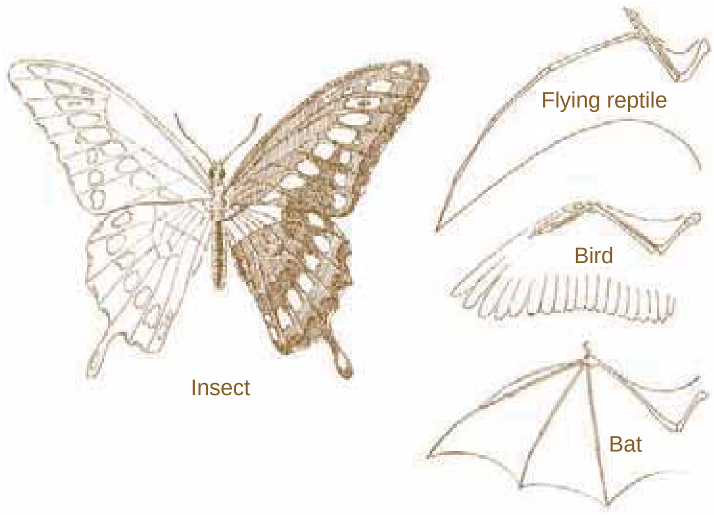


Figure 11.2. Analogous structures—the wings of a butterfly, bird, bat, and pterosaur (after Moody 1962). Figure by Robert Knabenbauer.

Bat wings have the same bone arrangement as other small mammals. Externally these wings are superficially alike, yet internally they are very different and thus analogous.

The term convergence is closely related to analogy. Some animal lineages having different ancestry have become more similar because of similar needs. Their structure has converged toward a common pattern (at least superficially) as they have evolved independently of each other.

The same principles of homology and analogy also apply at the level of physiology or biochemistry. Cytochrome c is a molecule found in virtually all living things, and amino acid sequences in cytochrome c have been studied in a wide variety of organisms from humans and donkeys to chickens and castor beans.[2] Between humans and monkeys, only one amino acid is different. But between yeast and humans, forty-five differences are found in the sequence of amino acids (fig. 11.3). If life has evolved, we would expect the differences to increase as we compare organisms farther apart on the scale, and that is what we find. As evolution progressed from the yeast, mutations in the cytochrome c molecule would increase as in other parts of the organism, and the cytochrome c would become more changed as life evolved. In general, the data fit this expectation, although the pattern of change is not very smooth.

	Human	Monkey	Pig, Cow, sheep	Horse	Dog	Rabbit	Kangaroo	Chicken, turkey	Duck	Rattlesnake	Turtle	Tuna fish	Moth	Neurospora	Candida
Monkey	1														
Pig, Cow, sheep	10	9													
Horse	12	11	3												
Dog	11	10	3	6											
Rabbit	9	8	4	6	5										
Kangaroo	10	11	6	7	7	6									
Chicken, turkey	13	12	9	11	10	8	12								
Duck	11	10	8	10	8	6	10	3							
Rattlesnake	14	15	20	22	21	18	21	19	17						
Turtle	15	14	9	11	9	9	11	8	7	22					
Tuna fish	21	21	17	19	18	17	18	17	17	26	18				
Moth	31	30	27	29	25	26	28	28	27	31	28	32			
Neurospora	48	47	46	46	46	46	49	47	46	47	49	48	47		
Candida	51	51	50	51	49	50	51	51	51	51	53	48	47	42	
Yeast	45	45	45	46	45	45	46	46	46	47	49	47	47	41	27

Figure 11.3. A diagram showing the number of amino acid differences in cytochrome c obtained from different species of animals, plants, and microorganisms (data from Villee 1977). Figure by Leonard Brand.

From this information, one can develop phylogenetic trees based on cytochrome c (fig. 11.4). The amount of homology determines how close together different groups are on the tree. Notice that the different groups of mammals end up together roughly as we would expect. The other relationships on this tree also are at least approximately what one would expect if life had evolved.

This study of biochemical homology can be applied in a very quantitative manner at various taxonomic levels. This method is being used extensively for research on the evolutionary relationships of groups of plants and animals. One paper uses biochemical data to analyze homologies and relationships between mammal orders

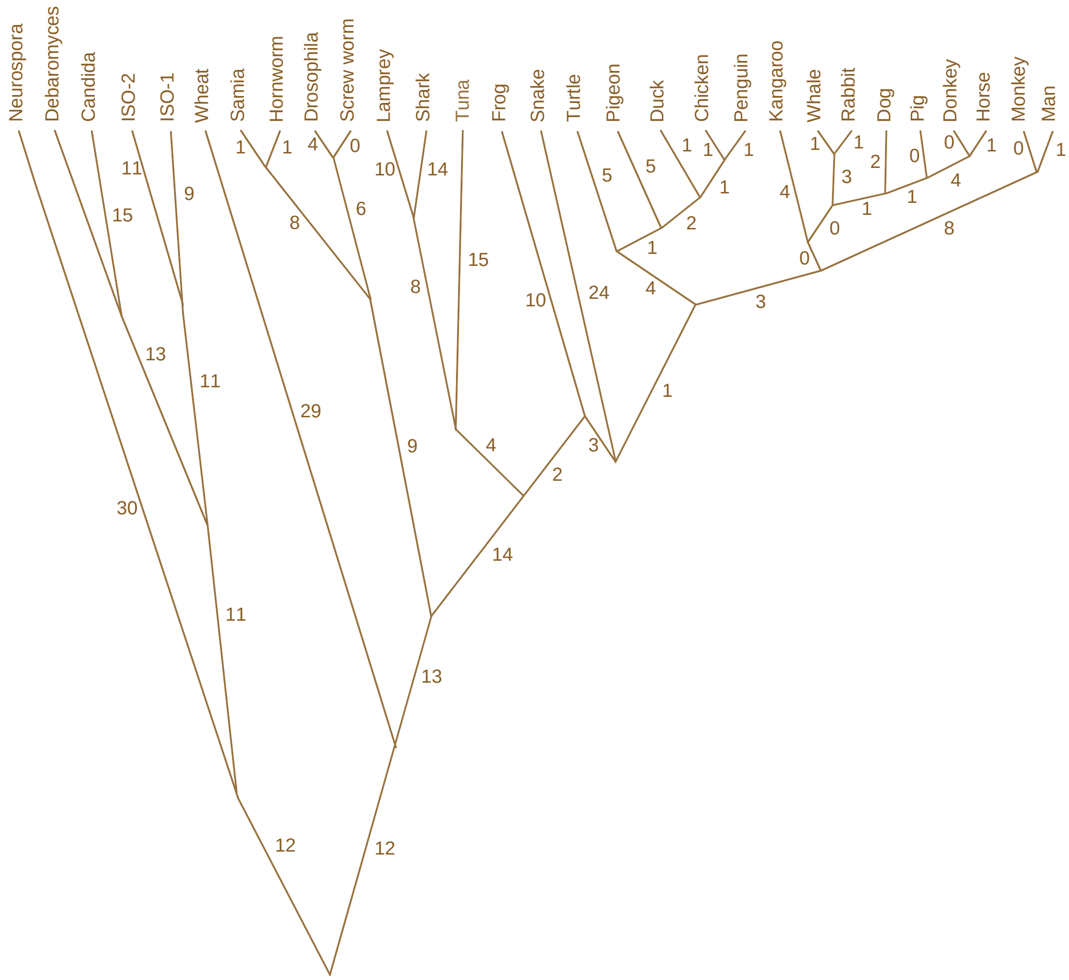


Figure 11.4. Phylogeny of vertebrates, based on the structure of the cytochrome c molecule (after Mettler et al. 1988). Figure by Leonard Brand.

(fig. 11.5).[3] The numbers next to the branches of the tree indicate the minimum number of amino acid changes needed to evolve from one group to another. This tree is similar to the one that would result from using morphological data.

Phylogenetic trees also can be based on comparison of DNA from different organisms, and this method is being widely used. The interesting thing is that if we make a tree based on bone structures, one based on amino acid sequences, and another based on DNA, they generally are similar. The interpretation of these data is that homologies show evolution from common ancestors. Increasing divergence in characteristics indicates increasing distance

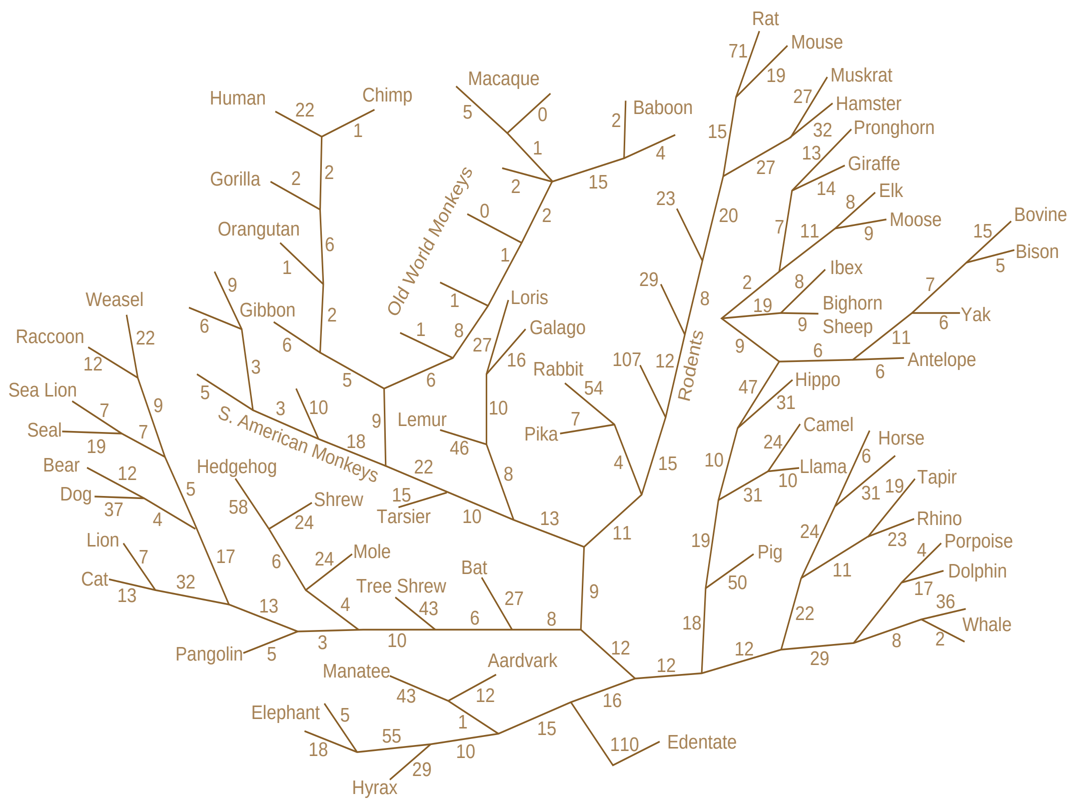


Figure 11.5. A phylogenetic tree of the eutherian mammals (includes all mammals except marsupials and monotremes), based on study of amino acids. Numbers indicate nucleotide replacements needed to account for the observed amino acid differences (after Miyamoto and Goodman 1986). Figure by Leonard Brand.

from the common ancestor. Homologies are the prime evidence used in developing phylogenetic trees.

We can carry this line of reasoning one step further. All forms of life are based on the same system of biochemistry. They essentially all use the same genetic system and the same DNA-based genetics. This indicates that all of life evolved from a common ancestor.[4] With this background, let's look at the interpretive definitions of homology and analogy. The functional definitions used above are not usually used. The more common definitions, which we will call interpretive definitions, are interpretations of the data based on evolution theory.

> Homology: The correspondence of features in different organisms due to inheritance from a common ancestor.
>
> Analogy: Features that are superficially alike but have evolved independently (a type of homoplasy—a non-homologous similarity).[5]

Embryology

In the nineteenth century, scientists noted that the embryos of different groups of vertebrates were much more similar than the adults of these groups. This led to the theory that ontogeny (embryological development) recapitulates phylogeny (evolutionary history); the embryo repeats its evolutionary history (fig. 11.6). This idea, as originally proposed by Ernst Haeckel, does not hold up to modern genetic evidence,[6] but some of Haeckel's observations are still relevant and form part of the modern understanding of the relationship between ontogeny and phylogeny. This modern theory of recapitulation recognizes that an embryo does not necessarily resemble the adults of its ancestors; but in its early stages, it resembles the embryonic stages of its ancestors because of evolutionary descent. The early embryonic stages of the different classes of vertebrates are very similar. But as they grow, they develop unique adult characteristics.[7]

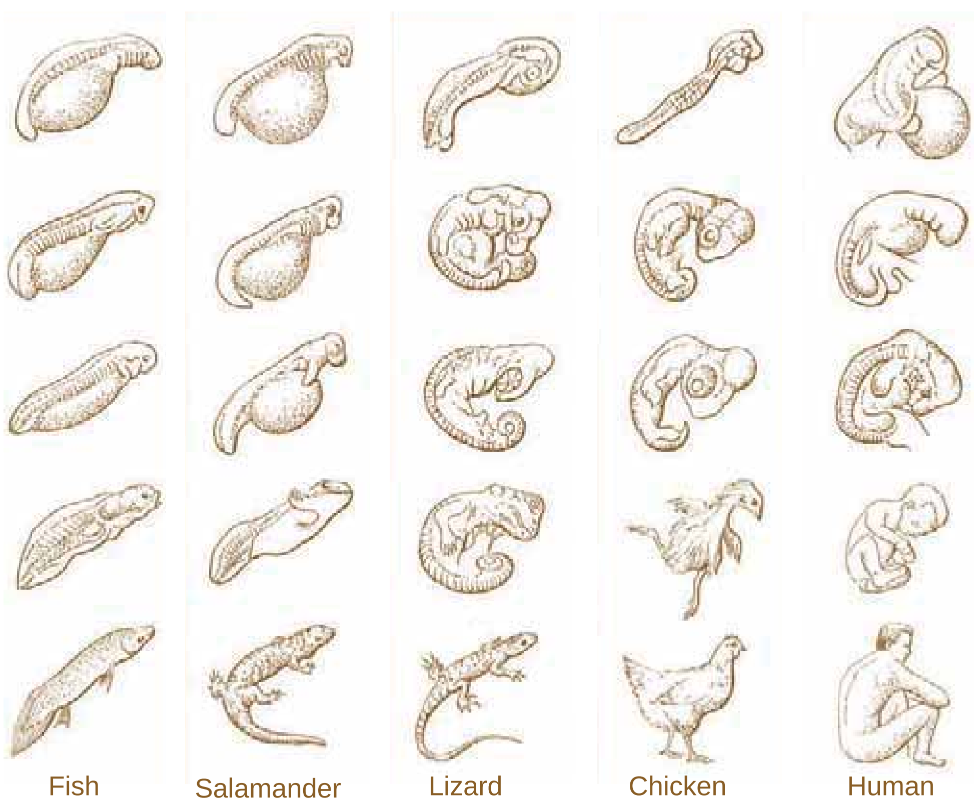


Figure 11.6. Comparison of various types of embryos, as used by Haeckel to support his theory of recapitulation (after Coffin and Brown 1983c). Figure by Robert Knabenbauer.

This same concept can be seen in the embryological development of the mammalian heart and kidney. The heart in a mammalian embryo goes through a developmental sequence similar to its evolutionary progression, from a primitive two-chambered state in the young embryo to the fully developed four-chambered mammal heart. A young mammalian embryo has a very simple kidney, similar to the hypothetical ancestral vertebrate kidney. It increases in complexity until it resembles the simple kidney of a hagfish.[8] When the complex adult (metanephric) mammal kidney completes its growth and is ready to function, the simple (ancestral) kidney atrophies and disappears. Thus it appears as if the kidney and heart repeat their evolutionary history in their embryological development.

Douglas Futuyma discusses additional embryological evidence for evolution.[9] Some aquatic salamanders have gills and fins for life underwater, but terrestrial salamanders develop entirely within the egg with gills and fins they never use and which are lost before the salamanders hatch (fig. 8.7). This seems more like an evolutionary remnant than a wise design.

The lower part of reptile back legs consists of the tibia and fibula and tarsal (ankle) bones, which articulate with the metatarsals in the foot (fig. 11.7). In the legs of birds, the tarsal bones apparently are fused to the lower end of the tibia. This combined structure is called the tibiotarsus. The fibula is vestigial, consisting only of a short bone along the upper part of the tibiotarsus. Armand Hampe devised an ingenious experiment in which a thin sheet of mica was put between the tibia and fibula in a young chick embryo.[10] The fibula then grew down to the ankle, and the tarsals developed as separate bones, as in reptiles. This seems to indicate that birds still have the genes for the "reptile" bones, but in a normal bird embryo, the tibia somehow inhibits the development of the fibula. When the fibula does not contact the ankle, the tarsals fail to develop.

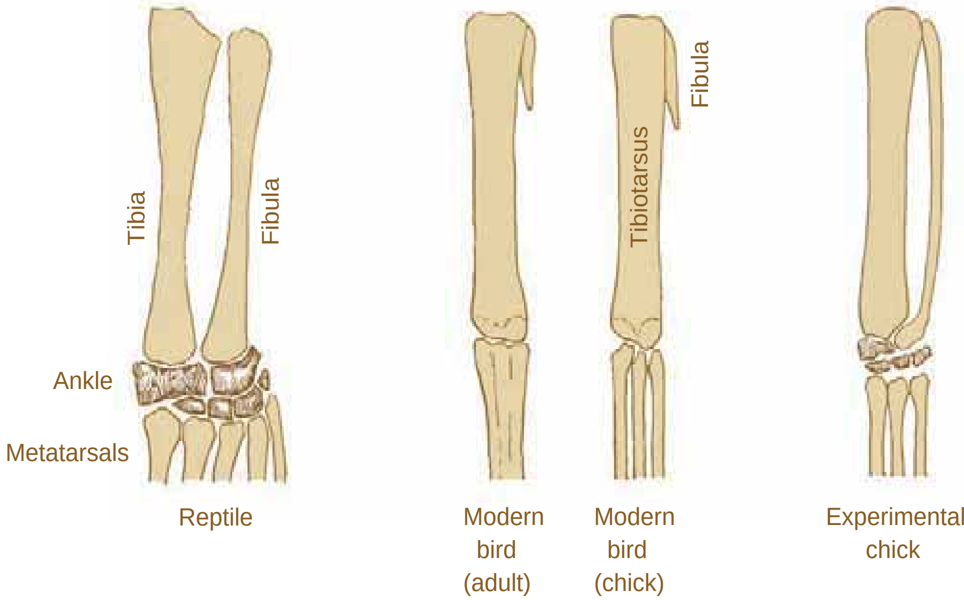


Figure 11.7. (A) Reptile and (B) bird leg bones and (C) bird leg bones that resulted from the experimental separation of the tibia and fibula (after Futuyma 1983). Figure by Robert Knabenbauer.

Vestigial Organs

Vestigial structures are remnants of an animal's evolutionary history. If animals are changing and evolving new structures, some old structures that are no longer needed will slowly disappear. During this process, a remnant or vestige of the original structure may still remain. Several organs fit the criteria of vestigial features (fig. 11.8).

The human appendix is a vestige that often poses a problem. It gets diseased and has to be removed. Another vestige is the caudal vertebrae, a remnant of a tail. Humans do not have a tail, but a short bony structure exists that is homologous to the tail of other mammals. Sometimes a human baby will actually have a short external tail that may have caudal bones in it.[11] Many invertebrates are segmented animals—especially worms and arthropods whose bodies are partially divided into many segments with muscles present in each segment. Some of this segmentation remains in vertebrates and is evident in the abdominal muscles of humans. Even though humans do not have hair covering their bodies as do other mammals, vestiges of hair are on parts of the human body. Most mammals have muscles that move their ears to get the best reception of the sounds they

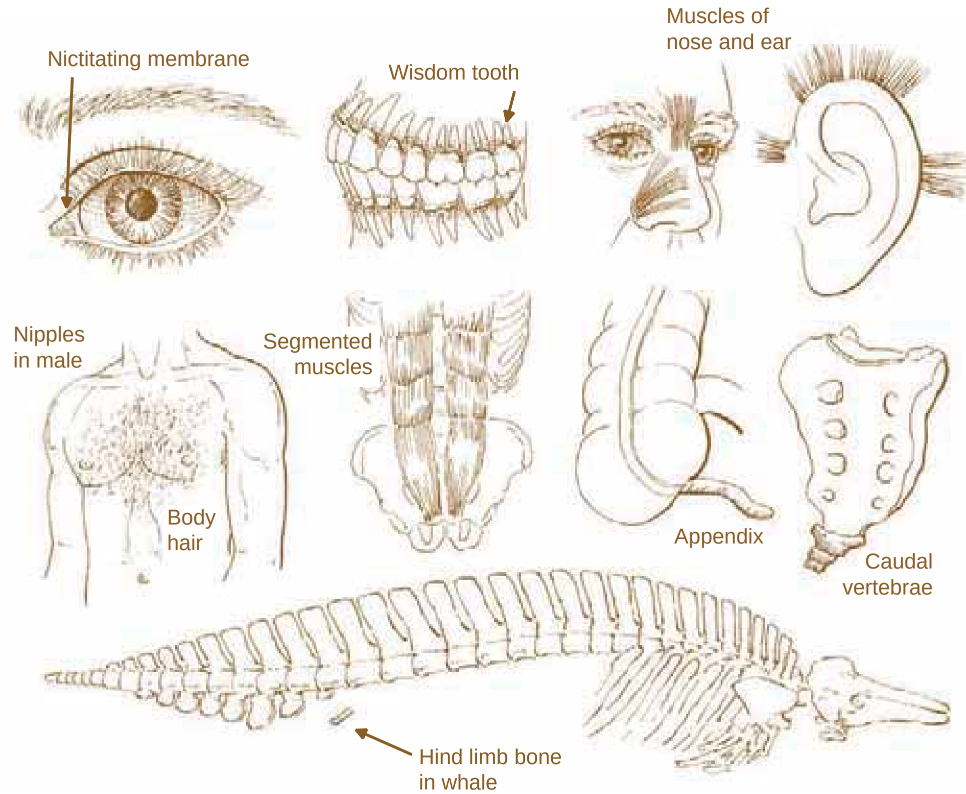


Figure 11.8. Several vestigial organs in humans and vestigial hind limbs in a whale (after Villee 1977). Figure by Robert Knabenbauer.

hear. Humans have the same muscles connected to our ears even though we cannot turn our ears and have no real need for these ear muscles. Some vertebrates have a third eyelid that can be brought across the eye to protect it. Humans lack that third eyelid, but they do have a small vestige of it, the nictitating membrane in the corner of the eye. Third molars or "wisdom teeth" are often a problem for humans, and sometimes they need to be taken out. Humans have canine teeth, which are still somewhat pointed, but they are not large enough to serve the original purpose of the long canines in many other mammals. These are all vestiges of things that we apparently do not need anymore.

Whales have front flippers and tail flukes but no hind limbs. Whales evolved from other mammals that did have hind limbs. In the process of evolution, the hind limbs disappeared except for two little bones embedded in the flesh—vestiges, apparently, of hind limbs.[12] Rarely a dolphin is born with rear flippers, indicating that the genes for these structures are present.

Another item that can be considered vestigial is junk DNA—the abundant dead genes that apparently once were functional but now are nonfunctional remnants of the evolution process. These include pseudogenes, similar to functional genes but with one or more mutations that eliminate their functionality.[13]

A number of examples at the microevolution level can illustrate the reality of the development of vestigial structures and show how the vestiges described above must have developed. Examples include blind cave salamanders with vestiges of eyes, flightless birds with vestigial wings, and flightless beetles with useless wings sealed under their fused wing covers.[14] All of these vestigial structures are evidence of evolution from other animals that needed those structures.

Mistakes and Imperfect Designs as Evidence of History

The study of evolution is in part the study of how organisms have adapted to their environment. But perfect adaptations or "ideal design is a lousy argument for evolution, for it mimics the postulated action of an omnipotent creator."[15] Adaptations that seem illogical or suboptimal are better indications of evolutionary history.

A number of years ago, I (Brand) bought an old house and proceeded to remodel it. In my crawling about in the attic and in the crawl space under the house, I encountered many interesting things. The heavy beams and pillars supporting the floor explained why the wood floor was not squeaky in spite of the house's age, and the water pipes all connected into a logical system. Other features were more intriguing. These included a set of concrete steps under the house and another set buried in the ground outside the house and a main sewer line that exited the house on the side opposite the sewer connection and then went halfway around the outside of the house to its destination.

Sections of sturdy foundation under the house looked like exterior wall foundations, but they did not support anything except the middle of a bedroom floor (which eased my concern about the weight of our water bed).

It soon became evident that these odd features could not be explained by logic or by the structural needs of a house. They could be explained only by history. The house had been through a series of remodelings and additions by previous owners. The unusual features were historical remnants of those events and were no longer relevant to the current structural needs of the house. The extra foundations were under exterior walls before the bedrooms were enlarged with new foundations and new walls. The old steps indicated the positions of exterior doorways at early stages in the home's history. The circuitous sewer line was explained by the existence of an abandoned septic tank at the place where the sewer line came out of the house. I began to feel like an archaeologist as I pieced together the history of the house (fig. 11.9) on the basis of these and other historical remnants, while my family thought I was under the house working hard. In the process of adding on to the house, I left a few historical remnants of my own. Thus if the next owner is of a curious disposition, he or she will have the material for many happy hours of archaeological investigation, but he or she also will have new difficulties because my work destroyed some of the evidence.

This story is exactly analogous to the study of evolutionary history using suboptimal adaptations or odd structures as evidence for historical, evolutionary events. Vestigial structures do not have a functional explanation; they are remnants of evolutionary history. Since life has a history, the types of adaptations that can develop in any given organism depend on the raw material that history has provided. For example, when bats evolved, they could not develop wings like insects or birds because their immediate ancestors already had the typical mammalian hand structure. So bats were constrained to develop a wing that was a modification of that mammalian hand

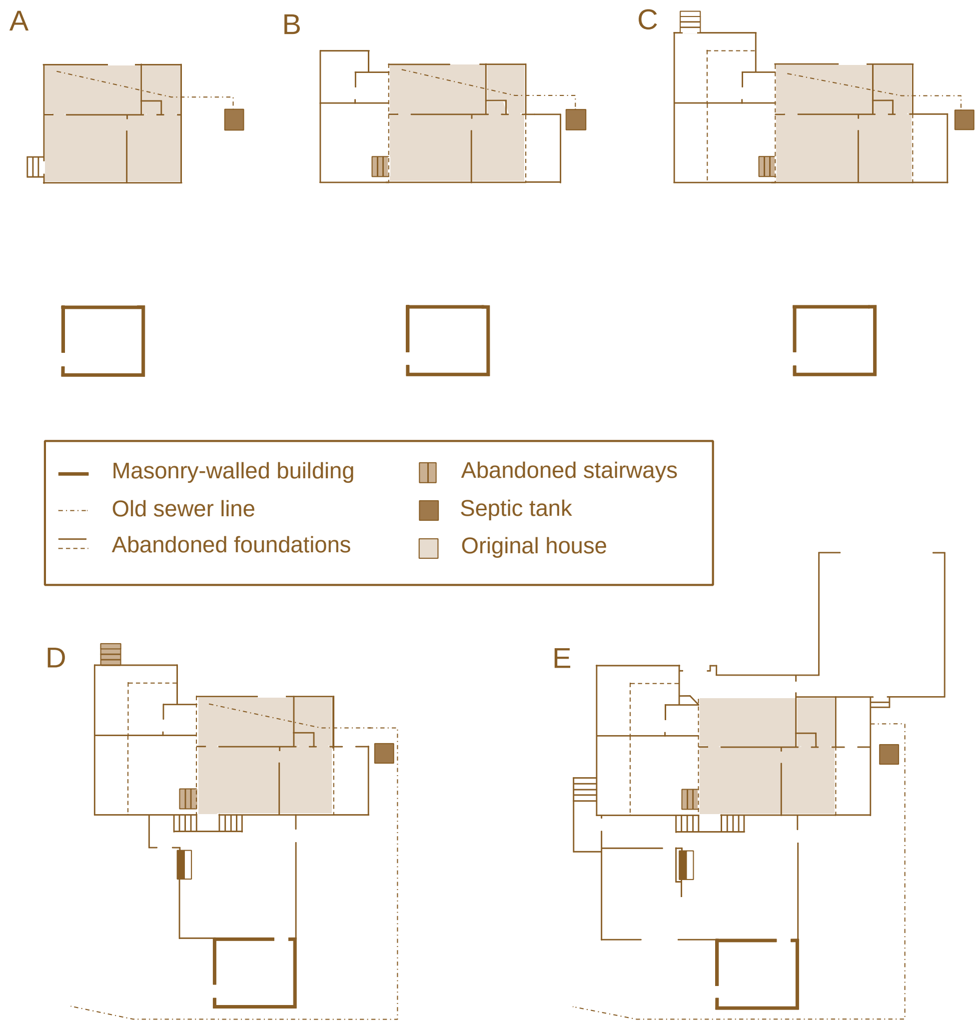


Figure 11.9. Sequence of additions to a house, reconstructed from the historical remnants of this series of events. Figure by Leonard Brand.

structure. If an intelligent Creator had designed life, why would a bat's wing not be uniquely and optimally designed for its purpose instead of being a mere modification of a terrestrial mammal's front limb? This is always the way it is: the structure of every organism consists of adaptations of existing characters of the group that it evolved from rather than showing the originality and creativity that we would expect from a Creator.[16]

This principle is illustrated nowhere better than in the panda's thumb.[17] The giant panda eats only bamboo, which it dexterously handles between its thumb and other fingers. The thumb, however, is not an ordinary thumb. It is

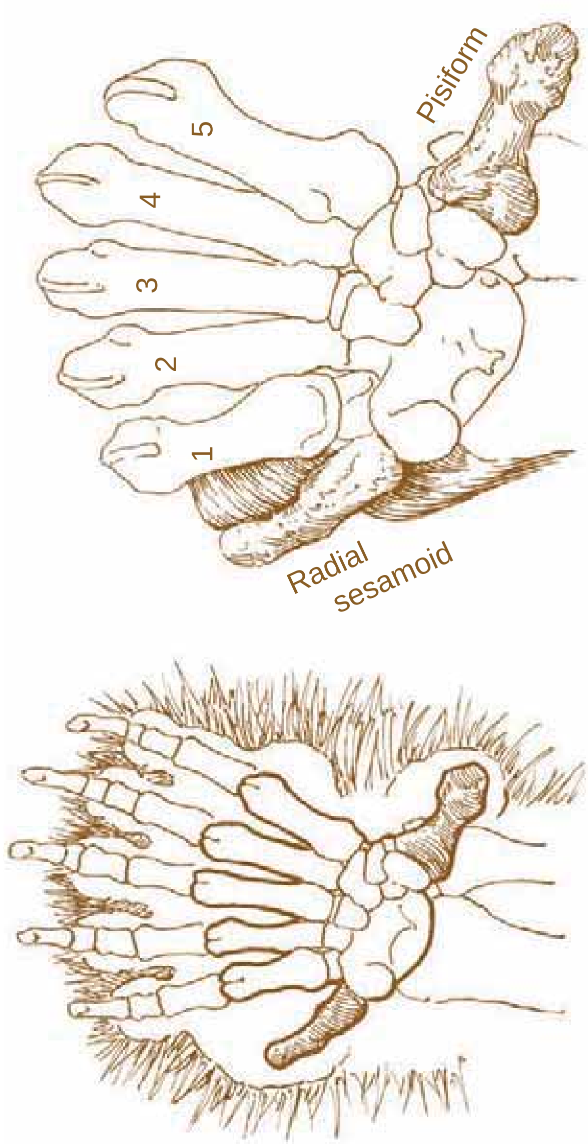


Figure 11.10. The structure of the Panda's foot, with its unique thumb (radial sesamoid). Close-up drawing on the right (after Ewer 1973; Gould 1980). Figure by Robert Knabenbauer.

a sixth "finger" that is really an elongated radial sesamoid bone in its wrist. The muscles present in other mammals have been modified to serve the panda's novel thumb (fig. 11.10). Other members of the bear family do not have an opposable thumb and, consequently, the panda did not have the raw materials to readily evolve a dexterous thumb like some other mammals have. Instead, it developed, from the already somewhat enlarged sesamoid bone that other bears have, an unusual thumb that adequately meets its needs. The panda also has an enlarged sesamoid bone on the other side of its front foot. The muscle attachments suggest that this bone also may be mobile,[18] though it has not been studied as much as the radial sesamoid.

The vertebrate eye has long been recognized as a poorly designed evolutionary accident because the cell layers in the retina are arranged backward. The light must pass through several cell layers before reaching the photoreceptors, resulting in a loss of efficiency in light transmission. Another type of suboptimal feature is the struggle, destruction, and cruelty so evident in nature, instead of the harmony that an intelligent Creator would be expected to produce. Some animals seem poorly adapted, such as the lemmings and locusts, which have no adaptation to prevent overpopulation. Their populations periodically experience uncontrolled expansion with devastating results to themselves and their habitat.[19]

The path taken by the recurrent laryngeal nerve in mammals can only be explained by our evolutionary history. In our fishlike ancestors, this nerve follows the sixth branchial arch directly to its destination. In mammals, it continues to follow the same path, but because of anatomical differences in mammals, it must go all the way down into the chest, around the aorta, and back to the larynx. In giraffes, this means it goes about fifteen feet farther than if it had been optimally designed to go straight from its source to its destination.[20]

Hierarchical Nature of Life and the Ascending Scale of Complexity

All animals share essentially the same basic biochemical functions, but when we compare features of physiology and anatomy, we can arrange the animal groups in an evolutionary scale of complexity (fig. 11.11). Protozoa are composed of only one cell. Sponges are multicelled but lack separate germ layers. Flatworms added separate germ layers, and roundworms were the first to have a complete digestive tract. Fish were the first to have an internal skeleton; amphibians were the first tetrapods, or four-legged animals; reptiles added a completely terrestrial life cycle; mammals and birds became warm blooded; and mammals bear live young. Each group added important features as life "climbed" the evolutionary scale.

The evolution of plants and animals occurred by a series of sequential, splitting events. For example, mammals split off from reptiles; then mammals and reptiles each split to produce various orders. The mammalian order Carnivora split into families, including cats, dogs, and bears. After that, the dog family split into wolves, jackals, and foxes. The result of this process is a hierarchical arrangement of living things in groups nested within groups (fig. 11.12). Objects that did not descend from common ancestors, like minerals, cannot be arranged that way.[21] If life had been created by an intelligent

	Multicelled	Germ layers	Complete digestive tract	Circulatory system	External shell or skeleton	Internal skeleton	Complete terres-trial life cycle	Warm blooded	Bear placental live young
Mammals	x	x	x	x		x	x	x	x
Birds	x	x	x	x		x	x	x	
Reptiles	x	x	x	x		x	x		
Amphibians	x	x	x	x		x			
Fish	x	x	x	x		x			
Snails	x	x	x	x					
Insects	x	x	x	x					
Earthworms	x	x	x	x	x				
Starfish	x	x	x	x	x				
Roundworms	x	x	x						
Flatworms	x	x							
Jellyfish	x								
Sponges	x								
Protozoa									

Figure 11.11. Principal animal phyla arranged in the ascending scale of complexity. Figure by Leonard Brand.

designer, we would expect more of a continuum of types of organisms, not a hierarchical arrangement.

Biogeography

Among Charles Darwin's most important lines of evidence were the patterns of geographic distribution of plants and animals, and the agreement between biogeographic distribution and presumed evolutionary history. The distribution of plants and (especially) animals matches the pattern that we would expect to see if each group originated at a particular geographic location and spread from there, adapting to the ecological conditions encountered. The historical explanation of such oddities as abandoned stairways and pandas' thumbs also applies to the oddities of animal distribution.

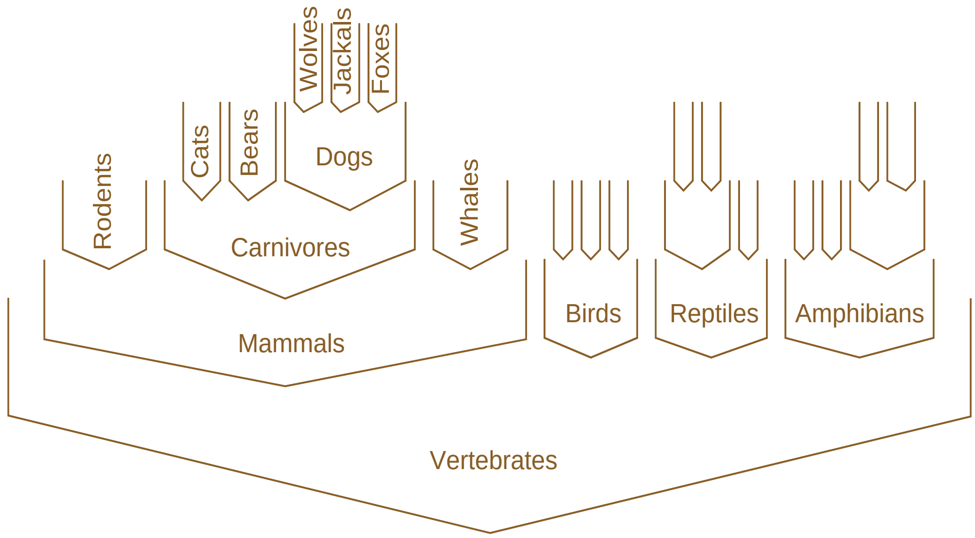


Figure 11.12. An example of the hierarchical arrangement of life. Figure by Leonard Brand.

Very few types of animals are widely distributed over the earth in their preferred habitat. Instead, the animal groups found in each geographic region have evolved species to fill the habitats in that region (fig. 11.13). Moles of the family Talpidae live underground in burrows and eat worms and other small animals. They are common in North America, Europe, and Asia. In Africa, the same niche is occupied by a different family of moles, the golden moles of the family Chrysochloridae. In Australia, moles look similar to the others but are marsupials unrelated to them. Many other examples could be applied to this principle. In the Galapagos Islands, a group of finches (Darwin's) evolved into an insect-eating species, some seed eaters, and a woodpecker. In other parts of the world, those same niches are filled by birds in families different from Darwin's finches. Oceanic islands, like the Galapagos, only have animals that would be able to cross great expanses of ocean.[22] If life was created, why wouldn't the Creator put giraffes on an island or two?

South America has a complex of about eleven families of rodents (sometimes called the hystricomorph or hystricognath rodents) with common skeletal features indicating that they are closely related to each other. But they do not share these features with other rodent families on other continents.[23] Apparently, the South American rodents originated there and radiated to fill the many

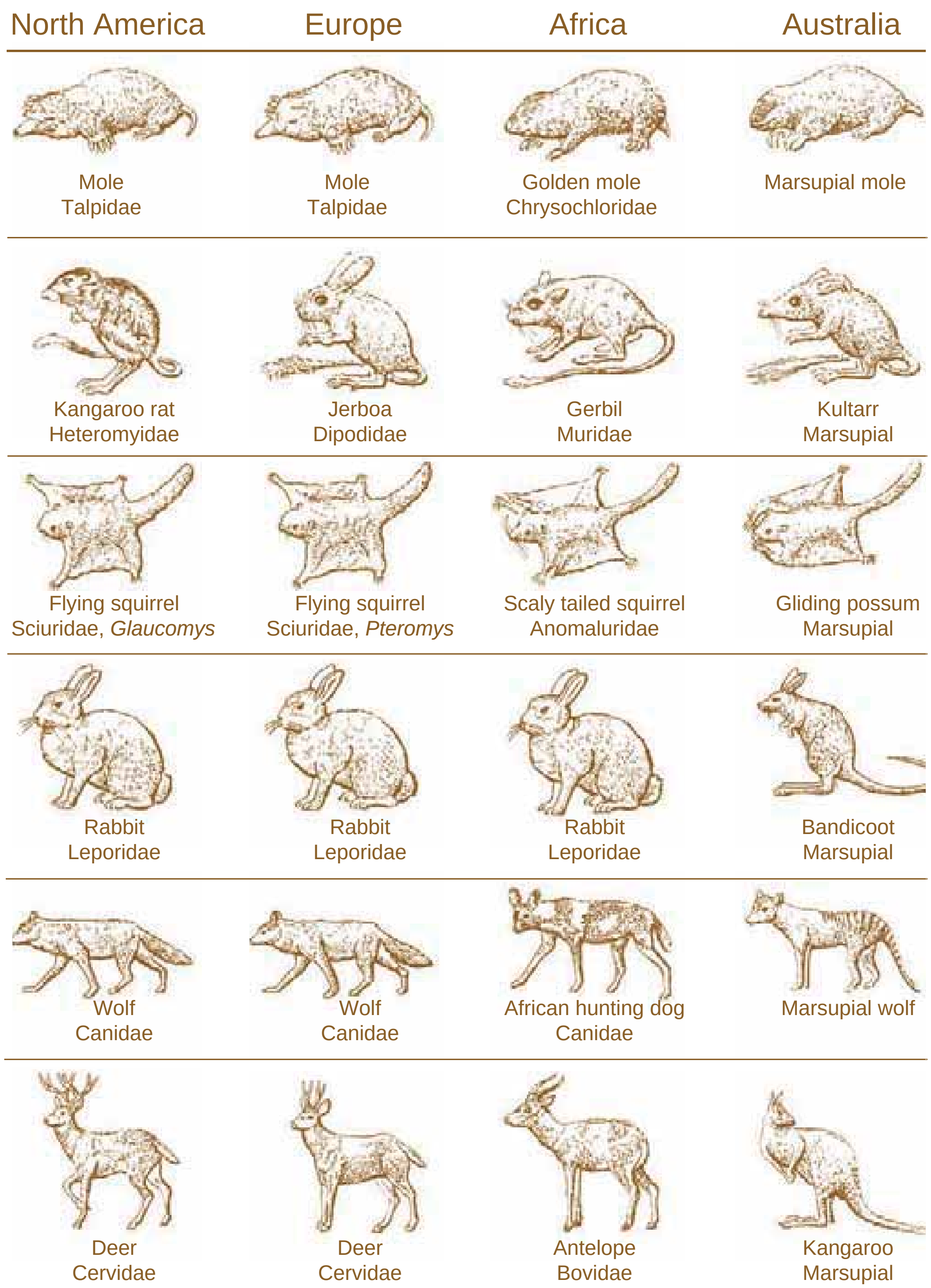


Figure 11.13. Ecological equivalents on four continents. The same ecological niche is often filled on different continents by unrelated animals. The animals on each row are ecological equivalents. Figure by Robert Knabenbauer.

ecological niches occupied on other continents by other families of rodents. Almost all the mammals in Australia are marsupials. These have radiated to fill the ecological niches occupied on other continents by nonmarsupials. "The only rational—that is, scientific—explanation for such patterns must be that species were not distributed over the face of the earth by the Creator but had originated in different places and had dispersed from there."[24]

Fossil Record

To really settle a question about the past, we need historical evidence. The fossil record is the most direct historical evidence available. Evolution theory implies certain expectations about the fossil record. For example, simple creatures should occur first (lower) in the rocks. More highly evolved groups should occur farther up.

Ideally, one expects to find series of links connecting different groups of organisms (e.g., if we compare fossil worms and molluscs, at some point, as we go farther down in the fossil record, they should become more similar and finally merge into a common ancestor through a series of evolutionary connecting links). The Grand Canyon is an elegant example of the series of layers of sedimentary rocks that cover a significant portion of North America. These layered rocks formed when sand, mud, or other sediments were washed into a basin by water, primarily, or carried by wind and were deposited one layer on top of another.[25] This stack of layers of rock is the geologic column, and its sequence of fossil deposits is referred to as the fossil record (fig. 11.14).

There are basic rules for interpreting this rock record. Since the layers are formed by the process described above, those on the bottom must have been deposited first. The result is a time sequence from oldest on the bottom to youngest at the top. This is true no matter how much or how little time we think has elapsed during the formation of the geologic column with its fossils. This fossil record has the potential to provide convincing evidence of whether macroevolution has occurred.[26]

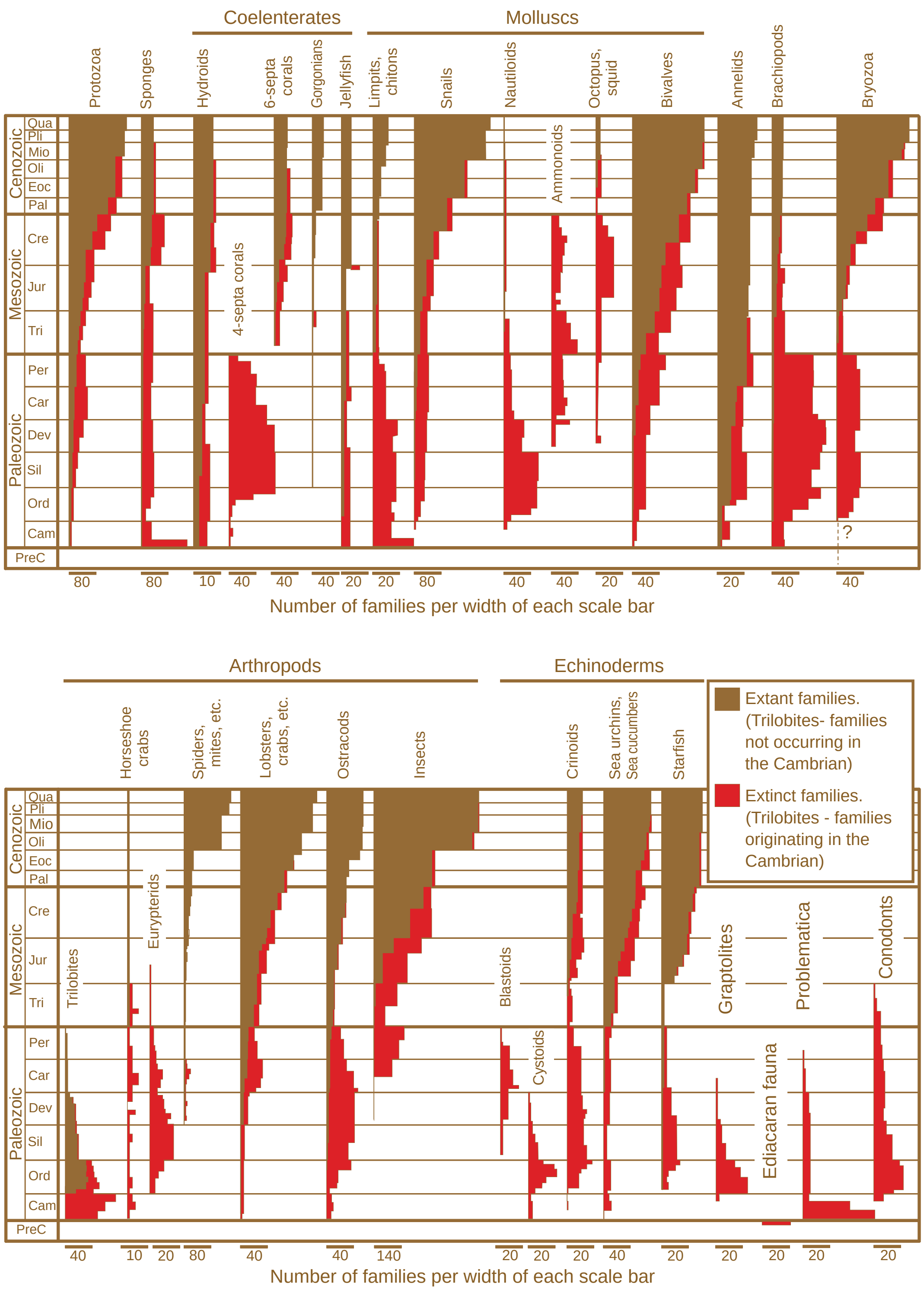
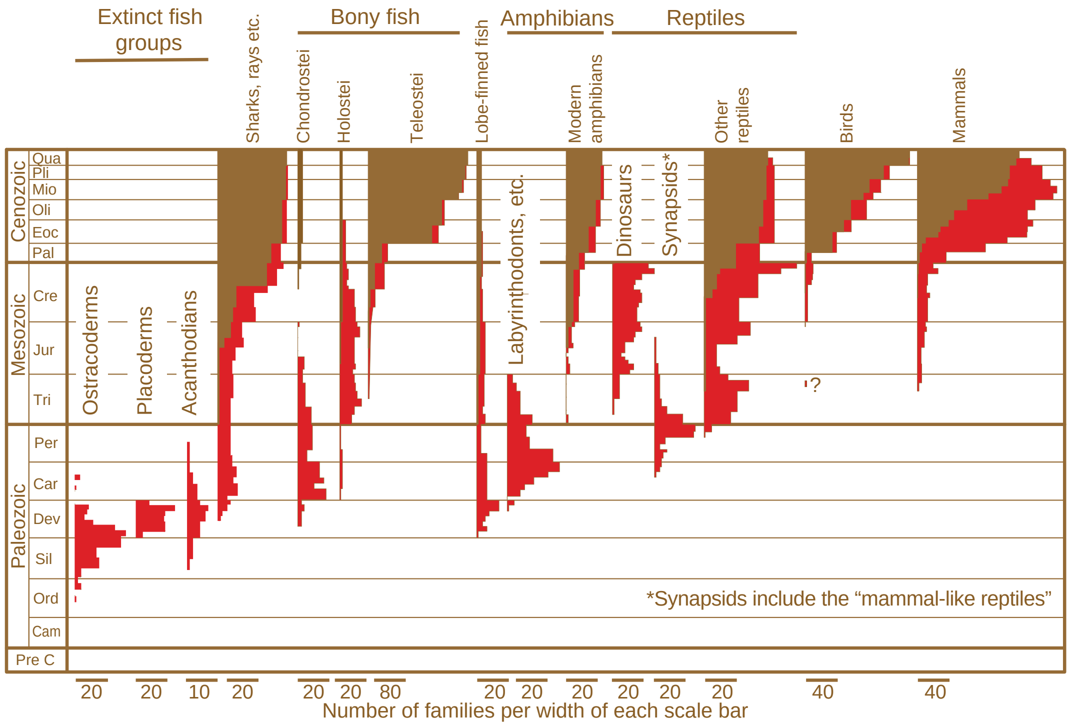
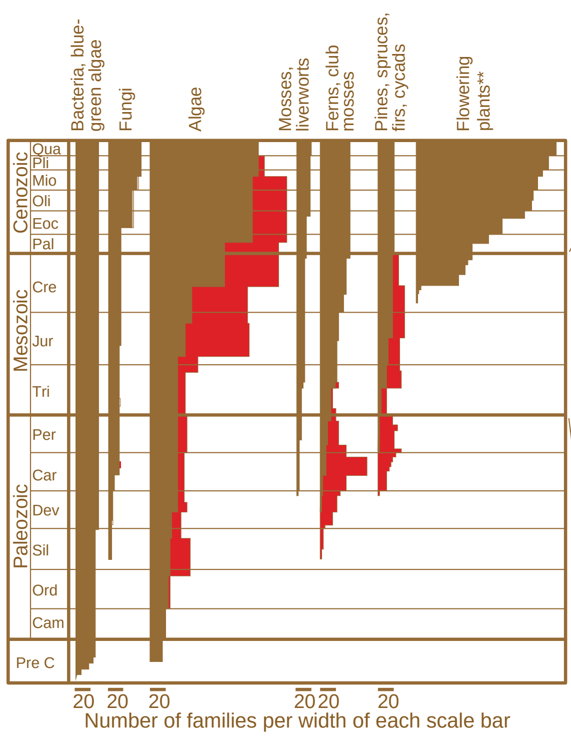
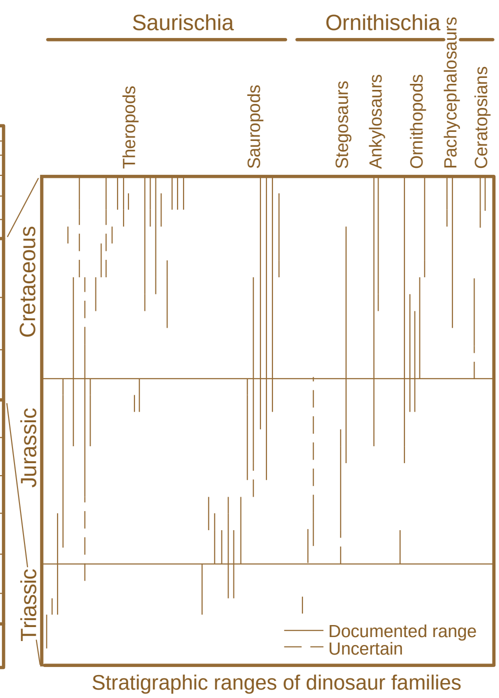


Figure 11.14. Stratigraphic distribution of major groups of animals in the fossil record, showing distribution of extant (still living) and extinct forms, and the stratigraphic ranges of dinosaur families (based on data from Benton 1993, with flowering plant data added from Harland 1967). Figure by Leonard Brand.


Extinct fish groups
Bony fish
Amphibians
Reptiles
Sharks, rays etc.
Chondrostei
Holostei
Teleostei
Lobe-finned fish
Modern amphibians
Other reptiles
Birds
Mammals
Cenozoic
Mesozoic
Paleozoic
Qua
Pli
Mio
Oli
Eoc
Pal
Cre
Jur
Tri
Per
Car
Dev
Sil
Ord
Cam
Pre C
Ostracoderms
Placoderms
Acanthodians
Labyrinthodonts, etc.
Dinosaurs
Synapsids*
?
*Synapsids include the "mammal-like reptiles"
20 20 10 20 20 20 80 20 20 20 20 20 20 40 40
Number of families per width of each scale bar


Bacteria, blue-green algae
Fungi
Algae
Mosses, liverworts
Ferns, club mosses
Pines, spruces, firs, cycads
Flowering plants**
Cenozoic
Mesozoic
Paleozoic
Qua
Pli
Mio
Oli
Eoc
Pal
Cre
Jur
Tri
Per
Car
Dev
Sil
Ord
Cam
Pre C
20 20 20 20 20 20
Number of families per width of each scale bar


Saurischia
Ornithischia
Theropods
Sauropods
Stegosaurs
Ankylosaurs
Ornithopods
Pachycephalosaurs
Ceratopsians
Cretaceous
Jurassic
Triassic
Documented range
Uncertain
Stratigraphic ranges of dinosaur families

The oldest rocks on earth are Precambrian rocks. In the Grand Canyon area, Precambrian rocks are exposed only in the very bottom of the canyon. The only fossils found in most of the Precambrian rocks are single-celled organisms, but near the top of the Precambrian layers are fossils of more complex animals (the Ediacaran fauna).[27] The portion of the geologic column above the Precambrian is called the Phanerozoic. This part of the column contains abundant fossils. The Phanerozoic rocks are divided into three portions: the Paleozoic (the lowest portion), the Mesozoic, and the Cenozoic (the highest portion), which contains the most recently deposited rocks. The lowest part of the Paleozoic contains only invertebrate fossils and fish.[28] Higher in the fossil record, different groups appear in a sequence.

The first fish[29] are followed by other kinds of fish, then amphibians, and finally reptiles including the dinosaurs. Fossils have yielded fascinating insights into the biology of this unique group, but scientists still argue over whether the dinosaurs were warm or cold blooded.[30] The last groups to appear are the mammals and birds.[31] Within these groups, the different orders and families also appear in an evolutionary sequence. Most of the familiar mammal groups that we see today do not appear as fossils until the Lower or Middle Cenozoic. Human beings appear first at the very top in the Pleistocene (fig. 11.14).

Clearly, a sequence in the order of appearance of different groups of animals occurs in the fossil record. This pattern also holds true at lower taxonomic levels (genus and species). This part of the evolutionary expectation is fulfilled quite well. The invertebrate animals appear first, and the more structurally complex types appear at successively later periods. There is also an ever increasing percentage of extinct groups as one goes farther back in the fossil record (fig. 11.14). The groups of animals and plants that live today are common as fossils in the Pleistocene and Upper Tertiary, but farther down in the record are more ancient groups that died out and were replaced by modern groups, showing the process of evolution through time.

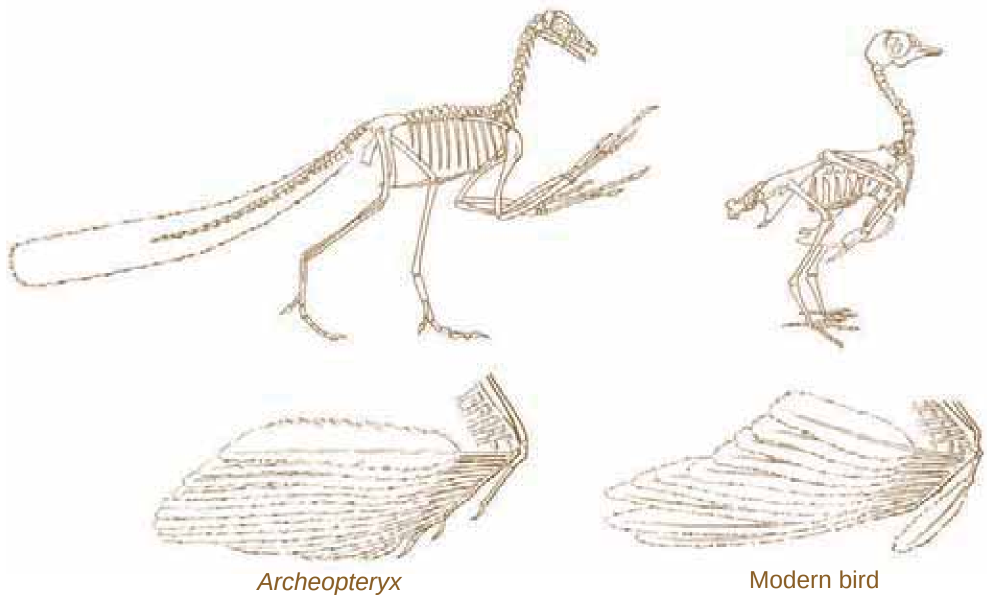


Figure 11.15. The skeleton and the arrangement of wing feathers for *Archaeopteryx* and a modern bird (after Carroll 1988). Figure by Robert Knabenbauer.

What about the second expectation for connecting links between groups? Darwin recognized that the fossil record did not show much evidence of connecting links. He thought that as much more fossil collecting was done over time, these links would be found. In the 150 years since Darwin's prediction, many fossils have been collected and have greatly increased our understanding of the fossil record. This improved database still suggests that, for most animals and plants, the fossil record does not contain connecting links between types. In most cases, some features of the fossilization process apparently have not allowed the series of connecting links to be preserved.

The major groups (phyla) of invertebrates first appear in the lowest Paleozoic and are distributed through the fossil record without links between the groups. The major groups of vertebrates do not appear as early in the record, and the vertebrate classes appear in the record in a logical evolutionary sequence.[32] The vertebrate record, in many cases, does not contain convincing series of evolutionary links between orders or classes. There are exceptions such as *Archaeopteryx*, which essentially had a reptile skeleton and feathers and could fly (fig. 11.15).[33] There are also some small dinosaurs with

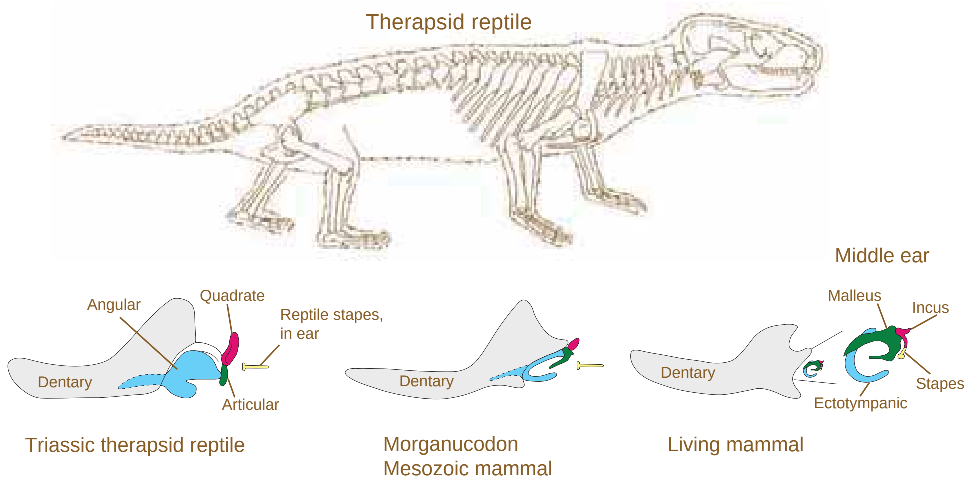


Figure 11.16. Upper: The reptile *Thrinaxodon*, a part of the therapsid line of reptiles that are interpreted as ancestors to the mammals. Lower: Homologous bones in the lower jaw and ear of a therapsid reptile, a living mammal, and *Morganucodon*, one of the presumed intermediates (after Carroll 1988; Benton 2005; and other sources). Figure by Robert Knabenbauer and Leonard Brand.

feathers,[34] providing evidence of the evolution of birds from dinosaurs.

The early mammals and mammal-like reptiles form a good evolutionary sequence from reptiles to mammals with many different species at various stages of the process (fig. 11.16).[35] Also, the first amphibians are remarkably similar in many features to their ancestral group, the rhipidistian fishes (fig. 11.17). Both have the unique labyrinthodont tooth structure, a large notochordal canal through the floor of the braincase (not found in other tetrapods), and other common features. Recently a new Late Devonian fossil was found, called *Tiktaalik*, that appears to be an intermediate between these fish and early amphibians. It has the body of a fish, but the fins have stronger bones than fish, perhaps for supporting itself on its fins,

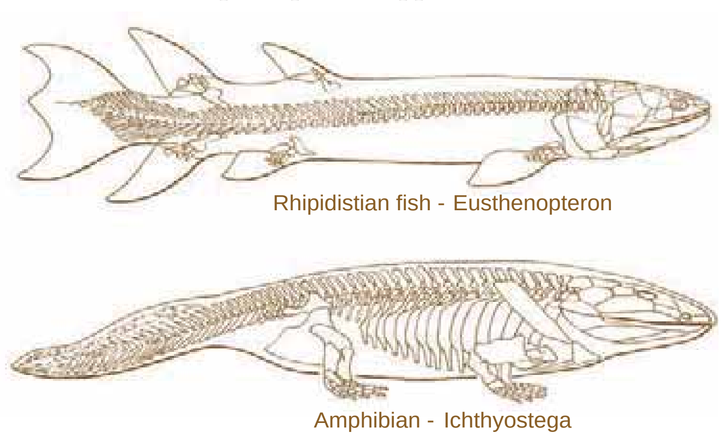


Figure 11.17. The rhipidistian fish *Eusthenopteron* compared to the primitive amphibian *Ichthyostega* (after Carroll 1988). Figure by Robert Knabenbauer.

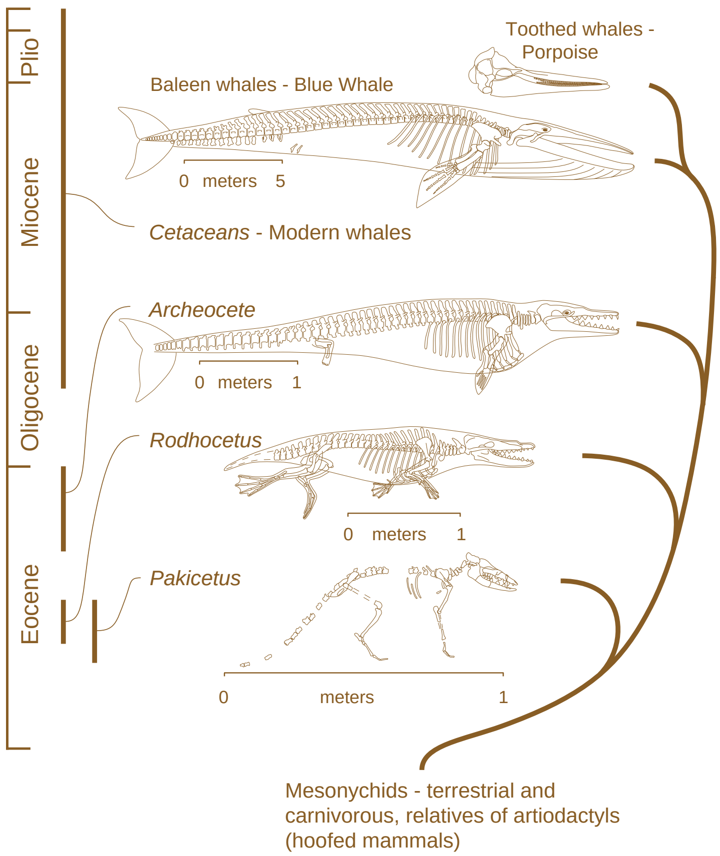


Figure 11.18. The stratigraphic distribution of whales in the fossil record and the theory of the evolution of whales from land mammals (after Savage and Long 1986; Gingerich et al. 2001; Thewissen et al. 1994). Figure by Leonard Brand.

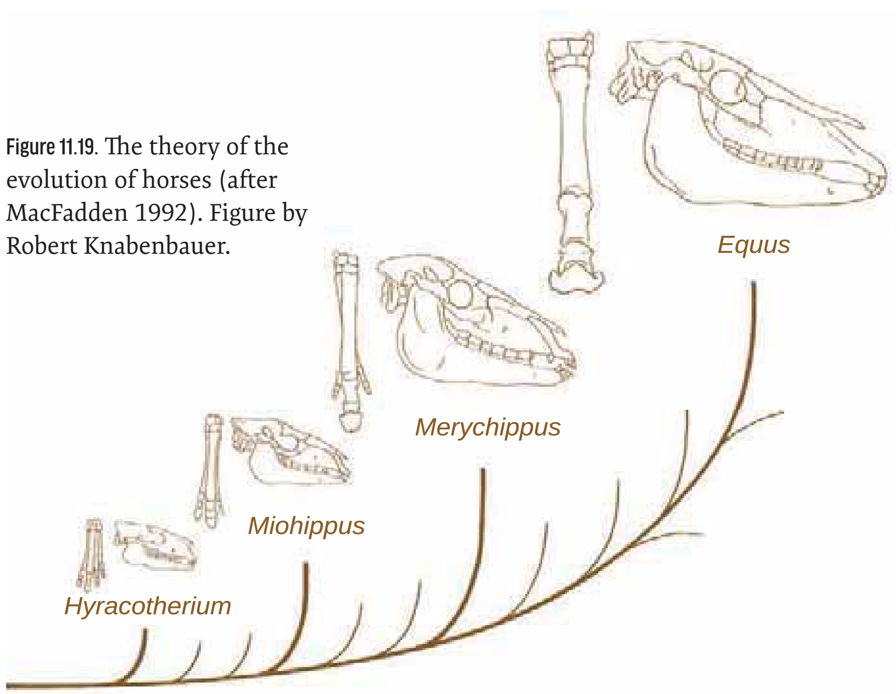


Figure 11.19. The theory of the evolution of horses (after MacFadden 1992). Figure by Robert Knabenbauer.

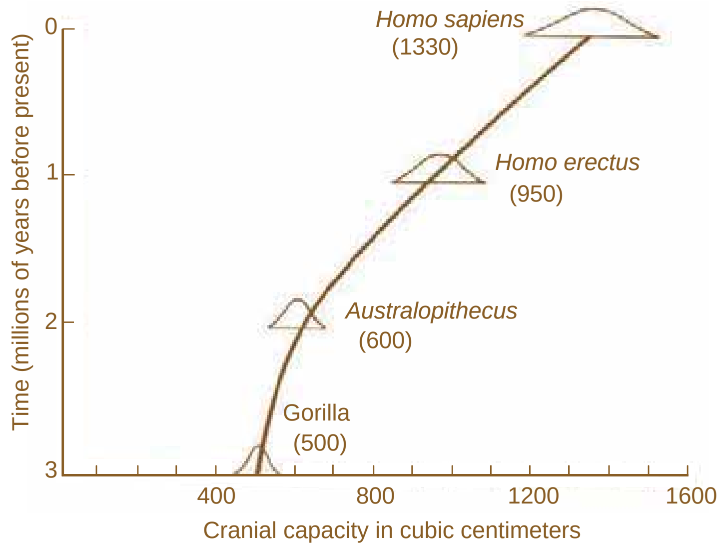


Figure 11.20. Average brain size of several groups of fossil hominids (after Mettler et al. 1988). Figure by Robert Knabenbauer.

and the skull is more flattened and crocodile-shaped than the Devonian lobe-finned fish.[36]

Some early fossil whales are found with small hind limbs (fig. 11.18),[37] and some fossils are being interpreted as semiaquatic animals linking whales to terrestrial ancestors. The fossil horses form a classic evolutionary sequence (fig. 11.19),[38] and hominid fossils (humans and “ape men”) form a sequence with increasing brain size (fig. 11.20).[39]

In spite of these notable exceptions, the general picture is that no fossil connecting links occur between most groups of animals. In plants, the lack of connecting links is perhaps even more striking. This is well recognized today by science. What is the reason for this lack of intermediate forms? Increased awareness of the lack of connecting links has led to lively discussions within evolutionary science in the search for the answer to that question. When the data do not occur as a paradigm expects, it can sometimes stimulate more careful research and thought.

The evolution theory as proposed by Charles Darwin maintained that evolutionary change occurs gradually, at a slow and fairly even pace. The many small changes that occur in the process of microevolution, over very long periods of time, add up and generate the larger changes that produce new species and families. Today, most recognize that Darwin's gradualist concept of evolution is not adequate to explain the evidence. It is recognized that new species are not likely to evolve in large, widespread populations but in small, isolated populations at the edges of the species range.[40] Rapid speciation in these small populations has much less chance of being preserved in the fossil record than the many individuals representing the status quo in the main population. As a result, new species generally appear suddenly in the fossil record, and very little change occurs between speciation events.[41]

The evolution of new groups of land animals occurs in upland environments where fossils are not likely to be preserved. This fact also works against the preservation of connecting links as fossils. The incompleteness of the geological record is another factor that reduces the probability that intermediates will be preserved. Fossilization is a rare event and any given population of animals has a very small chance of being preserved as fossils. If evolution of new body plans (new phyla) and of orders and classes within those phyla occurs quite rapidly, the sequences of intermediates likely would not be preserved, and we are fortunate to have even a few good sequences of intermediate forms.

Cosmology

There are larger issues that were not even thought of in Darwin's day. Cosmologists now know that the universe began with a huge explosion, the Big Bang, and has been expanding since then. This is what has given us our universe, with its ability to support life. In recent decades, it has been found that the physical laws that govern our universe are finely tuned to make life possible. Many factors in the fundamental laws have to be just as they are, with very little variation, or carbon-based life would be impossible, and if there were too much variance, the universe could not persist. Scientists have suggested answers to this dilemma. Perhaps life exists elsewhere in a different form, such as silicon-based life. Also the theory of the multiverse suggests there are multiple universes that we are not aware of.[42] If there are many universes, each with its own set of physical laws, then it would not be surprising if one universe just happened to have the right parameters to support carbon-based life. To claim that conditions on our earth require a Creator God is to give up trying to understand what other options there might be that are more consistent with a truly scientific, naturalistic perspective.

Convergence of Lines of Evidence

All the lines of evidence we have considered in this chapter, as well as the radiometric dates (to be discussed later) that indicate the great age of the fossils, point to the evolution of life through hundreds of millions of years. The fact that a few basic concepts contained in the theory of evolution can explain so many lines of evidence is a strong argument for macroevolution. Jerry Coyne said it well: "Despite innumerable *possible* observations that could prove evolution untrue, we don't have a single one . . . evolution always comes up right."[43]

CHAPTER 12

The Case for Informed Intervention

Overview

Sometimes one explanation can sound convincing, until we hear a different explanation for the same evidence. In this chapter, we cover the same ground as chapter 11, presenting interventionist interpretations for the same lines of evidence. The objective here is not to prove interventionism but to seek to develop an internally consistent interventionist theory, a theory that does not accept the assumptions of methodological naturalism. As we consider each issue, we evaluate the strength of the evidence for this theory, applying the principles of critical thinking. We conclude that an interventionist interpretation is at least as effective, and often more effective, in explaining the evidence.

Arguments and Human Relationships

We have examined the evidence for macroevolution—the evolutionary origin of groups of plants and animals that are different enough to be placed in separate families, orders, classes, and phyla. Is it possible that the same evidence might fit the idea of informed intervention followed by evolution below the macroevolution level? Could there be limits to the evolution process?[1] This chapter is longer than chapter 11 because it compares alternate interpretations and applies critical thinking—how are assumptions, plus the evidence, affecting conclusions? What is the inference-to-the-best-explanation?

The way we deal with this subject is important. Some creationists have a tendency to be sarcastic and to talk down to evolutionists. Scientists are portrayed sometimes as being very stupid to believe in evolution. That approach is neither true nor constructive. Macroevolution is not a theory to laugh at. One who is knowledgeable about the data can make a case for it that sounds quite convincing. We also can make a good case for an alternative point of view, but we are talking about things that are complex and that happened a long time ago. Thus neither paradigm can expect to have proof. A line of evidence may seem to point strongly in one direction, yet another good explanation may fit as well. In many lines of evidence, there is a parallel in what both interventionism and macroevolution would expect to see in the data. This makes the search for definitive answers more arduous than we might think.

Theoretically, we suggest that persons who believe in macroevolution fall into several types. Do noninterventionists deliberately want to push God out of the way? Probably some are in that category, but many do not think that way at all. Some are Christians and, to some degree, are interventionists, but they are not sure what to do with the evidence. Others have been trained to believe in naturalistic evolution and are not aware of another viable alternative. Others have looked at both theories and have decided that macroevolution is the correct one. Many intelligent, thoughtful people believe that life has come about through the evolution process. The education process has a strong influence on beliefs regarding origins.

Nothing is ever gained by making fun of others who have different beliefs on these issues. We each must carefully evaluate these philosophical questions and then deal politely and respectfully with those who disagree with us. Can a Christian do less than that? We will reconsider the lines of evidence that were discussed in chapter 11 and explore how the interventionist theory can handle the data. The emphasis is not to prove informed intervention but to show how it gives insight for finding better explanations. Part of our task is to attempt to develop an internally consistent interventionist theory, and then to evaluate the strength of the evidence for the theory.

Homology

How did the limb bones of the four mammals in figure 11.1 (the human, seal, bat, and dog) develop the way they did? The explanation given in chapter 11 is based on the assumption of naturalistic evolution. If we are open to other possibilities, what options are available? An engineer devising different kinds of machines would not start from scratch for every machine. Interventionist theory can explain similarities in vertebrate limb structure as application of a flexible general plan, which could be adapted for the lifestyle of each animal. The result is a series of homologies resulting from the work of a common Designer who created all of these animals in an organized fashion.

The same concept applies to analogies. Different kinds of wings (fig. 11.2) are analogous because the Designer gave different kinds of organisms some of the same abilities. He made insects with a body plan different from mammals and birds, but some representatives of each group were made to fly. Because of their different underlying structural organization, their flight mechanisms are described as analogous, not homologous.

What do we do with homologies in the details of physiology and biochemistry? Is our ability to arrange cytochrome c molecules in a logical phylogenetic sequence from bacteria to humans good evidence for macroevolution? There are different degrees of relationship and of similarity between various animals. Apes are structurally more similar to humans than to fish. This descriptive reality of nature makes it possible to draw phylogenetic trees, since those trees are based on degrees of similarity or difference in animal or plant characters. The important question is how did organisms get that way? Why are phylogenetic trees based on morphology often similar to trees based on biochemistry? Macroevolution is one possible theory, but another alternative design should be considered.

Anatomy is not independent of biochemistry. Creatures similar anatomically are likely to be similar physiologically. Those similar in physiology are, in general, likely to be similar in biochemistry, whether they evolved or were designed. The data show that nature is not organized in a chaotic fashion. In general, close integration exists between various aspects of living systems. However, within any given morphological plan, a certain degree of biochemical flexibility is also likely. When major groups of animals are compared, the degree of congruence between morphology and biochemistry exists for primarily functional, rather than evolutionary, reasons. Consequently, it is not surprising when anatomical and biochemical data produce similar phylogenetic trees. But those trees don't always agree. Sometimes they are quite different.

One assumption made in phylogenetic analysis is that the differences between organisms in the sequence of amino acids in some proteins indicate evolutionary distance between the organisms rather than being primarily the result of differences in functional requirements of the organisms. Is this a correct assumption? Or are the cytochrome c molecules (fig. 11.3; 11.4), for example, different in various animals for functional reasons? Michael Denton presents the cytochrome c data in a way that raises some interesting questions.[2] Starting at the upper left corner of figure 12.1 and moving across to the right, the number of differences in the amino acid sequence increases, as would be expected in an evolutionary sequence. However,

	Vertebrate animals											Insects			Plants			Yeasts			Bacteria
	Horse	Dog	Kangaroo	Penguin	Pekin duck	Pigeon	Snapping turtle	Tuna	Bonita	Carp	Lamprey	Screw-worm fly	Silkworm moth	Tobacco horn-worm moth	Castor	Sunflower	Wheat	Candida krusei	Debaryomyces kloekeri	Baker's yeast	Rhodospirillum rubrum C
Horse		6	7	12	10	11	11	18	17	13	15	20	27	26	40	41	41	46	40	42	64
Dog	6		7	10	8	9	9	17	16	11	13	19	23	23	38	39	39	45	38	41	65
Kangaroo	7	7		10	10	11	11	17	17	13	16	22	26	26	38	39	42	46	41	42	66
Penguin	12	10	10		3	4	8	17	17	14	18	22	25	25	38	39	41	45	40	40	64
Pekin duck	10	8	10	3		3	7	16	16	13	17	20	25	25	38	39	41	45	40	41	64
Pigeon	11	9	11	4	3		8	17	17	14	18	21	25	24	38	39	41	45	40	41	64
Turtle	11	9	11	8	7	8		17	16	13	18	22	26	27	38	39	41	47	42	44	
Tuna	18	17	17	17	16	17	17		2	8	18	22	30	28	42	43	44	43	42	43	65
Bonita	17	16	17	17	16	17	16	2		7	18	23	31	29	41	41	42	42	41	41	64
Carp	13	11	13	14	13	14	13	8	7		12	20	25	24	41	41	42	45	39	42	64
Lamprey	15	13	16	18	17	18	18	18	18	12		26	30	31	45	44	46	50	43	45	66
Screw-worm fly	20	19	22	22	20	21	22	22	23	20	26		13	11	40	40	40	43	39	44	66
Silkworm moth	27	23	26	25	25	25	26	30	31	25	30	13		5	40	40	40	43	39	44	65
Tobacco moth	26	23	26	25	25	24	27	28	29	24	31	11	5		39	40	38	42	39	42	64
Castor	40	38	38	40	38	38	38	42	41	41	45	40	40	39		10	12	45	43	42	66
Sunflower	41	39	39	41	39	39	39	43	41	41	44	40	40	40	10		13	47	44	43	67
Wheat	41	39	42	41	41	41	41	44	42	42	46	40	40	38	12	13		45	41	42	66
Candida	46	45	46	45	45	45	47	43	42	45	50	43	43	42	45	47	45		23	25	72
Debaryomyces	40	38	41	40	40	40	42	42	41	39	43	39	39	39	43	44	41	23		27	67
Baker's yeast	42	41	42	40	41	41	44	43	41	42	45	42	44	42	42	43	42	25	27		69
Rhodospirillum	64	65	66	64	64	64	64	65	64	64	66	64	65	64	66	67	66	72	67	69	

Figure 12.1. The cytochromes percentage of sequence difference matrix (after Denton 1985; data from Dayhoff 1972). Figure by Leonard Brand.

the number of differences between the bacterium *Rhodospirillum rubrum* and all other groups is astonishingly similar.

This discussion will not try to analyze whether Denton's diagram is a problem for evolution but will simply suggest that the evidence in his diagram is consistent with an alternate, interventionist hypothesis that the cytochrome c molecules in various groups of organisms are different (and always have been different) for functional reasons. Not enough mutations have occurred in these molecules to blur the distinct groupings evident in figures 12.1 and 12.2. Other interpretations may be possible, but this interventionist interpretation is still a valid alternative explanation of the data. If we do not base our conclusions on the *a priori* assumption of macroevolution, all the data really tell us is that the organisms fall into nested groups without any indication of intermediates or

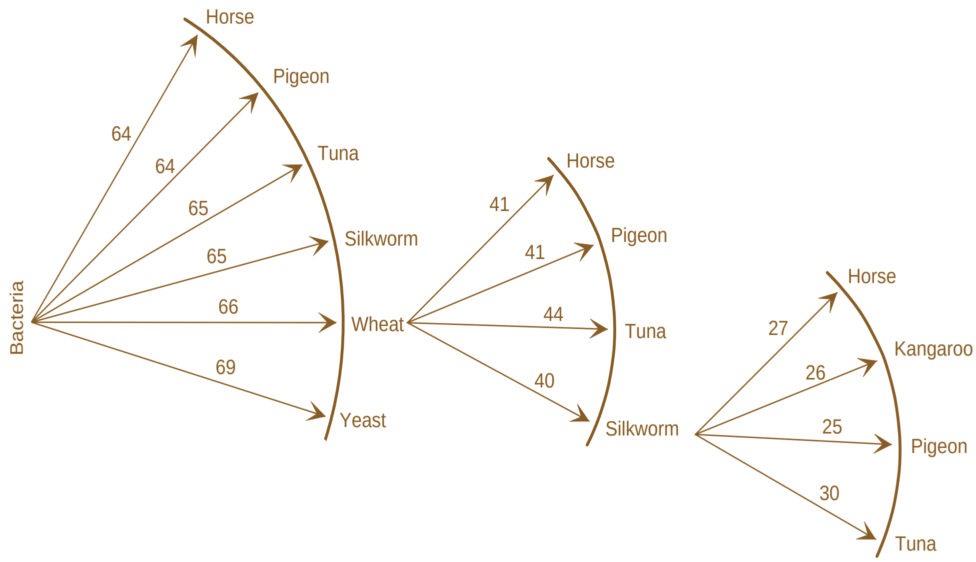


Figure 12.2. The genetic distance between bacterial cytochrome and other organisms is nearly equal, the same relationship for wheat and for silkworm, with organisms above them on the phylogenetic scale (after Denton 1985). Figure by Leonard Brand.

overlapping of groups and without indicating ancestor/descendant relationships. The evidence can be explained by a separate creation for each group of organisms represented in the cytochrome c data.

There is not always a close correspondence between phylogenetic trees from morphological and biochemical data. Cytochrome c is the textbook example, and even it has viable alternate explanations, as described above. Some phylogenetic trees based on biochemical data (e.g., fig. 11.5) match fairly well with morphological data, but in other cases, biochemical data yield phylogenetic trees that do not correspond so well with morphology or with trees based on different biochemical data.

When the same structures and/or gene sequences are found in unrelated organisms, this is generally interpreted as convergence—these features evolved independently in different taxa. These occurrences of convergence are so abundant all through the diversity of life that they become a serious challenge to explain by evolution. The application of inference-to-the-best-explanation leads to the conclusion that separate creation of similar or identical features is a more likely explanation. This is not god-of-the-gaps, but is simply application of sound biological logic. An example of such "convergence" is the finding that bats and dolphins have an identical gene for echolocation, even though bats echolocate in air and dolphins in water.[3] Is it realistic to think this gene, in every detail, evolved independently in these unrelated animals? There are many examples of independent similarities in different organisms, and convergence seems to be an explanation required by the assumption of naturalism, not by solid scientific procedure.

In a similar vein, Christian Schwabe discussed several incongruencies in molecular data, not in a discussion of evolution versus creation, but in an evaluation of various lines of evidence within the naturalistic evolution theory. He stated, "It seems disconcerting that many exceptions exist to the orderly progression of species as determined by molecular homologies; so many in fact that I think the exception, the quirks, may carry the more important message."[4] He compared several lines of evidence regarding the evolutionary divergence of cartilaginous fish (sharks, skates, and rays) from mammals. Each branching point on his diagrams (fig. 12.3) shows the purported amount of time in millions of years since the ancestors of the cartilaginous fish diverged from the ancestors of the mammals, according to either fossil or molecular evidence. The times for this divergence differ radically depending on whether it is based on fossil data, relaxin A, or relaxin B. These three lines of data point to very different conclusions and do not provide a clear picture for developing a phylogenetic tree.

Figure 12.3. Time of evolutionary divergence of mammals and cartilaginous fishes, based on paleontological data, relaxin A, and relaxin B (after Schwabe 1986). Figure by Leonard Brand.

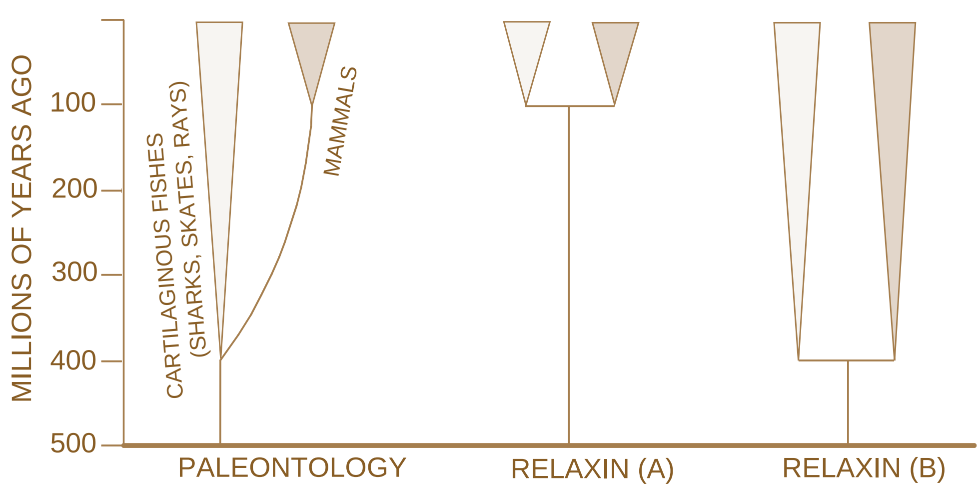


Table 12.1. Percent homology between relaxins from various species

	H1	H2	P	R	SS	SDS	SK
Human 1	—	77	46	46	46	45	34
Human 2	77	—	46	46	48	50	35
Pig	46	46	—	54	50	52	31
Rat	46	46	54	—	37	41	25
Sand tiger shark	46	48	50	37	—	75	42
Spiny dogfish shark	45	50	52	41	75	—	48
Skate	34	35	31	25	42	48	—

From Schwabe 1986

Relaxin is a molecule that widens the birth canal in organisms that bear live young. A table of percentage homologies of relaxin molecules in various animals (table 12.1) reveals that shark relaxin, for example, is no more different from pig relaxin than pig relaxin is from human relaxin—even though it would appear that mammals and sharks should have evolved relaxin independently. Shark relaxin widens the birth canal of mice and guinea pigs, acting "specifically on structures that developed only millions of years later in different species."[5] In the same paper, Schwabe lists several proteins with specific functions in higher vertebrates that also seem to occur in some invertebrates or even in plants. The head activator enzyme occurs in hydra, rat intestines, and the human hypothalamus and "has an identical sequence regardless of source. In the hydra, it causes regeneration of a severed head while its function in humans is unknown but presumably different."[6]

Schwabe did not conclude that we should turn to interventionism for the answer to these problems.[7] Since he begins with the assumption of naturalism, his only choice is to accept convergent evolution—repeated evolution of the same features. Interventionists suggest a different explanation for this evidence—independent design of the different animal groups; macroevolution did not occur.

It is important to remember that even an interventionist recognizes that microevolution does occur. Consequently, when we consider phylogenetic trees at the level of at least species or genera, part or most of the observed differences that appear in these trees are probably due to genuine evolutionary change. Anyone, interventionist or noninterventionist, can use these lines of evidence to estimate patterns of evolution of at least subspecies, species, and probably among genera.

The interventionist theory states that as we go up the taxonomic scale from species to genera to families and orders, at some point, homology does not result from evolution—it is a part of the original design. An interventionist goal is to find evidence of where that point is and what are the upper limits of the evolution process. Keep in mind that finding that point will not be simple because both the evolution process and intelligent design might be expected to produce a similar pattern. The Designer who made the original body plans and their genomes also made the genetic system to permit changes from those original plans—it is a coherent system.

From the interventionist theory, we can derive interpretive definitions of homology and analogy. These definitions are interpretations of the data. They are based on the assumption that the interventionist theory is correct, just as the former set of definitions are interpretations of the data based on the assumption that the macroevolution theory is correct.

> Homology: Correspondence of features in different organisms at higher taxonomic levels is due to the same basic structural plan in both organisms. In lower taxonomic categories, homologies result from correspondence of features in organisms due to inheritance from a common ancestor.

> Analogy: Correspondence of features in organisms that are not closely related because these features were designed for similar functions. In lower taxonomic categories, analogies may be features that are superficially alike but that have evolved independently.

Note that at lower taxonomic levels, both interventionists and naturalistic evolutionists are using the same definitions of homology and analogy. At higher levels, they use different definitions. It is true that the scientific process would be simpler if we stayed with only one set of definitions, either the design or the evolution definitions, at all taxonomic levels. This discussion makes the assumption, however, that science should be a search for true answers, whether or not they are simple. Another way to look at it is that the interventionist is asking a question that many other scientists are not asking: Is there a limit to the extent of evolutionary change that has occurred? There are interventionists who are searching for evidence that will help in determining the boundary line between the two types of homologies—of what the limit of evolutionary change is.[8]

The Process of Phylogenetic Analysis

Now let's look more closely at the process that is used in developing phylogenetic trees. We can collect evidence on the characteristics of organisms and construct phylogenetic trees (e.g., fig. 11.5). Does that tell us that those trees necessarily demonstrate macroevolution?

The process used in constructing phylogenetic trees begins with the collection of data on the characteristics of the groups being studied. If we study the relationships between several orders of mammals, we compare many characters shared among these orders, perhaps including tooth structure and skeletal anatomy, or whether they chew their cud. Many additional characters could be added, including molecular data. Then we tell the computer to compare unique characters found in each group, determine the similarities among them, and generate phylogenetic trees. At this point, the assumption of methodological naturalism, for most scientists, asserts its control over the process. The next few paragraphs describe how this "control" normally works.

Determining which characteristics are primitive (ancestral) and which are derived is called polarization. This is usually accomplished by including an outgroup in the analysis for comparison. The outgroup is a group that is believed to be closely related to but outside of the groups that are being studied. For example, a study of the orders of mammals might use alligators as an outgroup. The mammalian order with the fewest differences from the outgroup is considered closest to the common ancestor of the mammals.[9]

From a given data set, many different trees can be produced. For example, compare the trees in figure 12.4. The branch pattern in A indicates that organisms 1 and 2 are very similar to each other and organisms 3 and 4 are also similar to each other. Both groups (1 and 2, and 3 and 4) had a common ancestor farther back in time. Tree B indicates that as we compare groups, 4 is most like the ancestor, 3 is next most similar, and organisms 1 and 2 are more similar to each other. Tree C says that 1, 2, and 3 are more closely related, 2 and 3 are more closely related to each other than either is to 1, and they share an ancestor distantly with 4.

Which tree is the best hypothesis of relationships for these animals? In making such decisions, we most often use the principle of parsimony, which means that we accept the trees that provide the simplest explanation and require the least number of evolutionary steps—the least amount of convergence. A parsimonious tree requires evolution to reinvent structures independently the fewest number of times.

After several phylogenetic trees have been produced from our data, two levels of questions arise that we might want the computer to address:

1. Assuming these groups of organisms have evolved from a common ancestor, which of these trees is the most likely pathway for that evolution?
2. Are any of these trees correct? Or is it more likely that these animal or plant groups were not the result of macroevolution?

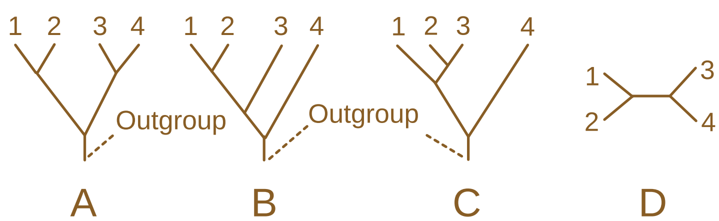


Figure 12.4. (A–C) Three alternative phylogenetic trees for four animal taxa. (D) An unrooted tree (indicates relationships but does not indicate which are ancestral and which are descendent groups). Figure by Leonard Brand.

Question 1 is based on the assumption that the organisms evolved. We ask only which is the most likely tree. Question 2 asks whether the evidence is best explained by unlimited macroevolution or by independent origins (which implies informed intervention) plus limited evolution within the polyphyletic groups. It is important to understand that science normally asks only question 1. Science does not ask the second, broader question. Question 1 is like a multiple-choice quiz that asks, Which of these options (which phylogenetic tree) is most likely correct? The answer "none of the above" is not even considered.

The process used in question 1 gives us a tree no matter what reality is in the history of life. The computer analyzing the characters and generating trees has been given no instructions that allow it to ask the second question. When we first put the data into the computer, it has no way to determine which one of the groups is the ancestor or closer to the ancestor. It can only produce an unrooted tree, showing which groups are more similar (D in fig. 12.4). An outgroup must be added before it can produce a rooted tree. However, the only reason to introduce an outgroup is if we first assume evolution of the two groups from a common ancestor. A study of mammals, using alligators as the outgroup, is based on the assumption that they both evolved from a common ancestor. If we make that assumption, then the computer looks for the order of mammals with the most characteristics in common with the outgroup. Now the computer makes that mammalian group the root of the tree that it can construct. It cannot construct a tree unless the researcher first makes the assumption of macroevolution by adding an outgroup. This is the basic reason this process is not capable of asking the second question. Phylogenetic trees do not pop out of the data. They come from massaging the data with evolution theory, dependent on accepting the assumption of unlimited macroevolution.

Does this tell us that this process is a waste of time? No, not at all. Even the interventionist uses it to study microevolution and speciation—to examine the very real evolutionary changes that may have occurred within major groups of organisms. Also, if a person chooses to make the assumption of macroevolution, it is logically consistent to use this method to determine the most likely phylogenetic tree for the animals he or she is studying, even for higher taxonomic categories. The important thing to remember is that this process is capable of answering only question 1; it cannot address question 2.

If we carry our logic one step further, we find that the ability to use the process described above to produce phylogenetic trees is not evidence in favor of either macroevolution or microevolution. A process of phylogenetic analysis that assumes the animals evolved from a common ancestor cannot be used to test whether they came from a common ancestor. That would be circular reasoning. Also, the fact that this process cannot prove evolution is not evidence for intervention. It simply reflects the limits in the ability of humanity to analyze the ancient past. Some other type of evidence is needed to answer the bigger questions of where we and our fellow organisms on earth came from. Colin Patterson, a prominent vertebrate paleontologist and evolutionist in England, made some interesting statements in a public lecture. No obvious evidence suggests that he favored interventionism, but he stated that he had "experienced a shift from evolution as knowledge to evolution as faith."[10] Perhaps this honest attitude is appropriate for all as we study what happened in the past, whether we favor intervention or macroevolution.

Now let's consider another side of the limitations in the process of generating phylogenies. Phylogenetic trees are based on homologies, and evolution theory is used to identify the homologies. But homology by itself cannot demonstrate evolution or intervention. Homology has two potential explanations: evolution from a common ancestor or design by a common designer. Which is correct? If homologies were the only evidence we had, we would have to say we do not know.

If we collect data from fossils and living animals and make the assumption of evolution, it is possible to draw phylogenetic trees. For any complex assemblage of organisms (or even machines), it is possible to draw a phylogenetic tree based on homologies. Are the trees true? Looking at a very general tree of the animals (fig. 12.5A), we note that those sharing more homologies in common are closer together on the tree. Does that show that they evolved? If we use the same process to analyze a group of wheeled vehicles, we can draw a tree based on homologous mechanical principles (fig. 12.5B). Nobody would say that the vehicles evolved. Homologous features can arise by another route—intelligent design. Such analogies never should be pushed too far. This one illustrates only one point: homology, in itself, cannot demonstrate evolution. If we ask only question 1—which is the most likely phylogenetic tree?—it is essential to rely on homologies to answer that question. That is perfectly legitimate. But if we are asking question 2—did they evolve or did they not?—then homologies cannot answer the question. They don't have the potential ever to do so.

Nevertheless, the claim is often made that if we can identify when in the history of life certain mutations occurred, we have demonstrated that the change was due to evolution. However, if the designer used a similar plan

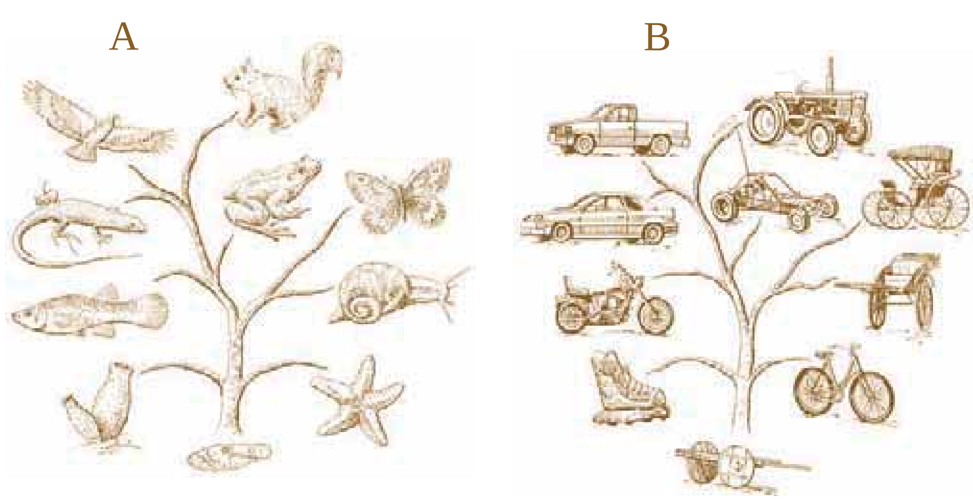


Figure 12.5. (A, B) "Phylogenetic trees" for animals and wheeled vehicles. Figure by Robert Knabenbauer.

in designing a variety of animals, modifying genes systematically to change the characteristics from one group to another, we could probably not determine if the change resulted from evolution or design. Consider the *Hox* genes as an example. *Hox* genes control the embryological development of animal bodies. They are switches that control other genes and determine the position and nature of the major body parts, and they are located in a sequence on the chromosome in the order in which they are active during development. The number of *Hox* genes is broadly proportional to the complexity of the organism, and this is believed to be the result of increase in the number of *Hox* genes at several stages in evolution.[11] Sponges have one *Hox* gene, more complex invertebrates have four to ten, and vertebrates have up to thirty-nine, arranged in four clusters. Early in chordate evolution, the number of *Hox* clusters, it is believed, duplicated, making two clusters, and then duplicated again, making four clusters in fish and other vertebrates.[12]

Now consider another explanation. The Creator designed *Hox* genes and the suites of other genes to be controlled by them. He carefully planned the developmental scheme of each group of animals to be created and included the number of *Hox* genes needed to manage the level of complexity of each animal group. He did not begin from scratch for each group, but used common elements, the *Hox* genes, and systematically adjusted the number of *Hox* genes according to the developmental complexity of each group. If this is true, then these genetic differences are the result of deliberate design, and not from evolutionary duplication of genes. If a researcher is committed to the naturalistic philosophy, he or she will not consider this possibility.

Embryology

Ernst Haeckel proposed that a vertebrate embryo repeats its evolutionary history as it matures (fig. 11.6). In reality, the early embryonic stages do not look as similar as Haeckel

Data and interpretations in homology and phylogenetic analysis

DATA

Lists of similarities between organisms (e.g., limb bones, biochemistry, and many others). Differences between organisms and which groups have "new" features not present in presumed ancestors. Statistics and trees generated by computer analysis.

INTERPRETATION

Here, as in most historical study, it may not be possible to apply inference-to-the-best-explanation because some explanations are not even considered.

Conventional science: This assumes naturalism and must interpret homologies and phylogenetic tree as resulting from evolution.

Interventionism: naturalism is not assumed; if not assuming naturalism, apparent homology can be interpreted as a result of a common designer. A phylogenetic tree generated by phylogenetic software is not evidence for descent from a common ancestor. Other reasons (scientific or otherwise) would be needed in order to make a well-founded evaluation.

pictured them.[13] The more realistic modern version of the theory suggests that an embryo in its early stages is like the early embryonic stages of its ancestor. As it develops, it gradually becomes less like the ancestral form and acquires the characteristic features of its own species.

Another logical explanation, not based on the assumption of naturalism, is consistent with that same data. Most vertebrates have an elongated body with a head on one end, usually a tail on the other, and four limbs on the four "corners" of the body. As all of these animals develop from a one-celled egg to a fully formed juvenile, it is not surprising that there are many similarities between them in the early stages. The embryo develops the basic body plan first. The unique features of the individual organism appear later in ontogeny. Similarly, a home builder builds the foundation first (houses that look very different when complete can have similar foundations) and adds the unique features of the home later. An engineer attempting to design the developmental stages of all these organisms would very possibly find that it is most efficient to follow a basic plan for all and add special features later in the process, as needed for each group, and then for each species within the group. Other problems also challenge the theory that ontogeny repeats evolutionary history.[14]

Even noninterventionist scientists recognize that the developmental stages of the mammalian heart and kidney are not historical remnants that provide evidence for evolution.[15] The argument given in chapter 11 is included because it is still encountered in some fairly recent college textbooks. In contrast, think of yourself as a bioengineer whose task is to devise the chemical distribution system for an embryo as it develops from the one-celled stage to a complete mammal. The mature mammalian heart and kidney are complex structures that require some time to be fabricated as the embryo grows. But the embryo cannot wait that long to circulate blood, distribute nutrients to the tissues, and eliminate metabolic wastes. How would you solve this problem? If naturalism is not assumed, we can consider that life's engineer has devised an intricate and complex solution. The heart begins as a simple structure that can develop and begin functioning quickly. As it grows, it gradually transforms into the four-chambered state and is fully functional during the entire process. The kidney follows a slightly different path. A simple kidney develops quickly and handles waste disposal, while the more complex metanephric kidney is developing. When the more complex kidney is ready to begin functioning, the simpler initial kidney disappears. The evolutionary scientist Alfred Romer recognized that the successive kidneys in the embryo are needed for functional reasons; they have nothing to do with evolution.[16] It appears that the mammalian heart and kidney would need to develop approximately this way, whether we evolved or were created, and thus the embryology of these organs tells us nothing for or against evolution or intervention.

Some aquatic salamanders have fins and external gills. Other species have aquatic larvae that leave the water as adults and lose the fins and gills. Some always live a terrestrial life and have fins and external gills only in the egg (fig. 8.7). It appears that salamanders have the genetic program to produce the equipment for an aquatic life, which they lose at whatever stage of life they leave the water, and regulatory gene alteration of the timing of this process, or epigenetic effects, determines when they lose their aquatic adaptations. A species that will not be living in the water may keep the gills only when in the egg. Why isn't the development of their gills aborted entirely? Perhaps the genetic information for all types of salamander life cycles are always present, and the only difference is in the timing—when some genes are epigenetically turned on or off—giving salamanders the created ability to adapt to different environments. These interpretations of salamander adaptations don't depend on whether we accept naturalism or intervention. They are realistic interpretations of adaptations to various living conditions under either worldview.

The experiments that demonstrated that birds still have the genes to produce "reptile" leg bones give intriguing insight into developmental processes (fig. 11.7). It seems very unlikely that an unused assemblage of genes for producing reptile bones would remain intact in birds for more than one hundred million years without serious mutational damage to those unneeded genes. It is more plausible that birds and reptiles have a common set of "instructions" for making legs and that the regulatory genes and epigenetic system controls the specific

How to explain salamander adaptations

DATA

Careful description of features in different salamander species.

INTERPRETATION

The differences have viable biological explanations irrespective of any assumptions. Species differences do not seem like they should be interpreted as separate creations, even for an interventionist.

There are no philosophical implications; this is consistent with either worldview.

application of these for making the structure appropriate for each animal. The experiments by Armand Hampe appear to say this is the case.[17] But why is it that way? The only reason for arguing this as evidence against informed intervention is to suggest a Creator would use a more efficient design. This is a very weak argument, indeed, until we understand the genetic system and embryological processes enough to accurately evaluate the efficiency of various approaches to designing organisms. Hampe's experiments may be revealing that living systems contain more genetic information than is evident and that regulatory genes and the epigenetic system are being used to control the operation of a broad set of genetic instructions.

Vestigial Organs

Vestigial structures are the presumed leftovers from our evolutionary past (fig. 11.8). At the turn of the twentieth century, a long list was compiled of vestigial organs in mammals.[18] The list was considered convincing evidence for macroevolution. More than eighty items were on the list, which included the thyroid, thymus, and pituitary glands; the olfactory lobe of the brain; and the middle ear. Now we know that these structures are vital for life and for our sense of hearing and smell. At the time the list was compiled, no one knew what functions they had. Researchers believed them to be vestiges from an ancestral form that needed them. As physiologists have studied, the list has shrunk drastically. The logic used in this line of evidence must be analyzed carefully. If we do not know the function for something, it becomes a candidate for a vestigial organ. We might call this vestigialism-of-the-gaps! The weakness in the approach is that the more we know, the greater the chance that we will learn of useful functions for these supposedly vestigial organs.

Several structures still appear in textbooks as vestigial organs. As we review them, keep in mind that an organ is often considered vestigial if it seems to have no function (and such a conclusion could mean that we do not know enough about it yet) or the function or the form of an organ is altered from its form in presumed ancestors. However, leaving the naturalistic assumption aside, before accepting an evolutionary origin of a presumed vestigial structure, we need to ask if there are any feasible alternate explanations. It is easy to propose a hypothesis to explain something. It is altogether another matter to demonstrate that it is the correct hypothesis and that all alternate hypotheses are wrong.

The human appendix was once routinely removed by physicians since it seemed useless and often caused trouble. Now it is known to be part of the immune system, and an important reservoir for beneficial gut bacteria.[19] We do have a disease problem with the appendix, and when it gets infected, it must be removed. However, one is better off with an appendix if it remains healthy.

Are the fused caudal vertebrae useless? Actually, this small structure has a very important function as an attachment point for the muscles that allow us to stand upright (and to provide padding when we sit down). It cannot be considered useless. The embryological pathway that makes a tail in other mammals is used in us to produce an important structure. Did this happen through evolution, or was it so engineered by an informed Designer? What evidence would answer that question? Not the evidence from embryology or from these "vestigial organs"—some other type of evidence is needed. The external "tail" that, in rare cases, is present on a human newborn is a small, usually boneless structure, not equivalent to the tails of other vertebrates.[20] However rare modifications to the regulatory genes/epigenetic system do rarely produce a mutant tail with some bones.

The segmented muscles on the abdomen are important for bending our body and for maintaining the tone of the abdominal wall. Whether this muscle arrangement came from a primitive ancestor is strictly conjecture. The muscles are not evidence for or against evolution or intervention.

Why do humans have hair on their bodies? Is it vestigial, or did a designing engineer intend it? The answers are a matter of opinion that depend on what assumptions we make, not evidence that should be used to choose a theory. The canine teeth in humans are a little more pointed than other teeth. Some may also prefer to consider this a vestige, but it is far from a compelling argument for or against anything. Why do men have nipples? They could exist for various reasons, and vestigiality is only one possible reason. Male nipples are not relevant to the question of origins.

In these examples, the vestigial-structures argument is not as convincing as it might appear at first glance. In fact, one can question whether any of them can be called truly vestigial. Even if we think they are, we may be calling them vestigial simply because we don't yet know their function. This line of evidence does not point clearly to either theory and should not be used as support.

The nictitating membrane in humans does not function as a third eyelid; it occurs in connection with the tear ducts. Its function is not entirely clear, but to declare it nonfunctional is probably unjustified.

Why are muscles attached to our ears? Some wish to call them genuine vestiges or say they give shape to our head or support the ears. More information is needed before deciding.

The third molars can be a problem in humans when there is not enough room in the jaw for them. This could be explained readily if humans were once larger than they are now or had heavier jaws because of differences in diet. They appear to be truly vestigial: vestiges of teeth needed by humans as they were originally designed but not needed now.

The claims of dead genes, pseudogenes, or junk DNA have met some serious setbacks with the discovery that so-called junk DNA generally is functional regulatory genes. It is questionable whether there is any genuine junk DNA. However, traditional Darwinists are loathe to accept this new discovery and are resisting it.[21]

The hind limbs of a whale are isolated bones buried in the tissue but with a definite function. They are the attachment point for muscles in the reproductive system. Interventionists can argue that the Designer modified the genetic instructions for hind limbs to make these structures serve their unique function. The rare dolphins with hind flippers indicate the genetic information behind them is present. There are fossil archaeocete whales with small hind limbs, but they do not have the structure of flippers. It appears that epigenetic processes are putting flippers where they usually do not appear.[22]

Many cases of truly vestigial structures have resulted from microevolutionary changes within created groups of organisms. Some populations of salamanders, fish, or other animals have lived in complete darkness in caves so long that no selection pressure favored the preservation of functional eyes. Blind cave fish have functional eye genes, and they are blind because epigenetic processes have turned off those genes that are not needed in their cave environment.[23] Some populations of birds have lost the ability to fly, even though they still have small front limbs. These flightless birds live primarily on islands where there are no predators, or they are too large to be bothered much by predators. Without the need to fly to escape from predators, apparently there was no disadvantage for some of these birds if mutations reduced their powers of flight. In fact, flightlessness can be an advantage. In some hurricanes, most flying birds were blown out to sea from some of the Pacific islands (David Cowles, personal communication). These explanations apply no matter what we think about the naturalistic assumption.

Some beetles have become nonflying, not by losing their wings, but by mutations and/or epigenetic alterations that fused the wing covers and made the wings nonfunctional. Perhaps additional alterations might eventually eliminate the useless wings. In fact, the energy saved from not growing these wings could be an advantage to the beetles. Why haven't all beetles lost their wings by this process? If flight is vital to a species (and it evidently is for most beetle species), a mutation that reduces the ability to fly reduces or

Interpretation of vestigial organs

DATA

An accurate description of the anatomical feature in question. Any fully documented knowledge of its physiological function or seeming lack of such.

INTERPRETATION

Conventional science: This assumes naturalism. The assumption does not require the feature to be vestigial, but this is an option if a good explanation for its function is not known.

Interventionism: The explanation can be similar to the above; at least some biological features could be interpreted to be vestigial, degenerated since creation. However, be cautious, as this interpretation is often the result of our lack of understanding of the feature. If a feature cannot be realistically explained as becoming vestigial after creation, then look for another explanation.

eliminates the chances for that individual to survive and reproduce.

In summary, many presumed vestiges actually do have functions and are not truly vestigial. Some are questionable and can be given various interpretations, and some are true vestigial structures resulting from microevolution since the creation.

Mistakes and Imperfect Designs as Evidence of History

An animal perfectly adapted to its environment can be explained as the result of natural selection or as perfect design by the Creator. Imperfections, suboptimal adaptations, or outright mistakes seem to point more strongly to an evolutionary explanation. Therefore, one must have objective criteria for determining if the adaptation is indeed suboptimal. Is the panda's thumb suboptimal? Is there evidence that the panda has difficulty accomplishing the tasks that require use of its thumb? If not, what objective reason do we have for calling it suboptimal? How could we determine if a Creator would use such a whimsical design?[24] The use of the panda's thumb (fig. 11.10) as a scientific argument against interventionism is valid only if we have objective data to support the hypothesis that a Creator would not use such a design; otherwise, it is only a philosophical conjecture. The data show us that if there is a Creator, He used a hierarchical design for life. How can we be sure that He would not use the genetic patterns of other bears to fashion a thumb for the panda rather than interjecting a feature from some other animal into the bear's already cohesive genetic system? Or could it be that the DNA was intelligently designed with sufficient information to allow such a structure to originate after bears were created?

The diversity of life follows a hierarchical system of design, which uses a basic plan for each group and modifies it for the needs of each member of the group. The opinion that this system is not creative or original is simply a subjective, personal opinion. One could just as logically argue that making a bat with such incredibly effective flying skills and a dog's foot from the same basic structural plan is very creative indeed. The panda's thumb and the bat's wing are not objective evidence for or against evolution or intervention.

Douglas Futuyma concludes that it is strange that an omniscient creator would make a bat's wing by just stretching out four fingers of the same type of hand that other mammals have.[25] This argument has meaning only if he is implying that the bat's wing is suboptimal. That argument is even more unconvincing for bats than for pandas. Bats are able to achieve incredible feats of flying acrobatics with their hand-like wings. Slow-motion movies of a bat using its wing, as we would use a hand, to catch moths and transfer them to its mouth while in flight without interfering with the effectiveness of flight makes it difficult to believe the argument that the design of a bat's wing is suboptimal. It is even more unbelievable because evidence documents bats locating, pursuing, catching, and eating two consecutive insects on the wing within one second![26] A bat's wing is ideal for its lifestyle.

Francisco Ayala claims that a human engineer could design living things with more effective designs than we see in nature.[27] OK, demonstrate to us a few of these better designs. Those are unrealistic, arrogant assertions.

The long-held view that the vertebrate retina is a poorly designed evolutionary accident because the cell layers are supposedly arranged backward has received a major setback. A paper by Kristian Franze and colleagues reports a reexamination of the retina.[28] It was found that the Müller cells in the retina have unique and unexpected properties. They are actually living optical fibers that transmit light through the outer cell layers and to the photoreceptors with very high efficiency. Rather than being an inefficient evolutionary accident, the retina is a highly efficient, very sophisticated design. Also, the photoreceptors need to be behind the other cell layers so they can be next to the capillary network bringing needed nutrients to them. Blood is more opaque than the other cell layers in the retina and thus cannot be put in front of the photoreceptors.

Why did the Creator not make a change in the pathway for the recurrent laryngeal nerve in higher vertebrates, instead of allowing it to take such a detour in mammals? Do we know that giraffes have always had such long necks? The data simply tell us that the same basic design was used for all the vertebrates. This gives us a little insight into the mind of the Creator. He didn't tinker with the design of individual species but devised an adequate developmental plan for all vertebrates. We can suggest that the Creator stuck with his plan for all of them, as long as the nerve impulses still move fast enough to do their task.

Other types of suboptimal features are fundamentally different in nature than the panda's thumb. Consider, for example, the lemmings' and locusts' inability to control their population size.[29] It is hard to justify this feature as a good design. The struggle, cruelty, and destruction in nature bother most of us, no matter what our philosophical views. The version of interventionism proposed here takes the Bible seriously and has an internally consistent answer for this problem. The Designer provided enough information to keep us from being confused by this enigma. Life was created in a perfect state, but the rebellion of the human race introduced degenerative forces into other parts of nature as well. The earth is no longer an ideal habitation. Organisms have adapted through natural selection to changed conditions, and many of these adaptations are far less than ideal. The concept of creation and subsequent rebellion cannot be studied by scientific methods, but the processes of change that have occurred after those events can be analyzed with the scientific process.

Hierarchical Nature of Life and the Ascending Scale of Complexity

Is the ascending scale of complexity (fig. 11.11) evidence for macroevolution? It is only so if we accept the assumption of naturalism. If we question that assumption, another potential explanation exists for the same data. In any complex assemblage of things showing great diversity with different combinations of features, be they machines or animals, one can arrange them in a sequence from simple to complex. Does this imply an evolutionary

Interpretation of presumed biological mistakes or imperfect designs

DATA

Documented description of the feature in question and any evidence-based assessment of its functionality.

INTERPRETATION

The question of whether an intelligent creator would do it this way is not testable, so it is not relevant to any interpretation.

Conventional science: Imperfect design is a philosophically feasible interpretation, but its accuracy depends on how well the feature has been studied.

Interventionism: Partly similar to the above, this worldview predicts no biologically poor designs left from the Creator's work. Biological decay from damaging mutations since creation is a feasible (and in some cases, a likely) interpretation. Presumed poor designs can often lead to a prediction that it is not actually a poor design, and there are discoveries to be made with more research.

sequence? Actually, the ecology of our world is extremely complex. It needs a great diversity of organisms to fill the many ecological niches so the intricate system will work. All the "advanced" features in mammals make them unsuited to fill the niche of a sponge. A creature with the suite of characteristics found in sponges is needed to fill that. One can arrange this great diversity of organisms in a sequence with those having a simpler organization at one end of the list and the most structurally complex organisms at the other. This "ascending scale of complexity" is only a description of nature. We must have a different type of evidence to tell us if the diversity came about by evolution or by informed intervention. The order in which these organisms appear as fossils is a part of the picture that is discussed later in connection with the fossil record.

The hierarchical arrangement of life illustrated in figure 11.12 has been used by Futuyma and others as evidence that life must have evolved.[30] They believe that if life were created, the characteristics of different organisms would be arranged chaotically or in a continuum, not in the hierarchy of nested groups evident in nature. If we think of that concept as a hypothesis, how could it be tested? Actually, to state how a Creator would do things and then show that nature is or is not designed that way depends on the unlikely assumption that we can decide what the Creator would be like and how He would function. The nature of life is empirical evidence that if life was created, the Creator used a hierarchical plan with a nested system of basic designs that were modified to meet the needs of each subgroup. There is no evident reason why such a hierarchical system of design would not be effective. The hierarchical nature of life is consistent with both macroevolution and interventionist theories. It is not evidence for or against either theory.

Biogeography

Since animals and plants first were created, there has been a complex series of changes in their distribution on the earth. During this time, evolutionary change has been occurring within the original independent groups. The species of finches and tortoises on the Galapagos Islands, and the honeycreepers and hundreds of species of fruit flies in Hawaii, have evolved as they colonized one island after another. No giraffes are found on islands because they are not able to get there by natural means. God did not necessarily put the species where they are now. A large part of the biogeographic data has the same explanation in intervention theory as in macroevolution theory.

Some of the large-scale biogeographic patterns are in a different category, however. Why are almost all Australian mammals marsupials with ecological equivalents to mammals such as wolves, mice, rabbits, and moles?[31] Why are eleven closely related families of rodents found only in South America?[32] Why do continents (i.e., South America and Australia) that are the farthest and most inaccessible from the landing place of the biblical ark have the largest number of unique groups of mammals and birds? These are challenging puzzles for the interventionist theory. Whether there is an effective solution depends on certain assumptions about the history of life since the intervention. Suggested solutions are best introduced after further discussion of the geological evidence, so we return to this question in chapter 16.

Fossil Record

The biological evidence doesn't look encouraging for the natural origin of life or for the radiation of life by macroevolution. Can we find hard evidence (pun intended) in the rocks? In spite of the biological problems for evolution, does the geological record with its fossils provide convincing evidence of the evolution of life forms through the ages? We will now turn to that question.

Much of the evidence examined up to now in this chapter can be interpreted in different ways and still be logically consistent. It can fit either theory. We need a historical record to tell us what happened. Only two types of sources even claim to be such a historical record. The first consists of written accounts that claim to give a record of the history of life. But if we want to evaluate what science can tell us about history, we need to look at the other source—the fossil record. This record is the line of scientific evidence that, theoretically, could settle the question between the two theories. The interventionist theory implies the following expectations from the fossil record: First, complex creatures could occur as low in the rocks as simple creatures. There would not necessarily be a sequence of ascending complexity. If a group of organisms does not occur in the lowest rocks, it would be for some reason other than that the group had not yet evolved. Second, convincing series of evolutionary connecting links are not expected in the fossil record. We will first evaluate the evidence for a sequence of simple to complex organisms.

Precambrian fossils are not as abundant as fossils in younger rocks, but they do form a sequence. The earliest fossils are single-celled prokaryotes, and then single-celled eukaryotes appear. Fossils of possible multicelled animals first appear near the top of the Precambrian (the Ediacaran fauna).[33] They may be multicelled animals, but they are not considered ancestral to the Cambrian organisms.[34] They are a unique, extinct assemblage of animals with no clear ties to other groups. One paper even suggested that they may be lichens.[35]

The fossil record (fig. 11.14) from the Cambrian through the Cenozoic is called the Phanerozoic—the age of abundant life—for good reason. At the beginning of the Cambrian, so many groups of animals suddenly appear as fossils that it makes a distinct break in the record.[36] This striking diversity of organisms[37] includes a number of groups of animals that have since gone extinct.[38] Even the first vertebrate fossils occur in the Cambrian.[39] Almost all the phyla of invertebrate animals that have a fossil record occur in the Early Cambrian, including the familiar sea creatures such as sponges, molluscs, trilobites, and starfish. This sudden appearance of so many modern phyla

Interpreting the sequence of fossils in the rock record

DATA

What rock deposit each fossil is found in and documentable vertical relationships when available.

INTERPRETATION

Conventional science: The naturalistic assumption *requires* that the fossil forms resulted from evolution of life through deep time.

Interventionism: This worldview assumes the fossil sequence generally has some other cause rather than macroevolution. Exceptions to the above can, and probably do exist, for any sedimentary deposits and fossils that formed after (and possibly before) the global catastrophe.

and additional extinct phyla in the Early Cambrian without obvious ancestors is referred to as the Cambrian explosion. This striking feature of the fossil record is a challenge to explain without informed intervention.[40] Interventionist theory proposes that the Cambrian explosion is not a record of the first appearance of life, but the first burials during a catastrophe.

Does the evidence indicate these earliest fossils were more primitive in the sense of being more crudely constructed or more simple? No. For example, trilobites are unique animals found only in the Paleozoic, but they have compound eyes, complex legs, and other features showing they are like arthropods of today.[41] The first arthropods are not underdeveloped or crudely put together. Furthermore, the first trilobites must also have had the same biochemical complexity as modern life forms.[42] Other groups show that the basic features of the phyla are present at the beginning of the record. Macroevolution theory recognizes that the first fossils in these phyla already had the basic body plan that the same phyla have today. A mollusc is a mollusc all the way through the fossil record. The term "primitive" in evolution theory does not mean crude—it just refers to animals or structures that appear early in the record. There is no such thing as a crudely constructed animal.

Phylogenetic trees in many texts and popular books show a complete tree all the way back to the beginning of life. Trees that show which parts are supported by fossil evidence and which parts are hypothetical are more interesting. Such trees show that the evolutionary connections between virtually all phyla and almost all classes are only theoretical. Noninterventionist scientists are aware of this. Charles Darwin identified this as the greatest weakness in his theory. He believed the intermediates would be found. However, most of the thousands of fossils that are found fall within the existing groups. As more fossils are found, it becomes clearer that the gaps between major groups of organisms are real, and sequences of intermediates are not likely to be found. This evidence has caused evolutionary theorists to look for new ways to explain the evolution of major groups consistent with the reality of the general lack of fossil intermediates.

The Cambrian explosion is striking for another reason. If life originated by macroevolution, it seems most reasonable to expect that life would first appear as a few basic forms, with much speciation within these few groups. We might expect that new body plans (new classes and phyla) would not appear quickly but would gradually appear one by one over geological time as life diversifies. The fossil record shows the opposite—essentially all the classes and phyla appear near the beginning of the fossil record, including some that have since gone extinct. The greatest diversity of phyla was at the very beginning (fig. 8.10). This is easiest to explain by creation of the body plans all at once and the fossil record forming after that creation event.

The fossil record rarely shows any animals changing through time (no change = stasis). This is a very prominent feature of the record, unexpected by the evolution theory. Species typically appear, then do not change for supposed thousands or millions of years, then disappear and are replaced by different species, which also then do not change.[43]

The plant fossil record is also very striking for its lack of intermediates. This evidence fits the expectations of the informed intervention paradigm. The groups of plants appear rather suddenly in the rocks without links to ancestors. Various groups of flowering plants that appear in the Cretaceous rocks are similar to those that exist now. No record has been found of their evolution. Why do they not occur before the Cretaceous? We will return to this question in chapter 16.

Mammals have the best fossil record of the vertebrates. For most orders, no fossils document evolution from presumed ancestors. However, the vertebrates contain the principal exceptions to the general lack of intermediates.

The Mesozoic rocks hold series of organisms that can be interpreted as a good evolutionary sequence from reptiles to mammals.[44] The therapsid reptiles, sometimes called the mammal-like reptiles, have clearly reptilian skeletons. Reptiles, including the therapsids, have some bones that mammals do not have. They also have only one middle ear bone rather than the three that mammals have. The articular bone in the reptile lower jaw articulates with the quadrate bone; in mammals, the dentary bone composes the lower jaw and articulates with the squamosal.

In other ways, the therapsids are not typical reptiles. Their legs are positioned upright under their body like mammals but unlike other Permian reptiles. Their skulls have several features that are mammal-like: a secondary palate separating the mouth from the nasal opening; teeth that resemble mammal incisors, canines, and cheek teeth; and a lower jaw composed mostly of the dentary with the other bones reduced. In the Triassic deposits, several groups simultaneously show more mammal-like traits. A few types seem to have remnants of the reptile articular-quadrate jaw joint and an incipient dentary-squamosal joint.[45] Some fossil forms seem to show reptile jaw bones evolving into mammal middle-ear bones (fig. 11.16).[46]

The mammal-like features in the therapsids are morphological traits related to an active lifestyle with a high metabolic rate requiring a higher food intake than other reptiles. Some have speculated that the therapsids were warm-blooded. The first mammal fossils are found in the

Triassic. Some seem to have a combination of characteristics making the choice to call them reptiles or mammals arbitrary.[47] The existence of a group of reptiles with features of anatomy and physiology parallel to the mammals' active lifestyle is not a problem for interventionist theory, but the confusing group of Triassic fossils with apparently intermediate structures is a puzzle. The evolution from cold-blooded, egg-laying reptiles to warm-blooded mammals with live birth can be seen as an unlikely transition for unguided evolution to accomplish. A suggestion for the ear bones is that perhaps the same genes form lower jaw bones or middle ear bones, dependent on epigenetic factors, and in these Triassic forms, there were epigenetic aberrations.

Another famous intermediate is *Archaeopteryx*, the early fossil that looks like a good link between reptiles and birds (fig. 11.15). *Archaeopteryx* is not the equivalent of the complex group of therapsids. They are just two species with several structural features that are different from other birds. *Archeopteryx*'s tail has a long bony skeleton, it has teeth, and it has claws on three digits of its wing. However, it has hollow bones, is fully feathered, has well-developed wings, and apparently could fly.[48] The existence of *Archaeopteryx* and other, similar, fossils does not help explain the difficult problem of evolving the power of flight.[49] They are a unique type of creature, perhaps related to other birds in the same way that monotremes (duck-billed platypus and spiny echidna) are related to the other mammals. Monotremes are mammals that have some bones normally found in reptiles but not in mammals, and they lay eggs. Since monotremes still live, we can study their soft tissues and verify that they are indeed mammals and are not suitable evolutionary ancestors to the other mammals.

Since there are no living *Archaeopteryx*, it is impossible to be sure of their true relation to the other birds. Various alternatives for the explanation of these important fossils can be considered, though there is no proof that they are or are not ancestral birds.

If the presumed feathers on some of the small dinosaurs are real,[50] this is not necessarily evidence for evolution of birds from reptiles, since we do not know of any reason why some dinosaurs could not have been created with feathers for insulation. One difficulty for the theory of evolution of birds from dinosaurs is that *Archaeopteryx*, a fully flying bird, occurs in the Jurassic, while the dinosaurs considered to be ancestral to birds, including the feathered dinosaurs, do not appear until the Cretaceous, supposedly twenty-five million years after *Archaeopteryx*.

The first amphibians have many skull features in common with the rhipidistian fishes, but the needed intermediate forms do not exist to help solve the problem of bridging the huge structural gap between fish with fins and amphibians like *Ichthyostega* with a fully terrestrial limb structure (fig. 11.17). The available evidence cannot tell us if the similarities between early amphibians and rhipidistian fish resulted from evolution or from common design elements used in two differing groups.

The tetrapod-like fossil fish, *Tiktaalik*, has some features that are more tetrapod-like than the rhipidistian fishes, and it could be proposed to be an intermediate stage. However, one vertebrate paleontologist has stated that "while *Tiktaalik* illustrates a plausible, intermediate way of life between marine fish and terrestrial amphibians, the absence of ossification of the vertebrae, their great number, and the divergent specialization of the forelimb suggest that this genus was not an immediate sister-taxon of any known tetrapod."[51] Also, its body and limb structure is still clearly a fish and barely begins to bridge the huge structural gap between fish and amphibians. The significance of *Tiktaalik* as a bridge to terrestrial amphibians has been further brought in question by the discovery of footprints of fully terrestrial amphibians in rocks dated at about twenty million years before *Tiktaalik*.[52]

The fossil archaeocete whales with small hind limbs are significantly different from living whales, especially in their teeth and the structure of their skulls (fig. 11.18). Living whales have unique skulls, with a number of bones moved far back from their normal position to allow the nasal openings to form the blow hole on top of the skull. These differences indicate there are two types of whales and do not indicate whether the two groups evolved or were created. Certainly, a greater variety of whales lived in the past, and the presence of some whales with hind limbs removes one obstacle for macroevolution theory. Perhaps, originally, a diversity of created whale body styles was extant, and those with hind limbs have gone extinct. It still needs to be explained why those with limbs came first in the fossil record before modern whales.

There are a group of fossils interpreted as an evolutionary sequence from terrestrial ancestors to whales.[53] This group includes terrestrial and amphibious forms, and they seemed to occur at the correct level in the fossil record to be ancestors. However, recent discovery of an archaeocete whale dated at forty-nine million years makes the oldest swimming whale about as early in the record as the presumed terrestrial whale ancestors.[54] In any case, whether the terrestrial species are ancestors to whales is an interpretation and relies on the assumption of naturalism.

Some hominids look like intermediates between apes and humans (fig. 11.20). One interpretation is that humans evolved from apes through these intermediates. Other hypotheses also are worth investigating. Perhaps Neanderthal man and even *Homo erectus* were degenerate forms of humans, while *Australopithecus* was another form of ape.[55] There is evidence of hybridization between different hominid types, and DNA analysis indicates that the genomes of most Europeans and Asians and some others are 2 percent to 5 percent from Neanderthals or other distant relatives.[56] A literal biblical creation indicates that human beings did not evolve from other primates, but we do not yet know what the proper interpretation is for some of the fossil hominoids.

These groups that seem like good intermediates are one of the strong points in favor of macroevolution. However, most of them have other plausible interpretations with the most difficult one being the mammal-like reptiles. If macroevolution of animals and plants occurred, it is puzzling why almost all of those major groups appear in the record fully formed with no evolutionary connecting links preserved and that so few contenders for a good series of intermediates between major groups can be found.

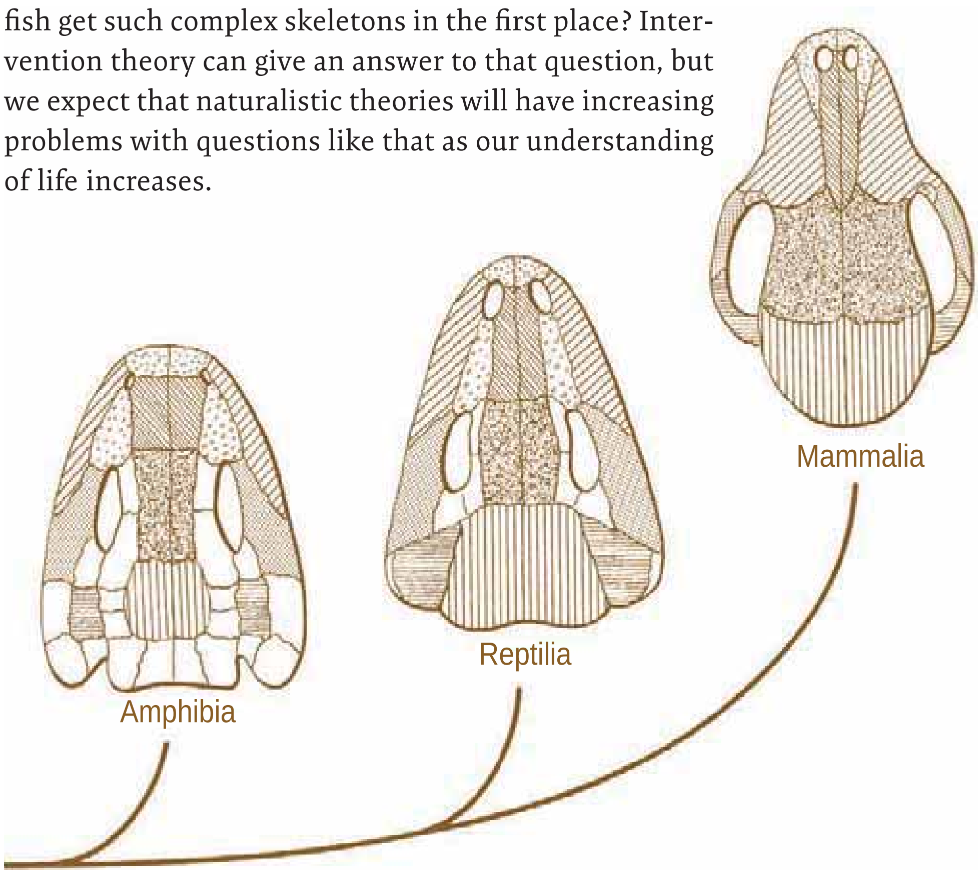
The series of fossil horses may be a true example of postcatastrophe microevolution and speciation. The differences seem well within the realm of environmentally related alterations through epigenetic processes.

When we consider the overall stratigraphic distribution of the fossils, many groups do not go all the way down through the fossil record (fig. 11.14). Fossils in the Precambrian are mostly one-celled organisms. The invertebrates enter the record next, and later on the fish appear, then amphibians and reptiles, and, lastly, birds and mammals. In that sense, a sequence of ascending complexity seems plausible. Mammals do not appear in the record until the Mesozoic, our familiar modern orders are not found as fossils until the Eocene, and few modern species appear before the Pleistocene. There is a definite order in which major groups of vertebrates appear in the record. This feature needs an explanation. Informed intervention theory, as defined in this volume, says that mammals were in existence at the time the Paleozoic fossils were being buried. The mammals were not buried at that time for some reason other than not yet having evolved.

The vertebrate fossil record is a mixed bag for the interventionist theory. Some scientists are seeking a new mechanism of macroevolution that will explain the scarcity of fossil intermediates. The challenge for the informed intervention paradigm is to find an alternate explanation for the apparent intermediates, for the sequence of fossils in the rocks, for the increasing percentage of extinct groups lower in the fossil record, and for the large-scale patterns in the biogeographic data. This, and not the biological evidence, is the major challenge for interventionist theories. For now, it can be simply proposed that an alternate mechanism is feasible for distributing most of the fossils in the sequence in which they occur. The sequence represents something other than an evolutionary sequence. It is more related to life habits, sorting, and burial processes during catastrophic events. That topic occupies the last chapters of this book.

Some groups of vertebrates have more complex skeletons than others. Some have more bones in the skull, for example, but the more complex skeletons of vertebrates are closer to the bottom, not the top of the fossil record (fig. 12.6). A definite trend shows a reduction in the number of bones—simplification of the skeleton—as we go up the fossil record from bony fish to mammals. Both macroevolution and intervention theories can suggest plausible reasons mammals would have simpler skeletons than fish or Paleozoic amphibians. But how did fish get such complex skeletons in the first place? Intervention theory can give an answer to that question, but we expect that naturalistic theories will have increasing problems with questions like that as our understanding of life increases.

Figure 12.6. Skulls of several vertebrate groups, showing progressive simplification of the skull bones (after Moody 1962). Figure by Robert Knabenbauer.



Hierarchical Nature of Life and the Ascending Scale of Complexity

Is the ascending scale of complexity (fig. 11.11) evidence for macroevolution? It is only so if we accept the assumption of naturalism. If we question that assumption, another potential explanation exists for the same data. In any complex assemblage of things showing great diversity with different combinations of features, be they machines or animals, one can arrange them in a sequence from simple to complex. Does this imply an evolutionary sequence? Actually, the ecology of our world is extremely complex. It needs a great diversity of organisms to fill the many ecological niches so the intricate system will work. All the "advanced" features in mammals make them unsuited to fill the niche of a sponge. A creature with the suite of characteristics found in sponges is needed to fill that. One can arrange this great diversity of organisms in a sequence with those having a simpler organization at one end of the list and the most structurally complex organisms at the other. This "ascending scale of complexity" is only a description of nature. We must have a different type of evidence to tell us if the diversity came about by evolution or by informed intervention. The order in which these organisms appear as fossils is a part of the picture that is discussed later in connection with the fossil record.

The hierarchical arrangement of life illustrated in figure 11.12 has been used by Futuyma and others as evidence that life must have evolved.[57] They believe that if life were created, the characteristics of different organisms would be arranged chaotically or in a continuum, not in the hierarchy of nested groups evident in nature. If we think of that concept as a hypothesis, how could it be tested? Actually, to state how a Creator would do things and then show that nature is or is not designed that way depends on the unlikely assumption that we can decide what the Creator would be like and how He would function. The nature of life is empirical evidence that if life was created, the Creator used a hierarchical plan with a nested system of basic designs that were modified to meet the needs of each subgroup. There is no evident reason why such a hierarchical system of design would not be effective. The hierarchical nature of life is consistent with both macroevolution and interventionist theories. It is not evidence for or against either theory.

God and Cosmology

When cosmologists arrived at the Big Bang hypothesis, it created considerable controversy among scientists because it meant the universe wasn't always here but had a beginning. A beginning implies a God who caused that beginning, and that was not a welcome thought to many persons. When God created the universe, did He do it in an explosive way that we have interpreted as the Big Bang? Or has the Big Bang theory missed something important? We don't know the answer as yet. So far scientists have also not provided answers to how the fine-tuning of the universe could originate without God, nor have they provided a feasible alternative to carbon-based life.

Carbon is a very unique element, which forms many millions of stable compounds. Carbon and all the vast array of types of molecules that it can form is apparently the only realistic basis for life. Silicon does not approach the potential of carbon, and no one has even begun to describe details of how silicon-based life could be constructed.[58]

The fine-tuning of the physical laws is very difficult to explain without an all-knowing Creator who invented those laws to provide the universe as a home for intelligent life.[59] To many scientists, the physical universe and its governing laws are the ultimate reality, and life is just an accident of evolution. But to the personal God of the Bible, the universe and its laws are just tools that provide homes for His ultimate reality—relationships between the living beings He created.

There is absolutely no evidence for multiple universes, and it is an untestable theory, so why does that theory even exist? The existence of the multiverse theory illustrates how tough it is to explain the fine-tuning of the universe without God. There is only one reason why the multiverse theory is given consideration by scientists—it seems to be the only way, a desperate attempt, to avoid the need for a Creator God. Even if multiple universes existed it still would not answer the questions of where matter and energy and the laws of nature came from if there were no God.

"When the Son of Man comes, will he find faith on the earth?" (Luke 18:8, NIV). Not very much faith.

The Convergence (?) of Different Lines of Evidence

The prestigious journal *Nature* published a list of the best arguments for evolution—"15 evolutionary gems."[60] Six were relevant to macroevolution and the other nine dealt only with microevolution. Of the six, "the origin of feathers" is puzzling, since the oldest fossil feather is a beautiful, fully formed *Archaeopteryx* feather. Another, "the origin of the vertebrate skeleton" is equally puzzling, since evolving from an invertebrate to the vertebrate skeleton is actually a serious challenge to macroevolution. A third, "microevolution meets macroevolution" relies on genome similarities in modern organisms, an argument that depends on the *assumption* of macroevolution. That leaves the land-living ancestors of whales, the transition of vertebrates from water to land, and the evolutionary history of teeth. These issues are also affected by assumptions. Are these indeed the best arguments supporting macroevolution?

Darwin was much too optimistic in his belief that many lines of evidence pointed to an evolutionary origin of all life forms. If we are willing to question the assumption of naturalism, we can recognize that much of his evidence has other plausible interpretations and new evidence has thrown out huge challenges to the viability of the macroevolution process. Claims that "evolution always gets it right" are quite uninformed. Both naturalistic macroevolution and interventionism explain some observations but also have difficulty with some evidence.

CHAPTER 13

Sociobiology and Altruistic Behavior

Overview

As it attempts to explain animal behavior, evolution has a problem with altruistic behavior (behavior that benefits another individual while possibly endangering oneself); natural selection should not allow altruism to evolve. The theory of sociobiology was the proposed solution to this problem. According to sociobiology, if individuals seem to be helping other individuals at their own expense, they are only doing this when those being helped are close relatives (kin selection) who can pass on genes shared with the one who is helping. Since the helper's genes are passed on because a relative was saved, the result is actually in favor of the helper, and thus is not really altruistic. Evidence for this can be found in the animal world. The theory has also been applied to humans and has been used to justify immoral behavior. Even rape is seen as just another strategy to pass on ones genes. These conclusions are dependent on the assumption that humans and other animals evolved from common ancestors, but sociobiology does not provide evidence for that evolution. Perhaps mutations after humans fell into sin have favored the more selfish side of our nature, but Christianity offers a solution, as we seek divine support to become more like Jesus Christ.

Animal Behavior and Evolution

The theory of sociobiology, the application of evolution theory to the study of behavior, developed as scientists searched for a more adequate evolutionary explanation for all forms of animal and human social behavior. In chapters 8 and 9, we discussed the process by which mutation, recombination, and natural selection can introduce a trait into a population. For example, a variation in color could make an animal better camouflaged. If the individuals with the new color survive and reproduce more successfully, the new color variant would become more common in the population. The impact on the next generation is determined entirely by how many offspring are produced that have the new color gene. The ability of organisms to reproduce successfully is described by the term "fitness." The individuals that produce the most reproductively successful offspring have the highest evolutionary fitness.

One can visualize how this functions in the case of morphological features such as selection between color variations (improving camouflage), between individuals that differ in size or strength (ability to secure food and defend against enemies) or speed (ability to escape). Could the same process be involved in explaining evolutionary changes in behavior? Could it explain why some species have monogamous mating systems and some are promiscuous, or why some species rely more on vocal communication and some focus on chemical communication? R. F. Ewer summarized the challenge with his statement that "unless the mechanisms which produce the behavior are explicable in terms of natural selection working in the orthodox manner, we will be forced to postulate special creation or some unknown mystical-magical process."[1] In many cases, microevolutionary explanations for the origins of behaviors could be suggested. A problem remained, however, in attempting to explain altruistic behavior. An altruistic act is any behavior that benefits another individual at the expense of or that is a risk to the one performing the behavior. Darwinian reasoning seems to predict that an individual animal would compete to survive rather than act selflessly toward other individuals, especially if that act may put its own survival into jeopardy.

A ground squirrel that gives an alarm call when a hawk appears warns others to hide, but it also draws attention to itself and may even increase the chances that it will be the one caught by the hawk. In evolutionary terms, a squirrel that is prone to give alarm calls may be decreasing its own fitness because it is decreasing the probability that it will live to reproduce. A squirrel whose genes predispose it to cheat, by benefiting from the alarm calls of others but not giving calls itself, would appear to be the one with the best chances of reproductive success and thus have the highest fitness.

Some species of birds, such as the Florida scrub jay or the African bee-eater, have nests that are cared for by the parents with the assistance of one or more other adult "helpers at the nest." Why would one of these helpers decrease its own fitness in order to help other birds raise their young rather than raising young that carry its own genes? Can evolution theory explain this?

Many who accept some form of creation by God consider the creation of humanity and morality to have been a separate and special act from other acts of creation. Therefore, an interventionist is tempted to simply dismiss any proposed evolutionary mechanisms for explaining altruistic behaviors. However, even interventionists must explain why evolution processes after the creation event appear to have eliminated many altruistic behaviors. Consequently, the question regarding altruism in animals remains essentially the same for everyone, no matter what philosophy we start from.

Sociobiology: A Proposed Answer to Altruism

In 1975, Harvard entomology professor Edward O. Wilson published *Sociobiology: The New Synthesis*.[2] He developed a new paradigm, which he defined as "the systematic study of the biological basis of all social behavior, . . . a branch of evolutionary biology and particularly of modern population biology."[3] This paradigm stimulated a considerable amount of controversy, but much of it has been generally accepted.

In *Sociobiology*, Wilson claims to have solved the problem of altruism. A cornerstone of sociobiology theory is the concept of inclusive fitness, which refers to the rate at which an animal's own offspring and its close relatives' offspring are successfully reared and reproduce. While fitness is an animal's rate of success in passing its genes to its own offspring, inclusive fitness is its rate of success in passing its genes directly to its own offspring and indirectly to the offspring of its close relatives because its relatives have many of those same genes. Two sisters share, on the average, 50 percent of their genes in common. If one sister helps the other successfully raise her offspring to reproductive age, she assists in the passing on of many genes that she shares with her nephews and nieces, thus increasing her inclusive fitness.

Sociobiology theory predicts that, because of this sharing of genes between relatives, altruistic behavior should exist only in situations in which the "altruistic" individual would actually increase its inclusive fitness by that behavior. Biologist J. B. S. Haldane is reputed to have once said that he would lay down his life for two brothers or eight cousins. The reason for this is that, on average, brothers share half of their genes and first cousins share one eighth of their genes. If Haldane died for one brother (thus eliminating his own chance to reproduce), his brother could only pass on half as many of Haldane's genes as Haldane himself could have done. However, if he died to save two brothers, he would, statistically speaking, come out even.[4]

If we apply this to our alarm-calling squirrels, sociobiology theory predicts that squirrels should be most likely to give alarm calls when they are surrounded by many close relatives. Hence the squirrels that are helped by the calls share many genes with the caller, thus increasing the caller's inclusive fitness. Research has shown this is true. When young ground squirrels mature, the males disperse to distant places before they settle down and choose a territory. Young females do not disperse. They set up territories near home. Consequently, females have many close relatives living near them, but males do not. Just as the theory predicts, it is the females who give the alarm calls. When a female calls, many of the squirrels who are helped are relatives who share her genes. Even if she is caught by the predator, her relatives who run for cover will pass on her genes that caused her to give the alarm call.[5] Natural selection in this situation is called kin selection. Favorable traits are shared by close relatives, and a family that helps its members survive will have more reproductive success than other families. Their behavioral traits are the ones that will become more common.

The processes of mutation and kin selection and their effects on inclusive fitness are the elements of the mechanism by which sociobiology proposes to explain the origin of altruism and of all other social behavior. Sociobiology theory says that the entire focus of life is reproductive success. Animals are "sex machines"[6] whose function is to pass on favorable genes that will improve the inclusive fitness of their offspring.

The evolution process has no room for unselfish actions that help a nonkin at the expense of the one performing the action. Thus one corollary of sociobiology theory is that there is no such thing as truly altruistic behavior. Some apparent exceptions to this are explained as "reciprocal altruism"—you scratch my back and I'll scratch yours. For example, an olive baboon male will solicit help from an unrelated male in an aggressive interaction against a third male. It often occurs that on another occasion the roles are reversed, and the original solicitor helps the same partner who is now the solicitor.[7]

Can sociobiology explain the helpers at the nest? Kin selection would predict that a bird nest has nonparent adult helpers only when the helpers' inclusive fitness is higher from helping relatives than from trying to raise their own young. Research has confirmed that this prediction is correct[8] and that the helpers are close relatives, usually offspring from a previous season. These helpers cannot secure territories of their own or are too inexperienced to be very successful in raising their own young in their first year. Until they are ready to do so, their inclusive fitness will be higher if they help raise their relatives who share many of their genes.

Behavioral Strategies

As animals compete with each other for resources such as food, living space, or mates, various behavioral strategies could be employed. The application of sociobiology theory suggests ways to predict which strategy will be most effective in different situations. For example, two competitors could simply fight, with the winner of the fight taking the resource. They could employ some type of conventional strategy (symbolic battle), like a stereotyped arm-wrestling match, that indicates which animal is stronger or more aggressive without the risk of anyone getting hurt. Game theory and the principles of sociobiology can be used to predict the benefits of each strategy.[9] Natural selection, in general, is expected to favor conventional strategies over all-out "war" in animal conflicts.[10] Many examples of this can be seen in nature.[11] Male rattlesnakes don't bite other males but wrestle each other, and the winner is the one that can pin the other's head to the ground with his own body. Lava lizards "battle" by hitting each other with their tails, and marine iguanas butt heads together and push each other backward. Deer and antelopes have potentially lethal antlers or horns, but when the males battle over mates they do not try to impale each other. They butt their heads together and wrestle in ways that usually do not cause serious damage.[12] Animals also commonly communicate the nature of their aggressive state to other individuals of their species, apparently to allow the other individual to respond appropriately, thus reducing the amount of fighting.[13]

Research under the guidance of sociobiology theory has led ethologists (scientists who study natural behavior of wild animals) to recognize the role of some animal behaviors previously thought to be only bizarre abnormalities. For instance, a male African lion sometimes kills all the babies in his pride. This happens when a battle between males occurs and the ruler of the pride is deposed. The new dominant male generally kills all the young, the offspring of his deposed rival. Consequently, he is able to mate and produce his own offspring much more quickly than if the females were occupied with offspring of his former rival.[14] Such infanticide is also known to occur in Hanuman langurs, mountain gorillas, chimpanzees, African wild dogs, and rodents.[15]

Implications for Human Behavior

Sociobiology has become the prevailing synthesis in the study of animal behavior and has been very successful. Apparently, sociobiological reasoning frequently provides useful and testable scientific predictions in animal behavior studies. What are its implications for human behavior?

The basic claim of sociobiology is that human behavioral traits are not a result of special creation. They have developed through evolution from nonhuman ancestors. Increased inclusive fitness is gained by increased reproduction by oneself or one's close relatives. Consequently, according to sociobiology, reproductive success is the dominant factor determining human behavioral tendencies. Though we may think that we are rational, moral beings, our behavior is more programmed than we think it is. In other words, "sociobiologists contend, we were designed to be reproduction machines."[16]

Many Christians believe that humankind has been given a set of moral rules for sexual behavior. These rules tell us what is right or beneficial and what is wrong and should be avoided simply because it is damaging to human relationships or is harmful to ourselves or others. Sociobiology says there are no morally right or wrong behaviors. Our behavior is the result of the selection pressures that have created us. Duncan Anderson summarized the concept this way: "The type of man who leaves the most descendants is the one who cuts his reproductive costs on all sides, by keeping a close watch on his mate and making sure he has no rivals; supporting his mate, if it seems that all her children were sired by him; and mating with other females—additional wives, single women, other men's wives—whenever a safe opportunity arises."[17] Some researchers suggest that evolution has programmed us so that babies do not look too much like their fathers, thus making adultery easier to get away with.[18]

Sociobiology: An Alternative to Religion

In sociobiology theory, right or wrong behavior does not exist in a moral sense, only different behavioral strategies with effects on inclusive fitness. Sociobiology could be said to be the naturalistic answer to Christianity's value system. "Wilson openly challenges Christian faith by offering a substitute belief system based upon scientific materialism."[19] Wilson believes that humanity has an innate tendency toward religious belief because, in the past, it conferred an adaptive advantage. He also believes that the content of religious belief is false and that we should replace it with a more correct mythology.[20] "This mythopoeic drive (i.e., the tendency toward religious belief) can be harnessed to learning and the rational search for human progress if we finally concede that scientific materialism is itself a mythology defined in the noble sense."[21] He urges us to "make no mistake about the power of scientific materialism. It presents the human mind with an alternative mythology that until now has always, point for point in zones of conflict, defeated traditional religion."[22]

Wilson does not deny that religion and moralism have value. He believes they can encourage reciprocally altruistic behavior by discouraging cheating. But he believes that moral values should be determined by science, which offers the "possibility of explaining traditional religion by the mechanistic models of evolutionary biology. . . . If religion, including the dogmatic secular ideologies, can be systematically analyzed and explained as a product of the brain's evolution, its power as an external source of morality will be gone forever."[23] Wilson feels our ideas of sexual morality should be more liberal. He bases this conclusion on a survey of the behavior of our presumed nonhuman ancestors and on his convictions that Christianity's moral laws did not come from God. These opinions apparently are based on his conclusion that with continuing research "we will see with increasing clarity that the biological god does not exist and scientific materialism provides the more nearly correct perception of the human condition."[24]

Is Sociobiology Real?

To what extent are the proponents of sociobiology correct? To address this question, several different concepts can be isolated and considered.

The proposed naturalistic origin of the higher groups of organisms, including the origin of humanity and the human brain. Sociobiology theory, as proposed by Wilson, is built on the assumption of the naturalistic evolutionary descent of all organisms from a common ancestor. Sociobiology does not provide evidence for that evolutionary descent, however. It merely assumes the naturalistic evolutionary origin of animals and develops hypotheses and explanations for behavioral change based on that assumption.

Kin selection and the evolution of behavior, at the level of species or genera of animals. The alarm-calling female ground squirrels, the bird helpers at the nest, and a host of other examples certainly fit the theory very well.[25] Whether future research will continue to support it remains to be seen. Late in his career, Wilson (controversially) abandoned his support of kin selection, believing rather that group selection (selection operates at the community level rather than on the individual) is where sociobiology functions.[26] But with mutations causing random damage to the genes that influence behavior, it does seem very likely that behaviors not supported by some type of selection process eventually would be weakened or eliminated, perhaps by epigenetic processes.

Kin selection and its genetic influence on human behavior. Aside from the question of whether humankind is the result of evolution, one can ask whether human behavior is controlled by genes, as claimed by sociobiology, or determined mostly by culture (i.e., learned rather than inherited). This debate has raged ever since (and before) sociobiology was introduced. Wilson actually does recognize that culture is an important component of human behavior, but he maintains that other important themes of primate behavior also are present in humans by inheritance.[27] Others disagree. This group includes scientists who believe Wilson's sociobiology goes too far in presuming biological determinism. Perhaps the most widely known person who challenged biological determinism was Stephen J. Gould, a colleague of Wilson's at Harvard. Gould praised most of Wilson's sociobiology, but he rejected what he saw as biological determinism in humans. He and others argued that there is no evidence for specific genes that determine human behavior and believe the theory of such genes is not testable.[28]

Some others carried the concept of genetic control of human behavior further than Wilson did.[29]

One must recognize that evidence does exist for genetic control of behavior in nonhuman animals.[30] These changes could be epigenetic changes rather than changes to the DNA.[31]

Consequently, even though much of human behavior seems to be modifiable by culture, the possibility that significant genetic control of behavioral tendencies exists in humans needs to be considered. If such control exists, the strong possibility, perhaps certainty, follows that mutations could alter that behavior. With random genetic damage of genes occurring, it would be difficult to escape the conclusion that some human behaviors can be altered or eliminated by mutations and would be subject to the processes of natural selection, including kin selection. Does that mean that sociobiological explanations of human behavior are correct? What does that say about morality?

Some sociobiologists emphasize that sociobiology does not try to indicate what our behavior ought to be,[32] but other writers do claim that sociobiology determines what we should do. Psychologist Robert Plutchik recommended that human emotions are best understood in the context of the history of their evolution from other animals and asserted that this view of emotions will benefit clinical practice in psychology.[33] Some ethics textbooks explicitly base their system of ethics on the principles of sociobiology.[34] Alexander concluded that conscience is "the still small voice that tells us how far we can go without incurring intolerable risks. It tells us not to avoid cheating but how we can cheat socially without being caught."[35]

Concepts of right and wrong for Christians are understood as a moral code given to humanity. The Ten Commandments and the teachings of Christ have provided a standard for human behavior. Clearly, humans do not follow that standard very well. The apostle Paul laments, "For the good that I will to do, I do not do; but the evil I will not to do, that I practice" (Rom. 7:19, NKJV). Perhaps we have fallen so far from our original created condition not only because of temptations to sin but also partly because mutations have affected our behavior. Perhaps both humans and nonhuman animals were created with well-balanced behaviors as well as morphologies that since have undergone generations of change driven by mutations or epigenetic influences and natural selection. As a result, part of human character reflects this change, and that has emphasized the selfish side of human nature.

The view presented here differs from current evolutionary thinking by proposing that the basic process of kin selection and its effect on inclusive fitness have operated only within humans and within other created groups of organisms. It has not carried behaviors from one such group to another, since these groups have not evolved from common ancestors (this concept is developed further in chapter 10). Christians also accept by faith (and by reasoning that is at least logical, even though not scientifically testable) that humankind is not biologically destined but has a measure of free will to seek the ability from God to act in ways that are truly altruistic and not just the result of gene modification and biological determination.

Does genuine altruism exist in humans? Observations of human behavior make it difficult to believe that some behavior is not truly altruistic because abundant examples of human altruism can be documented.[36]

An Interventionist View of Sociobiology

According to interventionist theory, the original animals had the greatest level of complexity in their behavior, and the interspecific and intraspecific interactions between organisms were the most finely tuned and harmonious at the beginning of life on Earth. Potential conflicts between animals over the division of territory and other resources were originally settled by nondamaging conventional displays like those still common in a number of animals. Examples include the male rattlesnake wrestling matches and the lizard tail lashing or head butting "battles."[37] True altruistic behavior may have been much more common. Perhaps, originally, subadult animals commonly assisted their parents in raising the next brood or litter. Population-control mechanisms were also much more finely tuned than at present. Behavioral mechanisms for maintaining a stable ecological balance were built into the animals' genetic makeup as part of an ecological system that originated through intelligent design rather than chance.

The instinctive behavioral mechanisms that prevented damaging conflicts were not originally subject to random mutational changes. Because of adequate protection from mutational damage, individuals with these behavioral mechanisms would not be subject to unfavorable competition from individuals who would benefit from "cheating." With the introduction of random mutations and defects in repair processes, these behavioral mechanisms began to break down. Epigenetic responses to conditions in the changed world after sin may have been important.

Natural selection and, especially, kin selection have acted to slow this breakdown. The altruistic behaviors that have survived the negative effects of mutation are primarily those that have been preserved by kin selection and increase the inclusive fitness of the organism. When mutations began to cause the loss of some of the original created behavior patterns, natural selection would determine whether the original type or the mutated type would become most common. If mutations in a female bird removed the original pattern of helping her parents raise their young and she built her own nest, she would likely produce more young in her lifetime than others who began reproducing later (this is the same result that would be expected by naturalistic theory). As a consequence, the "nonhelper genome" would become more common and eventually replace the "helpers." On the other hand, in some situations, the genes for "altruistic" behaviors are favored by kin selection. Consequently, they continue to be common in the population. The Florida scrub jay lives in a situation in which the young are not likely to reproduce successfully the first year. Consequently, their inclusive fitness is increased if they help their parents raise young, which share many genes that they also have.[38] Thus kin selection favors retention of the "altruistic" behavior in this environment.

An intelligent and benevolent Designer could choose to invent an ecological system with a balance of nature based on harmony rather than on competition. In contrast, mutation and natural selection have no ability to look at the "big picture" and see what is best for the overall ecological balance. Natural selection is strictly shortsighted—it favors any change that increases successful reproduction.

The ultimate result of the rule of natural selection is the competitive, vicious side of nature. Humans are not captive to behavior resulting from a mutated nature but can seek aid from our Creator to grow in moral strength and live unselfish and responsible lives.

Interpretations of sociobiology

DATA

Nonhuman animal behavior sometimes fits the predictions of sociobiology. Human behavior is often selfish (not altruistic).

INTERPRETATION

Conventional science: The naturalistic worldview requires that seemingly altruistic behavior must have a nonaltruistic explanation. Evolution has not allowed true altruism to evolve.

Interventionism: Organisms as created may have (and probably did) exhibited truly altruistic behavior. Humans, as created, are expected to have had truly altruistic behavior. In a sinful world, detrimental mutations and/or epigenetic alterations and bad choices after sin have reduced or eliminated much altruistic behavior in humans and nonhuman animals.

CHAPTER 14

The Geologic Record

Overview

This chapter introduces the reader to the science of geology. It also describes *conventional geology* theory, with essentially modern geological processes functioning for hundreds of millions of years, and *short-age geology,* with geological processes functioning for only thousands of years. The geological processes described include types of rocks and how they form, the depositional environments in which sedimentary rocks accumulate and how to recognize these environments, how mountains and landscape develop, and erosion processes that shape the land. Glaciation, the stratigraphic sequence of rock layers, and the fossils they contain and how they were preserved are also discussed.

Charting a Path for Two Theories

This chapter is an introduction to geology for readers without a background in geology. It also introduces two theories that attempt to account for the origin of the Cambrian to recent geological column and its fossils—conventional geology (541 million years of time) and short-age geology (a few thousand years). Both theories must account for a number of geological features and processes. These are reviewed in this chapter, including formation of rocks and minerals, accumulation of sedimentary deposits in various ancient environments, formation of mountains, erosion of the sediments to form our modern land forms, glaciation on mountains and over continents, and origin of the fossils in the fossil record. We discuss these and how geological theory for such processes and events is influenced by short-age geological theory.

In evaluating data and interpretations in geology/paleontology, it will often be difficult to apply the concept of inference-to-the-best-explanation because we are dealing with events that happened a long time ago and cannot be directly observed. If we don't have adequate modern analogues for comparison with the rocks (and we have never observed a global geological catastrophe), we will often be hampered in reaching confident interpretations.

The most direct source of evidence of the history of ancient life comes from the fossil record, and it poses difficulties for both interventionism and macroevolution. The vertical stratigraphic sequence of fossils from one-celled prokaryotic (cells with no nucleus) organisms in the Precambrian to eukaryotes (cells with a nucleus), invertebrates, fish, amphibians, reptiles, mammals, birds, and, finally, humans and the associated questions of geologic time with its support from radiometric dating are the real challenges that face interventionists who accept a literal biblical creation. Consequently, we now turn our attention to geology and a more extensive discussion of the fossil record. The following material introduces the basic concepts of geology with both conventional and short-age interpretations of the concepts.

Theories of Earth History

Conventional geology interprets geological history as follows. Geological processes, generally like those observable today, operating over a time period of several billion years produced earth's geological features (fig. 14.1).[1] Life has been on the earth during much of Earth's history. The Phanerozoic (Cambrian to recent) rocks formed during the last 541 million years, and the fossil record is a record of the evolution and extinction of life forms through this time and before. The modern field of geology traces its roots

Figure 14.1. A sequence of sedimentary rock formations in the Grand Canyon. Figure by Leonard Brand.

back primarily to Charles Lyell, who developed the theory of uniformitarian geology.[2] Modern geological theory is a modification of Lyell's uniformitarian views and recognizes that Lyell was partly wrong. The term "uniformitarianism," as used by Lyell, actually includes four different concepts. These four aspects of uniformitarianism with an evaluation of each are summarized in table 14.1.[3]

Short-age geology. The Phanerozoic record was formed during a few thousand years. The major taxonomic groups of animals and plants arose at the beginning of that time through independent origins (by creation). Much of the fossil record consists of remains of these organisms that were buried in a sequence resulting from the order of events before, during, and after a worldwide geological catastrophe rather than from an evolutionary sequence. After the catastrophe, geological processes gradually slowed to the rates observable today and significant fossil deposits formed as a result of the progressively less catastrophic events during this time. A significant part

Table 14.1. Four separate concepts in Lyell's uniformitarianism

1. Uniformity of law: This is a part of science in general, and not unique to geology. It is still accepted that natural law is indeed uniform. Water never flowed uphill in the past.
2. Uniformity of geological processes: The present is the key to the past. The application of this means we do not invent unique processes if modern processes can explain the observations. But this is only partly valid; it is now known that in some ways the geological past was very different from what we observe today.
3. Uniformity of rates of processes: Geological processes have always been slow and gradual. There have not been any catastrophic geological events. This is now known to be false.
4. Uniformity of conditions: Conditions on earth have always been the same, cycling endlessly with no direction. This is not true. Conditions in the Cambrian, for example, were quite different from conditions today. For example, our existing continents were largely covered with shallow seas during the Cambrian. Also the fossils in different parts of the geological column are not the same.

of the Cenozoic fossil record, probably formed after the global catastrophe, includes evolutionary sequences of organisms within the individual created groups. Short-age geology interpretations of the four aspects of uniformitarianism (table 14.1) will be similar to those given above. Whether the basic structure of the earth and the lower portions of the geological column (e.g., the Precambrian) had a recent origin or formed over billions of years is a separate question outside of our present discussion. Here we will discuss short-age geology as it pertains only to the Phanerozoic part of the geological column.

Can Short-Age Geology Theories Be Tested?

The short-age geologist proposes that, at some time in the past, a disturbance in the earth's crust temporarily disrupted the normal relationships between land and water bodies, initiating a period of rapid geologic activity on a global scale. This period of rapid erosion and sedimentation produced a significant but unknown portion of the geological column. The geological and geophysical processes occurring during that event determined the characteristics of the rocks formed at that time and the distribution of fossils in the rocks. They influenced the distribution and character of radioactive elements in those minerals used in radiometric dating.

A short-age geology theory expressed in this form is a simple descriptive statement. It says nothing about the untestable question of whether God was involved in initiating this geologic event. It does not attempt to explain any process or event that may have operated outside the known laws of geology, chemistry, or physics. This descriptive theory can be used as a basis for defining specific hypotheses concerning the sedimentary processes and the amount of time involved in depositing individual formations or in shaping the earth's landforms. These hypotheses can be tested in the same way that any geologist tests hypotheses.

Two geologists could be doing research on the same rock formation, perhaps one of the Paleozoic formations in the Grand Canyon. One geologist believes that the formation must have taken a long time—thousands or millions of years—to be deposited. The other geologist believes the formation was deposited far more quickly. They will probably ask different questions (as discussed in chapter 5), but they both look for the same general types of data as they study the rocks. Each must analyze their own data, as well as other published data, and interpret their meaning. When they disagree, each geologist analyzes the other's work and their own work and tries to determine what additional data are needed to clarify the issue. If each is doing good work, the findings will be published in a scientific journal so others can benefit from it. In time, as more data accumulate, more conflicts will be resolved and the total body of data will favor a single explanation. It will point to rapid deposition, very slow deposition, or something in between.

If we are completely fair with the data, eventually the data will tell us which theory is true unless our inability to go back in time and directly observe what happened limits the data too much. All geologists will use the same observational and experimental procedures in their research. There will be differences in the questions each group asks and in what they are likely to notice. We will come back to that later. But one primary difference in the research approach of short-age geologists and other geologists is what they predict the eventual outcome will be: The short-age geologist is confident that when "the data are all in," they will indicate that much of the geologic column was deposited in a short time. A conventional geologist is more likely to have confidence that the data eventually will indicate that the entire geologic column was deposited very slowly or in rapid spurts with long periods of time between. Many would say the data already are conclusive and have disproved the short-age theory. However, the short-age geologist notes with interest the definite trend toward catastrophism in geology that began a few decades ago.[4]

Nevertheless, a number of lines of evidence challenge the short-age theory. Discrepancies between a theory and the available data can arise in at least two different ways: either (1) the theory is wrong or (2) important discoveries are waiting for the diligent researchers who use the theory to guide their research. Interventionists/short-age geologists recognize that if their theory is true, significant phenomena have yet to be discovered. Does interventionism stifle research, as some have suggested? If interventionism is understood correctly and if its predictions of new phenomena waiting to be discovered are taken seriously, it can be a stimulus for vigorous new approaches to research. We will explain why we believe the scientist who uses the Bible as a source of ideas for developing hypotheses should be able to operate as a successful researcher and even have an advantage in generating successful hypotheses.

We will now review the basic concepts of physical and historical geology and make initial comparisons of how the two theories deal with this evidence. The following two chapters will examine these differences in more detail.

Rock Types and Processes for Their Formation and Weathering

Different geological processes produce different types of rocks. Each rock type is composed of a particular combination of minerals, such as quartz, calcite, or feldspar. Table 14.2 presents the principle categories into which rocks are classified. This basic descriptive information is not specific to any one theory, but forms a part of the foundation for any geological theory.

While the processes described in table 14.2 are occurring, another significant process, called weathering, is altering the rocks. Ground water and weak acids seep through the rocks, gradually breaking them down by chemical action. The minerals are changed into (1) clay; (2) dissolved chemical ions including sodium, potassium, and calcium; and (3) quartz and other sand-sized grains. The dissolved ions and clay are carried in streams and rivers to lakes and oceans, where the clay settles to the bottom in the quiet water and the ions determine the water chemistry in these water bodies. The sand grains may be transported by water and/or wind and accumulate to form sandstone formations.

Rate of Sediment Accumulation and Erosion

The average thickness of the sediments on all the continents is approximately 1,500 meters, but in some places it is much thicker. How long does it take to deposit such sediments? The answer depends on our theory of geological history. Some may answer that radiometric dating provides an accurate, unambiguous answer. Radiometric dating is considered in the next chapter, along with other geological evidence that challenge the time scale based on radiometric dates. For now, we will consider factors that can have a great influence on rate of sediment movement.

In the hills behind my (Brand) home, there is a small, precipitous canyon cut into a hillside (fig. 14.2). To estimate how long it took to erode the canyon, I made some

Table 14.2. Types of rocks

Igneous rocks	Form as molten magma cools to form rock. Examples: **granite** and **basalt** (volcanic lava). A mass of granitic rock forms some mountains and underlies each continent. Fossil content: uncommon in igneous rocks, since hot magma would normally destroy any organisms. Exceptions occur when lava or volcanic ash surround an organism and preserve it.
Sedimentary rocks	Form by a four-step process. Older rocks erode—break down to form sediments, such as sand, mud, or pebbles. Water or wind transports the sediment to basins where it is deposited in layers (fig. 14.1). If conditions are right, the deposited sediment will become cemented or compacted into sedimentary rock. Rivers carry sediment until they slow down enough for the sediment to settle out of the water and form layers. The four steps in making sedimentary rock are erosion, transport, deposition, and cementation or compaction into solid rock. Fossil content: animals or plants are often buried in the sedimentary layers, and the majority of fossils are found in sedimentary rocks. Even volcanic ash, which has an igneous origin, often is deposited as sedimentary layers. These layers of ash are effective agents for preserving fossils. Representative types of sedimentary rocks are classified by the size of the grains or particles that compose them: **shale and siltstone**—very small grains; **sandstone**—larger, sand-sized particles; **conglomerate**—a mixture of fine particles (sand or mud) and larger rounded pebbles (rounded by transport in flowing water); **breccia**—mixture containing angular (not rounded by water transport) pebbles or rocks; **limestone**—principally calcium carbonate, in the form of the mineral calcite ($CaCO_3$) precipitated out of ocean water or alkaline rivers, streams, or lakes. Some limestones are an accumulation of the calcium carbonate shells or skeletons of organisms such as corals or molluscs.
Metamorphic rocks	Form when rocks are subjected to sufficient heat and/or pressure (perhaps by burial under additional rocks) and chemical changes to alter them into a different type of rock. These altered rocks are called metamorphic rocks. Fossil content: any fossils are generally destroyed in the process of metamorphism.

measurements. It is thirty-five meters long, an average of ten meters wide, and eight meters deep. That means that about 98,000 cubic feet (2,882 m^3) of sediment was eroded in the formation of the canyon (data). Present erosion rate is quite low, perhaps two cubic feet (0.06 m^3) per year. If that is correct, it took roughly thirty thousand to forty-nine thousand years to carve the canyon (interpretation). There is one small problem with that calculation. For some years, I have walked a path past the head of that canyon several times a week. The canyon did not exist at all seven years ago; it was a smooth hillside with almost no depression at the site of the existing canyon (data).

The canyon was entirely eroded in one rainy season, influenced by two factors. Developers made a new dirt road for about one hundred yards along the side of the hill and didn't provide proper drainage control. This channeled water down the road and over the side of the hill where the canyon now is. This was followed by a year with more than average rain, and the canyon was cut within a maximum of two to three weeks of actual storm activity (data). Since then, the water flow and erosion has reached a new equilibrium, and the canyon has not noticeably changed.

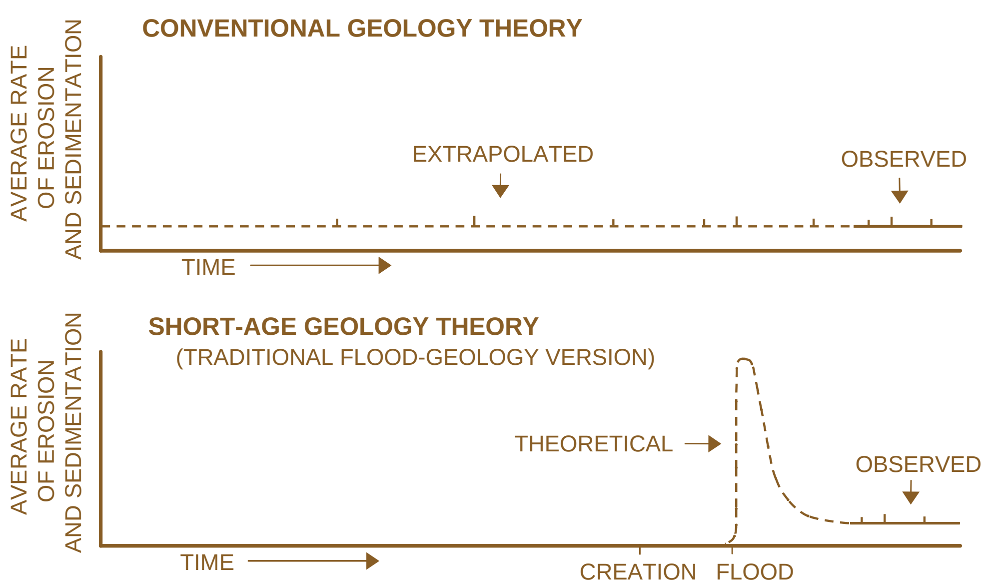
My estimate of the length of time to carve the canyon was incorrect because it was based on the assumption of a constant rate of erosion. From this example, we can derive a simple principle: little water, much time and much water, little time. Thus if a flood of water on a global scale caused much of the erosion and subsequent deposition

Figure 14.2. A canyon that formed in one rainy season after a short new road changed the drainage pattern. Figure by Leonard Brand.

of sedimentary rock, it could have formed much more quickly than what we have observed in modern geological processes (interpretation). This is obviously an oversimplification of the complex geological principles involved in shaping our earth. It should not be applied uncritically, but it is one way to begin defining the difference between the two theories of geological history (fig. 14.3).

We have observed the earth's geological processes for only a short time—represented by the solid line in figure 14.3. Conventional theory assumes this line approximately extrapolates into the past. Variations in the rate of sedimentation and catastrophic events have happened along the way; but over the long haul, the average rate has been about the same. However, short-age geology draws a very different conclusion. This theory concludes that in the not-too-distant past, the relative stability of the earth's structure was disrupted, causing a great deal of rapid geological activity over a short time—indicated in the theoretical curve (fig. 14.3). This activity did not stop suddenly. It gradually slowed to the rate of change observed on the earth today. A transition of perhaps a few hundred or a thousand years probably occurred while the earth was gradually returning to a stable condition.

Figure 14.3. A major difference between the two geological theories is in the magnitude of water action on the earth in the past (average rate of erosion and sedimentation) and the resulting amount of time involved in shaping the geological structure of the earth. Figure by Leonard Brand.



Geological study of the earth, as we know it, has been done since that time.

The processes of rock formation are the same, in many ways, in both of these theories (estimate of the data), but the amount of time for the formation of the Phanerozoic rocks, according to the conventional theory (little water, much time), was 541 million years. In short-age geology theory (much water, little time), it was only thousands of years, and in the traditional flood model, a significant amount of the geologic record accumulated in one year. These time differences (interpretations) must imply significant differences in geological processes. In coming chapters, we will discuss what differences are implied by geological data.

Modern Depositional Environments

If we look around us today, we can identify environments where sediments are being deposited. These will be in low areas, or basins, into which water and to a lesser extent wind carries sediment. In the San Bernardino Mountains, a stream runs between the mountain ridges, flowing down the slope to the nearly level valley at the base of the mountains. Smaller streams high in the mountains erode sediment and carry it into the larger stream. As it travels down the network of streams, some is deposited on the stream bottom and some continues downstream.

The mountain valley with the fast-flowing stream has a deep deposit of large boulders high up in the mountains (fig. 14.4A). These are mixed with smaller pebbles and sand, but predominantly, there are boulders up to six feet (2 m) in diameter. Farther down the mountain, where the stream slope is not so steep, the stream bed is composed of smaller rocks, up to a foot (0.3 m) in diameter (fig. 14.4B). Several streams join to form a river, and below the mountain, the river flows through a gently sloping valley. The riverbed here has no boulders, but primarily sand (fig. 14.4C). As you can see, the largest sediment particles or clasts (clast = any size of rock particles) in the stream or

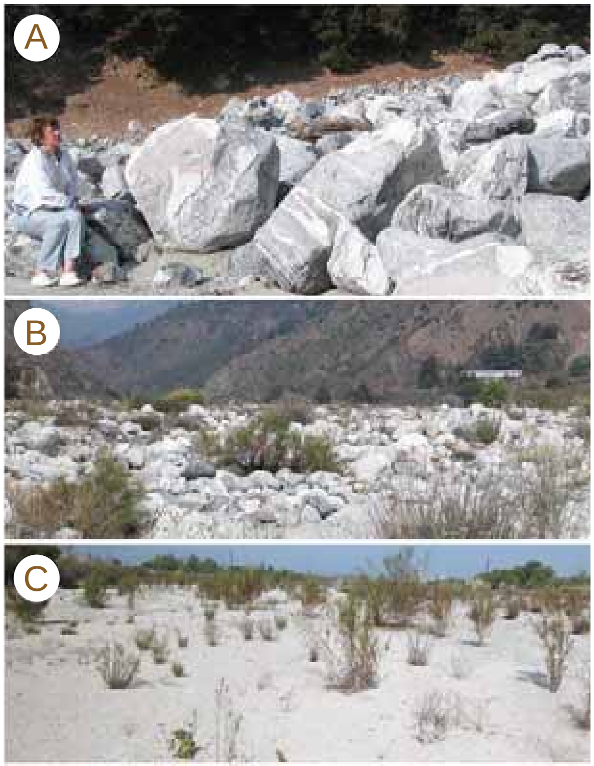


Figure 14.4. Sediment accumulations along the length of a mountain stream, showing (A) boulders high in the mountains where stream energy is sometimes very high, (B) smaller rocks farther downstream where the ground slope and resulting water energy are lower, and (C) sand deposit on the plain below the mountains. Figure by Leonard Brand.

river bed are smaller as we go downstream. This is because the size of clasts that can be carried by water depends on how fast the water is flowing. In fact, when the speed of the water doubles, the size of clasts that it can carry at least triples.[5]

Fast-flowing water is called a high-energy environment by geologists. Up in the high mountain valley, there are sometimes spring flash floods with sufficient energy to carry huge boulders down the stream. As the slope gets less steep, the water flow rate and energy decreases until it cannot carry such large boulders, so they remain in the streambed. There is still sufficient energy to carry cobbles (rocks smaller than boulders) a few inches to a foot in diameter farther downstream, but when the river enters the valley, its energy level (flow rate) is no longer high enough to carry even these cobbles, and the last rocks stop moving. The water is then only carrying sand and smaller particles, and the sand is being transported by the water or is being deposited, depending on the water speed at that point.

When flowing water is transporting and depositing sand, it makes ripples in the new sand deposits and the size and type of ripples varies according to the size of sand particles, water depth, and water flow rate (fig. 14.5).[6] Ripples made in a steady current are also different from ripples made by waves. Waves that oscillate back and forth make symmetrical wave ripples—the crest is in the middle of the ripple. Flowing water makes current ripples, which are asymmetrical—the crest of the wave is at

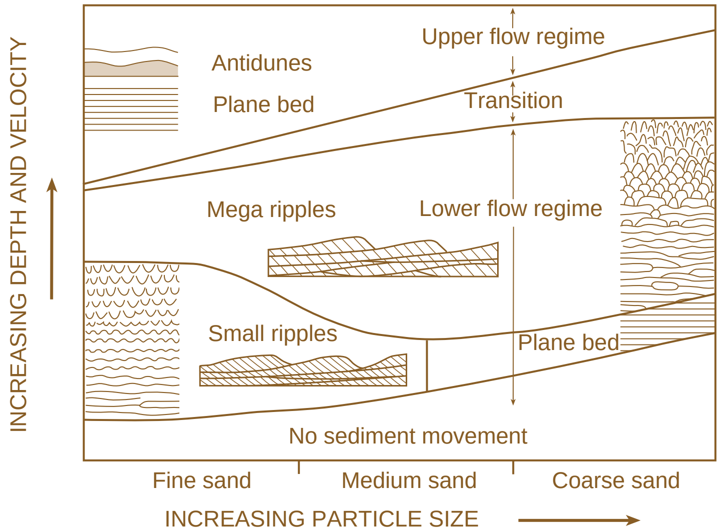


Figure 14.5. Summary of the relationship among sediment texture (grain size), sedimentary structures (ripples and other patterns that form in the layers of sediment—shown here in cross-section), and the depth and velocity of water flow that will produce those features (after Reineck and Singh 1980). Figure by Carole Stanton.

the down-current edge of the ripple, giving that side of the ripple a steep slope compared to the gentle slope of the up-current side.

Something else is happening to the boulders and rocks as they move downstream. When rocks and boulders initially fall into the stream, they are irregular in shape and are angular with sharp corners. As they are carried along by flash floods, they scrape against each other, breaking off pieces from the sharp corners, and in this way, the corners are rounded. High in the mountains (fig. 14.4A), some of the boulders have come about five miles (8 km) and are well rounded, but some have apparently come only one or two miles (1.7–3.3 km) and are only partially rounded. If rocks and boulders are carried by a landslide instead of by flowing water, they do not get sorted or rounded. A deposit of these angular rocks in a matrix of sand or mud is called breccia.

Rivers and streams are generally flowing fast enough to keep most of the silt and clay in suspension. But after the river flows into a lake, the water now has only very low energy, and the silt and clay are deposited in these low-energy environments. Geologists call the low-energy environment of a lake a *lacustrine* environment, and the higher-energy environments of flowing water (rivers,

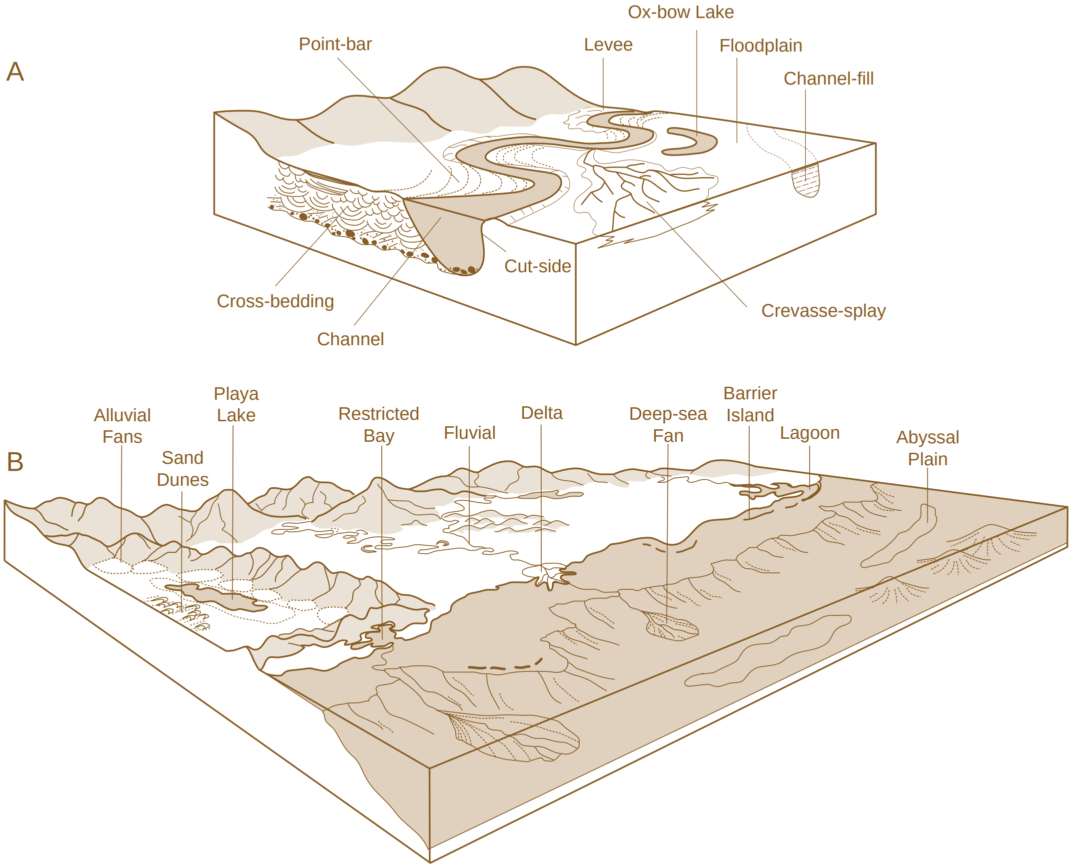


Figure 14.6. (A) Details of depositional environments involving fluvial processes—flowing water in rivers, streams, and floodplains. (B) Continental and marine depositional environments (after Hamblin and Christiansen 1995). Figure by Carole Stanton.

streams, etc.) are called *fluvial* environments. Some common depositional environments are *deltaic* (formed by river deltas), *eolian* (wind-blown sand), *submarine shelf* (deposits in shallow ocean water on the continental shelf), and *deep marine* (fig. 14.6).[7]

The types of minerals found in sediments may be important indicators of the depositional environment. For example, sediment containing calcite was deposited in a marine or alkaline lake or stream environment. Dolomite is similar to limestone but forms when magnesium is available in the water.

The types of fossils in the rock tell much about the depositional environment as long as we are very careful in interpreting the data. Rock containing marine fossils suggests that the sediment was deposited in the ocean, and an interpretation of the original environment can be constructed (fig. 14.7). Fossils of terrestrial mammals

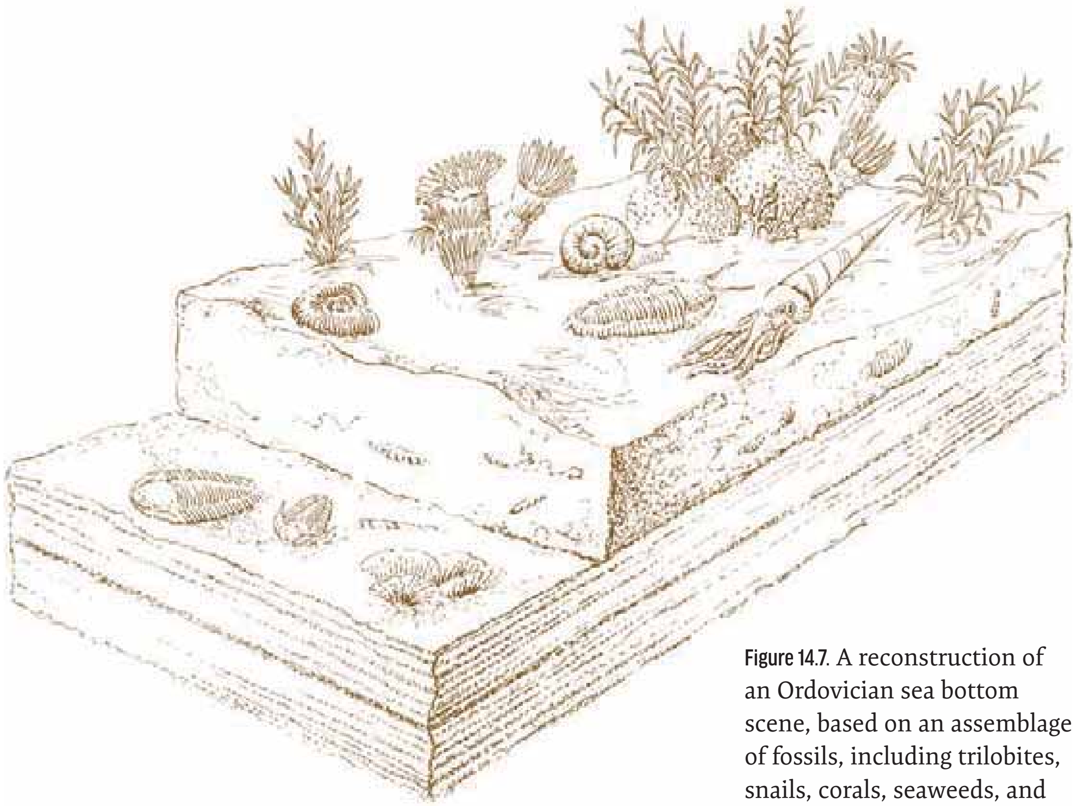


Figure 14.7. A reconstruction of an Ordovician sea bottom scene, based on an assemblage of fossils, including trilobites, snails, corals, seaweeds, and straight-shelled nautiloid cephalopods (after Moore 1958). Figure by Robert Knabenbauer.

Interpretations of paleoenvironments

DATA

Size of clasts carried or deposited depends on energy level (speed of water flow). Distance of movement determines rounding of clasts. Type of ripples is determined by particle size, water depth, and water flow rate.

INTERPRETATION

Both worldviews use the above data in similar ways to infer a paleoenvironment.

Conventional science: Naturalistic assumption exerts a strong bias toward paleoenvironments that are like modern analogues.

Interventionism: More open to possibility that depositional processes may have been more catastrophic and with a larger geographic scale than modern analogues.

suggest that the rock was formed in an environment such as a streambed, a lake (animals could be washed into the lake or even into the ocean), or a floodplain. However, we would need additional evidence, including some detailed characteristics of the sediments and the fossil assemblage, to provide clues to the exact environment.

Three Examples of the Interpretation of Ancient Depositional Environments

Examples of rock formations in the western United States illustrate the process of interpreting depositional environments. Now that we have learned, from the modern analogues discussed above, about high- and low-energy environments and things like rounding and sorting, we can look at some sedimentary rocks and attempt to identify the ancient sedimentary environments (paleoenvironments) in which they were deposited. Features like particle size, amount of rounding, and ripple type can serve as *criteria* to identify various paleoenvironments.

Anza Borrego

Our first example will be in the desert hills of Anza Borrego Desert State Park in California, where there are beautiful exposures of sedimentary rocks. Some of these are mostly sandstone (fig. 14.8), with a small amount of fine-grained deposits (siltstone or claystone), some small lens-shaped deposits of conglomerate (rounded pebbles in sand), and many asymmetrical ripples. The criteria evident here are sand-sized particles with some larger pebbles, current ripples, and only a small amount of clay or silt. This indicates the sediment was deposited in a fairly high-energy, fluvial environment (with water flowing fast enough to bring in the sand), with some episodes of even higher energy water depositing the lenses of conglomerate and only limited episodes of quieter water to deposit the silt and clay.

One area has finer sand and symmetrical ripples. In what environment was this latter deposit formed? The criteria are small particle size, implying lower energy, and wave ripples, seemingly indicating a lake. They do not occur over a large area, so it was apparently a small, temporary lake or pond among the high-energy streams.

Figure 14.8. Sandstone in Anza Borrego Desert National Monument, with features indicating it was deposited in a relatively high-energy environment of the braided stream type. Figure by Leonard Brand.

There are other fascinating sedimentary features in these Anza Borrego rocks that can serve as environmental criteria. There are layers of sandstone with thin, curved claystone objects in them. This could seem mysterious until we look around in the modern dry desert streambed nearby and find curved clay objects of the same size and shape, which began as layers of clay deposited in low places along the side of the streambed (fig. 14.9A). Winter storms bring small floods down these streams, and as the water flow subsides, clay is deposited in standing water in low places. When the water evaporates, mudcracks (or desiccation cracks; fig. 14.9C) form in the drying clay, and further drying causes the thin clay layer to curl up into mud curls. After this happens, the next storm that sends a stream of water flowing through may pick up the mud curls and deposit them in sand before they have time to soften and break up. This seems to be what we saw in the rock—fossil mud curls (fig. 14.9B). These are another type of criterion, and they indicate that the sedimentary rock formed in an environment with plenty of flowing water, but sometimes alternating with episodes of drying and mud curl formation. To make the picture complete, the fossil mud curls are not far from clay layers with fossil mudcracks (fig. 14.9D) and fossil bird tracks.

It is not always so easy to identify paleoenvironments because environments and their criteria can be quite complex, sometimes with criteria that overlap in different environments and also because we do not always have modern environments (modern analogues) that match the characteristics of the ancient sedimentary rocks. There often is debate about the correct

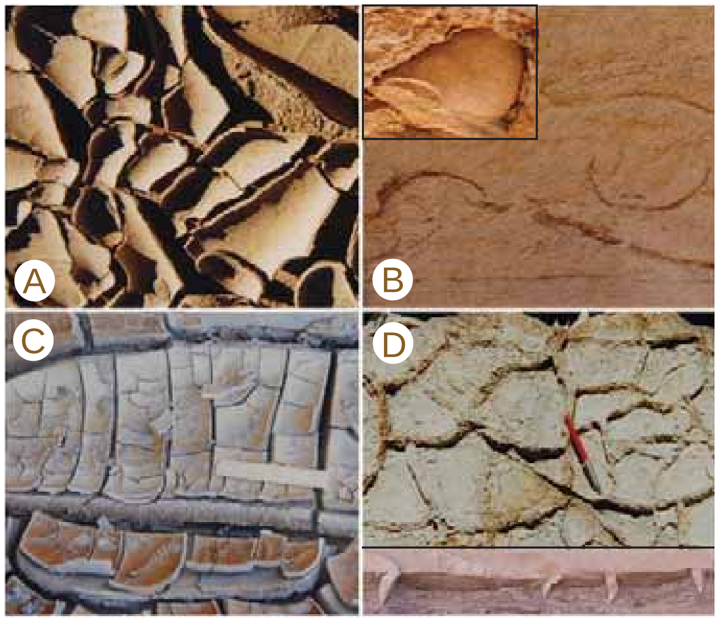


Figure 14.9. Photos of (A) modern mud curls, (B) fossil mud curls (cross-section, and surface view in inset), (C) modern mudcracks (desiccation cracks), and (D) fossil mudcracks (top: bottom surface of sand that filled the cracks; bottom: cross-section of sand-filled cracks in shale). Figure by Leonard Brand.

paleoenvironmental interpretation. Reliability of these interpretations of paleoenvironments can be improved if the geologist is able to study the overall physical layout of the sediment features on a large scale. For example, it would be much easier to identify sand bars in a river when viewing the river from a nearby mountainside than by close examination of the internal structures of various sand deposits. This type of large-scale study of rocks generally requires techniques, like seismic surveys, that can determine the underground structure of the sedimentary rocks.

A conventional geologist tries to determine what modern sedimentary environment (fig. 14.6) is the most likely interpretation of an ancient sedimentary deposit by comparison with modern analogues. A short-age geologist reaches many of the same general conclusions. Even during a global catastrophe, many of the same processes would still occur. No doubt fluvial processes (fig. 14.6A) would occur in some areas, and deep-water and shallow-water marine deposition (fig. 14.6B) would be elsewhere. The short-age geologist expects that these processes in the geological record must have occurred at faster rates and on a larger geographic scale than is observed in most modern analogues, with little or no time between episodes of sedimentation.

Green River Formation

Now we will go farther north to the Green River Formation (GRF) for a second example of an ancient environment and its interpretation. The GRF covers large areas in Wyoming, Utah, and Colorado and contains millions of fossil fish in association with a few terrestrial vertebrates, including a small Eocene horse,[8] large turtles, crocodiles, and others. The fossils occur in very extensive sequences of thin layers of shale. In what environment was the GRF deposited? This example illustrates one problem that complicates the interpretation of depositional environments and paleoecology. Probably most fossils (especially vertebrates) were not buried where they lived. They were transported by water and then buried. If organisms from different environments got mixed together while being transported, as has often happened, the result can be a confusing picture to interpret. In the case of the fish and horse, it is helpful to ask whether it is more likely for a small horse to be washed into a lake or for millions of fish to be washed onto the prairie. The type of sediment containing the fossils also provides important clues to the environment.

The geographical distribution of the Green River sediments, the types of sediment, the kinds of fossil fish, and the mineralogy of the sediments indicate that the area was once a series of large lakes. At times, fresh water filled the lake, and at other times, salt water or even hypersaline (higher salt content than the ocean) lakes occurred.[9] Areas that would have been the middle of the lake reveal large fossil fish; baby fossil fish are found along the ancient lake shoreline along with fossil cattails, insects, and other organisms that would be expected to live along the shore.[10] Some areas have evidence of rivers flowing into the lake. Thus many indications show that it was a lake with the animals living in normal ecological relationships. That is how most geologists would interpret it. And since this deposit is in the Eocene, the upper part of the geological column, a short-age geologist is likely to conclude that this was a lake that existed during the time after the global catastrophe. He would predict that when we understand all the evidence, it would indicate that the lake was filled in to form the GRF in a much shorter time frame than usually is believed. The excellent preservation of most fossils in the GRF is consistent with this interpretation.

Shinarump Conglomerate

The third example is the Shinarump Conglomerate, a deposit that averages about fifty feet thick and covers more than one hundred thousand square miles in Utah and neighboring states, an area called the Colorado Plateau. This formation is composed of sand and rounded pebbles like those found in streambeds. The usual interpretation suggests that a network of braided streams flowed over this area for a very long period of time. The streambeds of a braided system frequently change. Some think that as the streams migrated, they gradually covered the entire area with stream deposits.[11] A short-age geologist compares this deposit to modern analogues and is sensitive to indications that it may not match a modern depositional environment. For example, is there any place in the world today where streams are depositing sand and conglomerate like this over a huge area (100,000 mi^2) with such a uniform thickness and composition? Not that we know of. Streams make deposits that wander through a valley, leaving a mosaic of sand and mud deposits, but they do not create uniform deposits over thousands of square miles. Explaining this as a catastrophic event over a large area in a fairly short time seems more realistic.

Overall Pattern of Depositional Environments

Short-age geology theory suggests that much sediment was deposited underwater. A series of maps presents an interpretation of how much of North America was under water at successive geological periods (fig. 14.10).[12] These scientists do not interpret the maps as pointing to a global flood, but the evidence reveals an interesting picture. These maps were made by examining the sediments for evidence that would indicate if they were deposited under water or in some other depositional environment.

In the Cambrian, virtually all of North America, except a few areas in eastern Canada, shows evidence that it was underwater. Eastern Canada is known as the Canadian Shield. It has almost no sediments younger than the Precambrian. Consequently, on all of these maps, the presence or absence of water over that area is a guess. The Cambrian evidence is consistent with the possibility

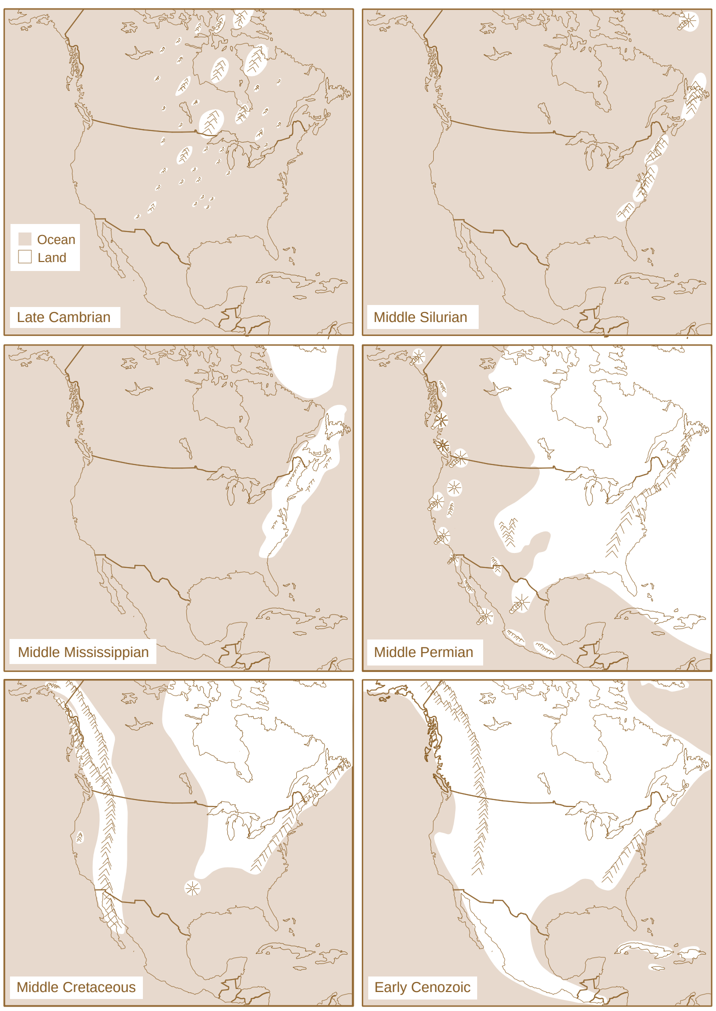


Figure 14.10. Maps of North America during successive geologic periods (showing approximately every other period). Shaded areas have been interpreted as being under water at the time those sediments were deposited (after Dott and Prothero 1994). Paleoenvironmental interpretation of eastern Canada (the Canadian Shield) is very speculative, since it has almost no post-Precambrian sediment. Figure by Leonard Brand.

that much or all of North America was under water. The maps show successive stages through the geologic column from the older rocks to the most recent. As time passed, the amount of land covered by water seems to have fluctuated.

In the Late Jurassic and Cretaceous, the water again covered a larger area. During the Cenozoic, evidence of terrestrial environments increases, indicating that the oceans had receded and more of North America appeared to be above water—more like the continent as we know it. However, even these sediments and their terrestrial fossils were almost all deposited by water. During the Pleistocene, a lot of water was locked up in ice, and therefore, ocean levels were lower with more land than now appears.

The evidence indicates that the earth (insofar as North America is representative of the rest of the planet) was covered largely by water sometime in the past. Is this proof of a global flood? While it seems to fit what a short-age theory would predict, we must avoid that word "proof." Other theories of earth history also can account for these data, but it is fair to say that geologists of different philosophical backgrounds agree that much larger areas of our continents were covered with water at times in the past.

Interpreting what parts of continents were under water

DATA

Fossil and sediment features in the rocks.

INTERPRETATION

Process of inferring how much area was underwater will be similar in both worldviews.

Conventional science: If continents were underwater, interpret this as a long-term noncatastrophic situation, such as epicontinental seas.

Interventionism: Interpret areas of significant water cover as part of short-term global catastrophe or postcatastrophe adjustment process.

Accumulation of Sedimentary Deposits

In one year, a river may deposit new sand in one area, and the next year erode it away and deposit sand in another part of the valley. Through the years, the sediment gets repeatedly moved around, eroded, and redeposited, but over time, there is no net accumulation of new layers of sand one above another. This is typical of modern geological processes above sea level. What does it take to deposit the vertical succession of rock formations that we see in the geological record without the sediment being eroded away again?

If the earth's crust under that river valley began to slowly sink, forming a deepening basin, the sediment carried by the river could accumulate layer after layer in the new basin (fig. 14.11). This is what is required for a significant accumulation of sediment. There must be an adequate source of new sediment from erosion of other rocks, sufficient water flow to transport the sediment, and a deepening basin to store it in. The basin can be as small as a little river valley or as big as an ocean, but as it fills, it must keep sinking so it can continue to accumulate more layers of sediment. A short-age geology theory must incorporate this concept, and the basins will need to sink a lot faster than most geologists think they do.

Mountain Building

New sediments are normally deposited in horizontal layers. However, the layers do not always stay that way. Mountains rise up, tilting and folding the layers of sediment.

Several processes can produce mountains (fig. 14.12):

- Folded mountains arise by compressional forces in the earth that uplift and fold sediments into permanent wavelike structures.
- Fault-block mountains form when a section or block of the earth's crust moves up or down along a fault.

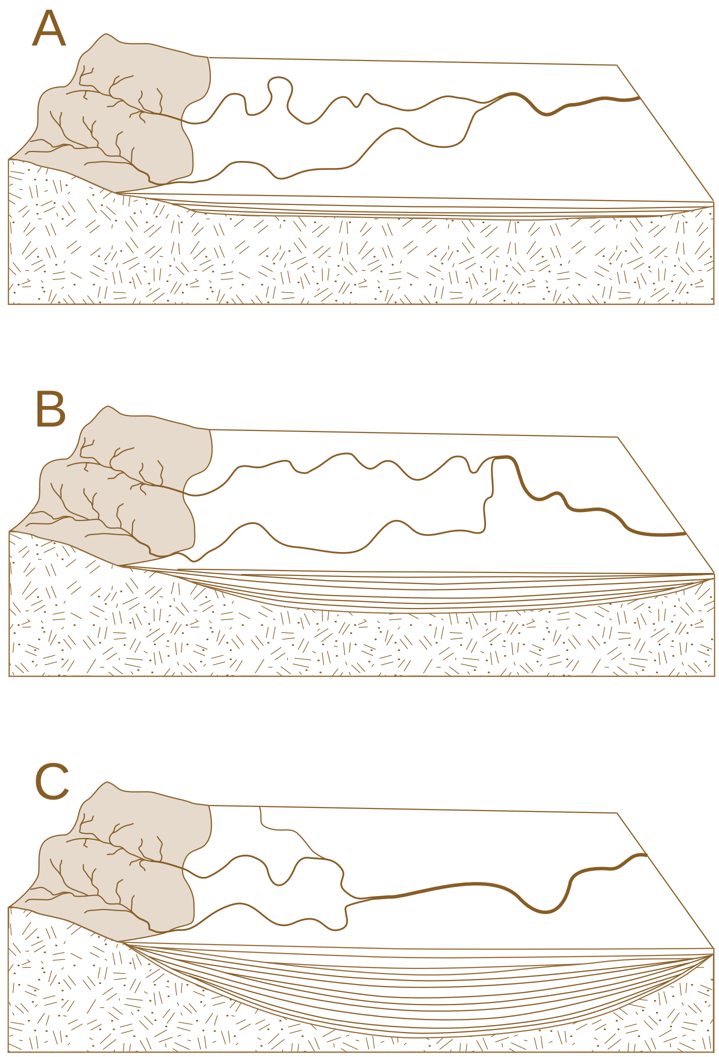


Figure 14.11. Diagram illustrating the sinking of geologic basin as sedimentary layers accumulate in the basin, from time A to time C (Brand 2006a).

- Erosional remnants are mountains that remain when parts of a thick sequence of sediments have been eroded, leaving the uneroded areas as mountains.
- Volcanoes form mountains composed of the magma that comes up through breaks in the earth's crust as lava flows or as volcanic ash blows up into the air and drops down to form a volcanic cone.
- Intrusions of magma into or through the sediment occur in different ways. If the magma simply pushes up between sedimentary rock layers and does not break through the surface, it produces a blister-like

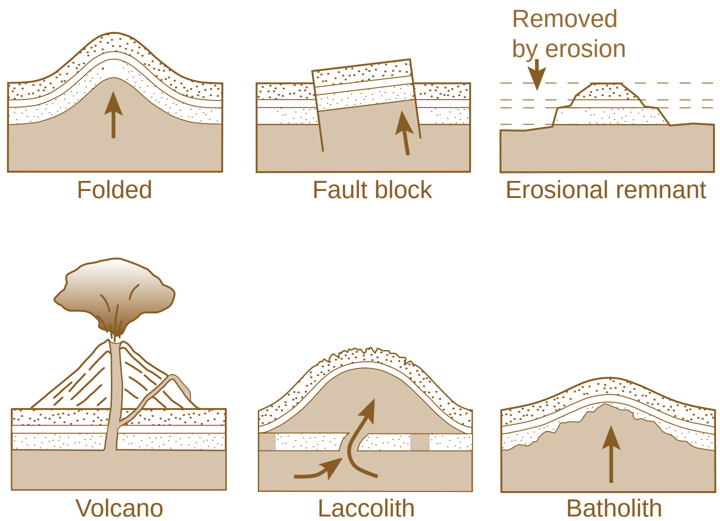


Figure 14.12. Cross-sections through several types of mountains. Figure by Carole Stanton.

> intrusion called a laccolith. A batholith is an intruded rock mass that has pushed up everything above it to form a mountain.

In reality, mountains are often a combination of these processes. For example, the Sierra Nevada Mountains in California are composed of a number of batholiths that have shifted upward along a fault on the eastern side of the range.

How does a short-age theory relate to these processes? The different types of mountains are geological realities supported by abundant evidence. There certainly is room for differing opinions on details, but any geological theory must incorporate these basic processes and mountain-building events into its structure. In a short-age theory, the rate of mountain formation will have to be much faster than in conventional geology.

Cross-cutting relationships refer to a case where one layer or structure cuts across another, such as an igneous intrusion that cuts through preexisting layers. The layers had to be present in order for the intrusion to cross them. Such structural relationships may indicate at what point in a sequence of geologic events a mountain arose (fig. 14.13). This is not the same as determining the absolute age

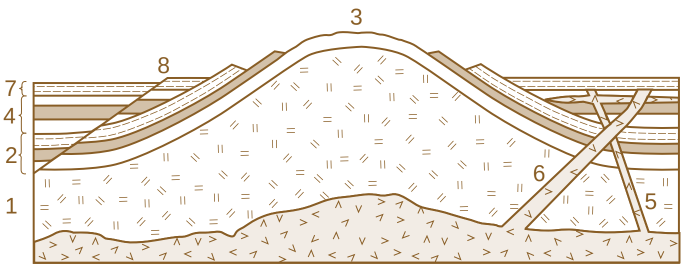


Figure 14.13. Cross-cutting relationships illustrating how a sequence of geological events can be determined. (1) A granite base was present, and then (2) several sedimentary layers were deposited on the level granite base before (3) an uplift raised the granite and sediments to form a mountain. Subsequent sediments formed after the uplift are horizontal. (4) Three of these new sedimentary layers formed and then (5) were cut by a dike of molten rock. (6) Another dike then cut across the sediments and the first dike. Then (7) more sediment was deposited, and (8) all the sediments shifted along a fault. Figure by Carole Stanton.

of the mountain in years. That is another question. Cross-cutting relationships indicate the relative age of different structures: in this case, which rocks were there before the mountain appeared and which rocks were formed after the mountain arose. These relative ages of rocks in any one area indicate a sequence of events that any theory of geology must explain. Short-age theory recognizes this sequence of events but disagrees on how long ago and how fast these events occurred.

Erosion and Landscape Development

During and after the uplift of mountains, water flows down the mountains and erodes valleys and canyons and shapes the mountain into a relatively stable structure. Water always goes downhill; even a catastrophic flood will not change these laws of nature. Water erosion carves characteristic stream drainage patterns into the landscape as the water finds its way downslope, eventually to the ocean. How this occurred and how long it required depend on the nature of the mountain-building process, how fast it happened, and how much water was available to do the job. If the erosion results only from rainwater falling at normal rates as a mountain rises very slowly over thousands or millions of years, the erosion takes a long time. However, if the mountain quickly rises and/or the amount of flowing water increases suddenly and dramatically, the erosion process can occur rapidly.

In modern times, rapid erosion has been observed or inferred in several situations that illustrate what is required to produce it (fig. 14.2). When Mount St. Helens erupted in 1980, a large volume of volcanic material was blown out and deposited north of the mountain. Water draining out of Spirit Lake flowed across this volcanic ash, eroding it rapidly.

How mountains form

DATA

Geometrical relationships between geological features as pictured in Figure 14.13.

INTERPRETATION

Conventional science: Some of these processes could have happened rapidly, but most were very gradual, and the entire sequence took millions of years.

Interventionism: More open to rapid rates for these processes; the entire sequence occupied a short time.

When erosion occurs on the side of a mountain or through sediment previously uneroded, it continues to cut down through the sediment until it reaches a stable stream profile. High on the slope, the stream valley drops steeply; at lower elevations, it gradually levels off. This stream profile is in equilibrium. Sediment in the stream is being eroded and deposited at about the same rate, resulting in minimal net erosion that occurs only very slowly. Events at Mount St. Helens (as at the recent canyon near my home) illustrate what happens when a stream or river has not reached this equilibrium state.[13] The streams flowing across the new St. Helens sediment rapidly carved canyons one hundred feet deep with typical dendritic drainage patterns. These canyons reached a mature profile very quickly, within a year or much less.

A field near Walla Walla, Washington, has a canyon more than one hundred feet deep that was carved through sediments within a few days when water escaped through a break in an irrigation canal. In eastern Washington, an area called the Channeled Scablands has a crisscrossed system of large canyons up to nine hundred feet deep. They were cut through the very hard Columbia River Basalt in a few days during the Pleistocene ice age when an ice dam broke and released giant floods from glacial Lake Missoula (fig. 14.14).[14]

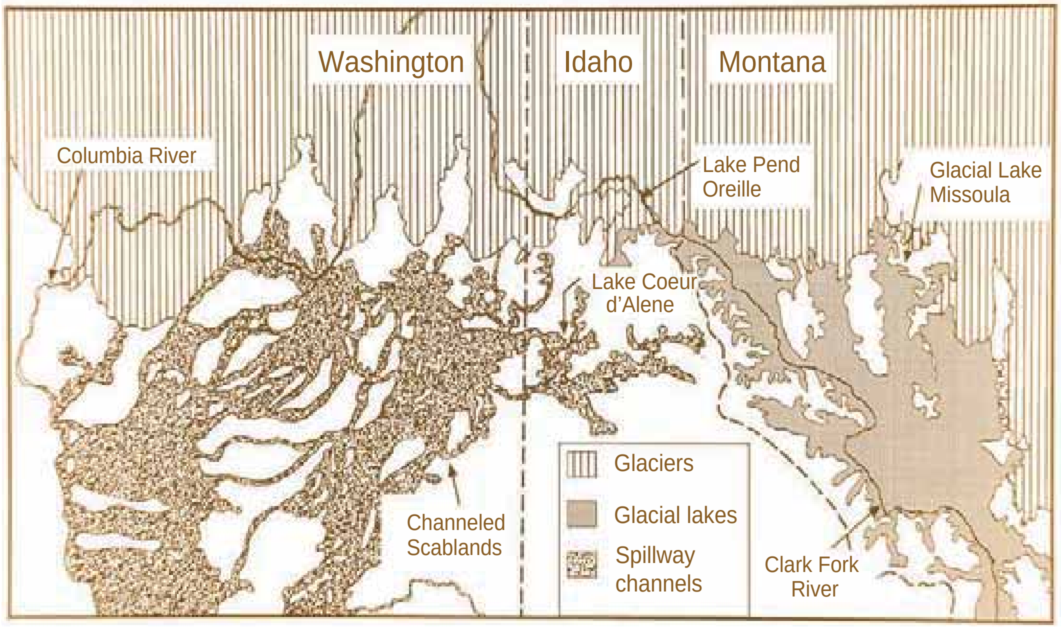


Figure 14.14. Map of Glacial Lake Missoula and the Channeled Scablands, which were carved by the Spokane Flood, initiated by the failure of a glacial dam (after Stearn et al. 1979). Figure by Robert Knabenbauer.

A major river canyon in Iceland three hundred feet (100 m) deep was carved by three extreme flood events caused by volcanic eruptions under a glacier. Each event eroded as much as 1.2 miles (2 km) of canyon through bedrock in a few days.[15]

The processes of erosion that shape the landscape can be observed today and have been an important part of earth history in any theory. A short-age theory differs primarily in suggesting that much of the important erosion that has shaped the earth occurred during a major catastrophe, and during a still somewhat catastrophic adjustment period afterwards. Such an event would be an ideal situation for rapid erosion and landscape development, slowing down as drainage systems came into equilibrium until they reached the generally stable state and relatively slow pace of erosion on the earth today. This mirrors on a larger scale what I observed in the little canyon near my home.

The amount of erosion that has occurred is astonishing. Mountain ranges formed and then were largely or completely eroded away. Some major, existing mountains in North America have experienced heavy erosion. The original Rocky Mountains, before the sedimentary

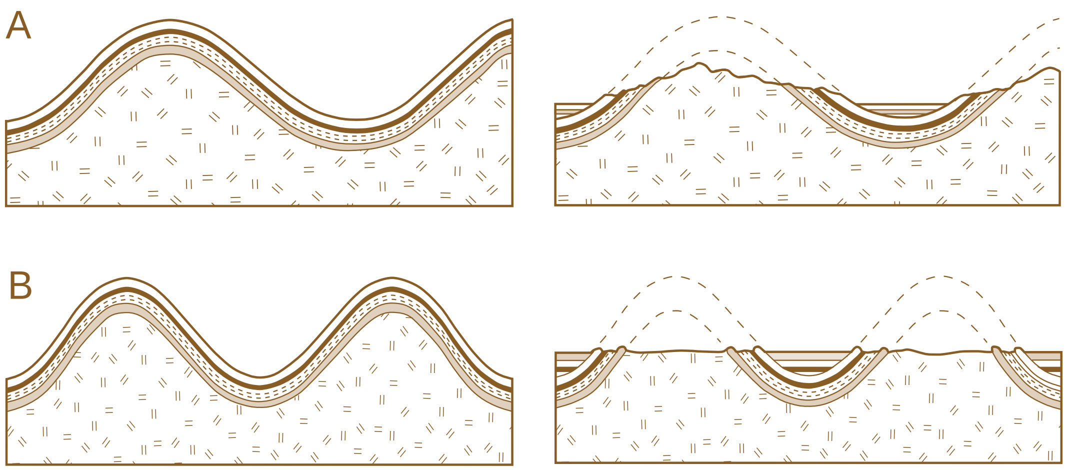


Figure 14.15. Cross-sections through (A) the Rocky Mountains and (B) the Appalachian Mountains, showing the apparent original shape and the current shape of the mountains after erosion. The magnitudes of the original uplifts were approximately equal, but the Appalachians are lower because they are more eroded. Figure by Carole Stanton.

layers were eroded off the mountains and into the valleys, were apparently thirty thousand feet high (fig. 14.15) compared to fourteen-thousand-foot peaks today.[16] The Appalachian Mountains in the eastern United States are no more than five thousand feet high, usually less, but originally they were probably as large as the Rocky Mountains and have been eroded down until all that remains are the roots of the original mountains. The short-age theory proposes that this significant erosion occurred rapidly during times when the sediment was relatively unconsolidated and a large amount of water was available to do the eroding.

How landscapes were formed

DATA

Shapes of landscape features. Observations on erosional events in modern landscapes.

INTERPRETATION

Conventional science: Erosion could be interpreted as occurring rapidly or slowly, but bias is toward very slow and prolonged.

Interventionism: Erosion of landscape features varied from rapid during a catastrophe to slow in the modern world. Simply ask, “Does the evidence favor rapid or slow processes?” Expectation is for most ancient processes to be rapid.

Can This Complex Series of Events Occur Rapidly?

The discussion above proposes that a very complex series of sedimentary deposits was formed, cemented to form rock, uplifted in mountain-building episodes, and eroded to our current landscape—all in a short time. Is this realistic? Figure 14.16 shows a cross-section through a complex set of sedimentary units. How long would it take to form each of the lower horizontal layers and then each of the sloping layers? On top is another series of horizontal layers and a layer of fine mudstone on top of that. Each layer had to be deposited in a manner that allowed it to maintain its identity. How much time is needed after each layer for it to become cemented or compacted before the next layer is deposited?

Some assume that a series of sedimentary events requires a long time. However, the series of deposits shown in figure 14.16 is called the Bouma sequence—the sequence of sedimentary units that is deposited within a few seconds or minutes as a turbidity current passes over a given spot. As the passing current slows down, it deposits the set of sedimentary structures in the Bouma sequence or some portion of that set.[17] A complex deposit is not necessarily an indication of a long passage of time, and the sediment does not become cemented between the deposition of successive layers.

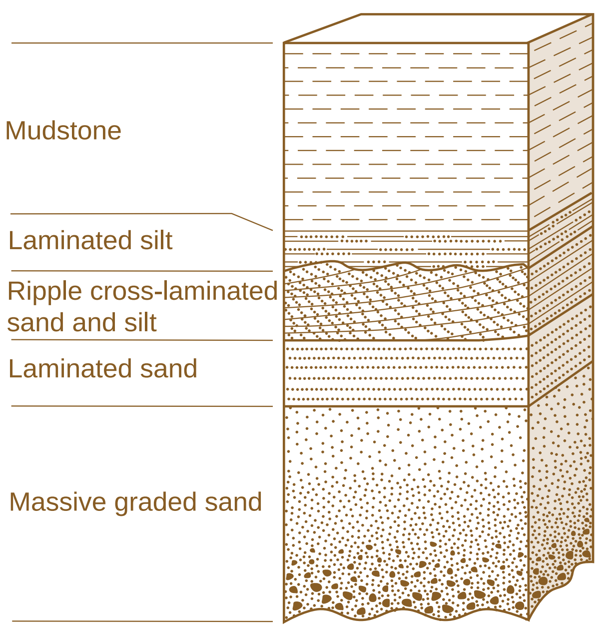


Figure 14.16. A complex sequence of sediments, called a Bouma sequence. Figure by Carole Stanton.

How long does it take for mountains to form? Modern tectonic processes involving small movements along faults would take a very long time. Do we have any hard evidence to indicate that it cannot occur rapidly? Because we experience a stable modern world, we tend to assume geologic processes always took a long time. That assumption may not be justifiable. Today, the overall process of erosion occurs slowly, but it can be extremely rapid in an unstable geologic situation like the eruption of Mount St. Helens and its aftermath. A global catastrophe, of course, would be the ultimate unstable setting that could yield rapid erosion rates and earth movements until a new geological balance is reached.

Could sediments become cemented quickly enough to maintain their integrity during all of this rapid upheaval? More research is needed on this question. Some evidence indicates rapid formation of rocks.[18] Coal has been formed in the laboratory within a year,[19] and granitic crystals can grow within days.[20]

Many unanswered questions remain regarding how fast these large-scale geological processes can occur, especially since we have never witnessed such a catastrophic, global event. Research in recent decades reveals evidence for increasingly catastrophic geologic processes. We predict this trend will continue. The challenge to a short-age theory does not seem to be the overall number and complexity of geological events. However, more specific processes seem to give evidence of requiring time (e.g., deposition of sequences of "tidal cycles," growth of coral reefs and other biological structures in the rocks, recycling of fossils and rocks, chemical weathering, distribution of radioisotopes, etc.). Much more study of such processes and their relation to the geological record is needed. We will come back to this topic.

Glaciation

Another force that has helped shape the landscape is glaciation.[21] Geologists can have more confidence in their understanding of glacial processes than is possible in some other areas of geology. No one has ever seen a mountain arise where none was before except for some volcanoes. Modern mountains are currently rising only centimeters per year. However, in the far north or in high mountain areas, glacial processes and their effects can be observed. One-tenth of the earth is still covered with ice, including Greenland, parts of Antarctica, and large areas in northern mountain ranges. The Antarctic ice sheet is 50 percent larger than the United States. Were glaciers even much more extensive in the past? Was there really an ice age? To answer these questions, let's review the process of glaciation and the evidence glaciers leave behind. We can then look for this evidence in areas supposedly covered by ice during the ice age.

High up in cold mountain ranges, the snow pack accumulates and compacts into ice. When this ice pack is heavy enough, gravity begins to move it slowly down the mountain. As the ice moves, its weight pushes and drags rocks and sediment along with it, cutting and scouring the underlying rock. This unsorted mass of debris accumulates on and in the ice, along the edges of the glacier, and eventually gets deposited along the side of the valley and at the foot of the glacier. The ice continues to move downward and the glacier gets longer until the foot of the glacier reaches an altitude at which the ice is melting as fast as it is moving. It does not get any longer unless the accumulation of snow and its compaction into ice exceeds the rate at which the ice is melting. Table 14.3 lists several of the effects that an active glacier has on the land.

We can look for this same kind of evidence in areas where glaciers do not occur today to evaluate the possibility that glaciers were there in the past. It is not always easy to identify ancient glaciation, since other processes leave some of the same evidence. Deposits of unsorted sediment (resembling glacial till), striated rocks, and grooved and polished bedrock can be produced by such mechanisms as underwater mud or debris flows or impact of extraterrestrial objects.[22] Consequently, multiple lines of evidence are required to confidently identify ancient glaciation. Landforms—the spatial arrangement of glacial features—such as moraines (fig. 14.18) and other features in table 14.3 in relation to a U-shaped mountain valley (as seen in Pleistocene and modern glaciation; fig. 14.17) are the most definitive.

Table 14.3. Evidence left behind by glaciers

U-shaped valleys	When rivers flow through mountain areas, they carve downward and sediment slumps into the river, producing a V-shaped valley (fig. 14.17, left). When a glacier moves down a valley, it scours out the sides, producing a U-shaped valley (fig. 14.17, right).
Cirque basins	At the glacier's point of origin, the ice is continually moving down, away from the high mountain ridge. Snow and ice fill in the gap and freeze in the cracks in the rocks. This cracks the rocks even more, and as the glacier moves, the rocks come loose and fall onto the glacier. This process carves out amphitheater-shaped basins called cirques, which can be seen at the head of a glacier.
Glacial grooves and polish	As the glacier moves down the valley, it carries a large amount of ground-up rock debris and scrapes it against the underlying rock, polishing the rock and cutting grooves oriented along the direction that the glacier is moving.
Moraines	The rock debris and soil eroded by a glacier accumulate on and in the glacier or are pushed along with it. This process does not sort sediment by size of particles or grind off the sharp edges of the rocks as much as flowing water does. This results in an unsorted mixture of fine sediment and angular rocks and pebbles called "till." Till accumulates along the edges of the glacier in ridges called lateral moraines (fig. 14.18), at the foot of the glacier in terminal moraines, and at a medial moraine where two glaciers meet. These ridges of unsorted rock debris arranged in specific spatial patterns on and around a glacier are left behind in that pattern in the mountain valley when the glacier melts.
Erratic boulders	As a glacier moves, rocks and boulders fall onto the glacier and may be carried far away from their source before the glacier leaves them on the surface as it melts. These rocks, called erratic boulders, will be a different rock type from the underlying rock strata.

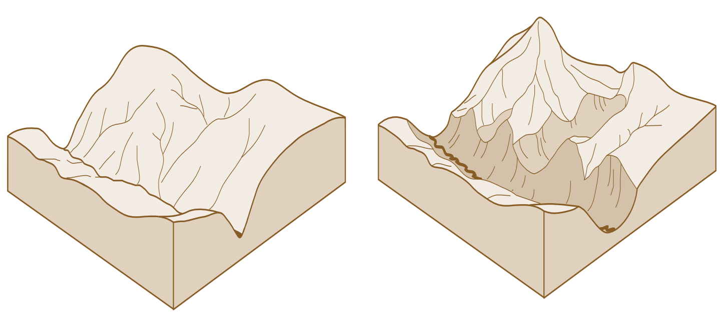


Figure 14.17. Cross-sections illustrating (left) a V-shaped river valley and (right) a U-shaped glacial valley. Figure by Carole Stanton.

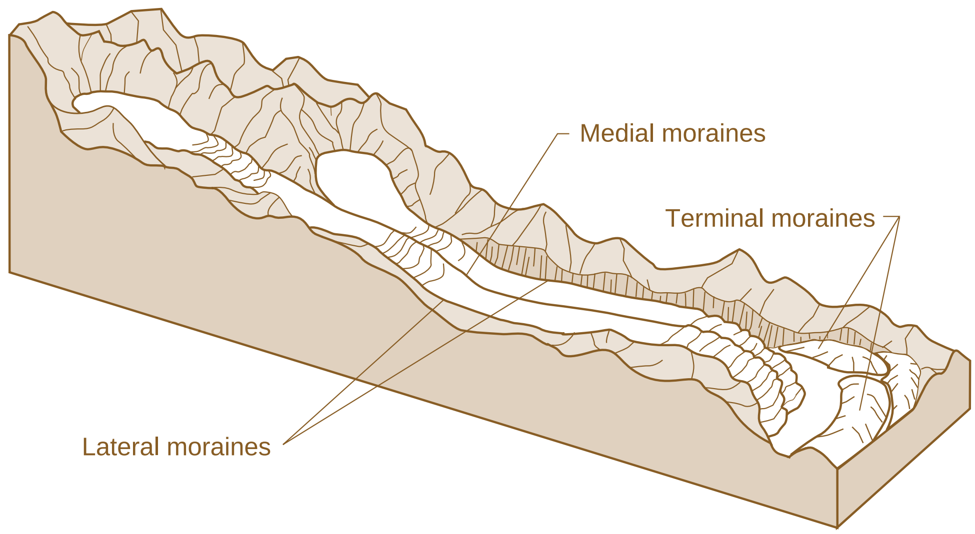


Figure 14.18. The arrangement of moraines in a glaciated valley. Each glacial branch begins in an amphitheater-shaped cirque. Figure by Leonard Brand.

Modern Distribution of Glacial Evidence

During the Pleistocene ice age, the Sierra Nevada Mountain valleys apparently contained large glaciers like those now found in northern Alaska. In the high valleys of the central Sierra Nevadas are cirque basins along the ridges, just like those produced by glaciers. Down the U-shaped valleys from those cirques are polished and grooved rock; farther down are accumulations of sediments that exactly fit the characteristics of moraines. These moraines do not occur in small, local valleys but occur only in the long valleys that extend far up into the mountains and contain other evidence of glaciation. Moraines are seen most easily along the east side of the Sierra Nevadas at the mouths of the larger canyons.

Convincing evidence indicates that the Sierra Nevada Mountains were once heavily glaciated. The same evidence also can be found in high mountain ranges in other parts of the world, indicating that ice was once more widespread than it is now.

The Pleistocene glaciation, according to theory, not only affected the mountains but also covered extensive northern parts of continents, even where there are no mountains. Does the evidence support this theory of continental glaciation? First, remember that continental glaciation can be observed on the earth today. Greenland and Antarctica support huge continental ice sheets up to a mile thick. Evidence of the same kind of glaciation can be found in South Dakota and other places. New England has areas of grooved and polished rock, and the grooves just happen to be oriented as one would expect if an ice sheet had moved in from the north. Evidence of glacial action can be found over large areas in northern regions (fig. 14.19). The types of evidence and their geographic distribution consistently point to the conclusion that essentially all of Canada was covered in ice, and the ice extended down into the United States in Washington, the Dakotas, and extensive areas in the northeastern United States. All of northern Europe, in addition to the mountain ranges, was covered with ice.

The amount of glaciation has fluctuated through history, even after the Pleistocene ice age. Around A.D. 600, the high passes through the Alps were free of ice. Historical records tell of roads going over these passes from Switzerland to Italy. Today, these same passes are covered with glaciers. From about A.D. 1450 to 1850, the so-called Little Ice Age occurred.[23] Historical records from throughout

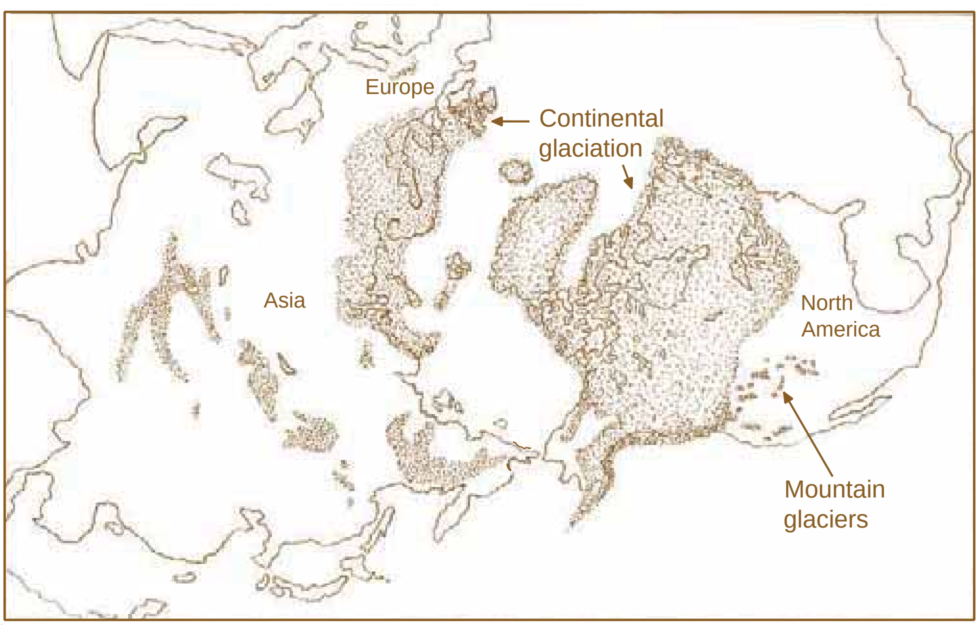


Figure 14.19. The maximum distribution of Pleistocene glaciation. Figure by Robert Knabenbauer.

Europe document this period of very cold weather. The River Thames froze over (it does not now), along with many other rivers, and agricultural and business records show that warm-weather crops shifted downward in elevation and to the south during that time. Climate, in the long run, is not as stable as we sometimes think.

Two factors are needed to initiate an ice age: cool summers and adequate precipitation. Much of the earth already has cold enough winters, but summers must be cool enough so winter's snow pack does not melt away. Also, winter precipitation must be sufficient to build up an ice sheet. Large areas of Siberia and Alaska do not show evidence of glaciation. They are cold enough, but apparently they did not receive enough precipitation to generate an ice sheet.

One prominent theory suggests that these glacier-generating conditions can result from reduction in the amount of sunlight reaching the earth's surface. During the Little Ice Age, the number of sun spots was greatly reduced. Some believe this reduces the amount of radiation from the sun.[24]

Large volcanoes can discharge enough volcanic ash into the atmosphere to affect climate. When Mount St. Helens erupted, enormous amounts of ash spewed into the air, and Mount St. Helens was not even a very large volcano. In 1912, Mount Katmai in Alaska erupted, and European weather stations reported lower temperatures for some time afterwards.

The year 1816 is sometimes referred to as the year without a summer.[25] That year, New England had six inches of snow in June and, in fact, reported snow every month of the year. Some think the cool weather was the result of a series of large volcanic eruptions in 1812, 1814, and 1815. These eruptions built up so much ash in the air that it cooled the earth enough to cause the summerless year of 1816. It has been calculated that a drop of a few degrees centigrade in the average annual temperature for the earth is adequate to bring on an ice age. If this is correct, it suggests that if the volcanic eruptions discussed above had been followed by a continuing series of eruptions, another ice age possibly could have begun.

How does short-age geology deal with glaciation? The evidence indicates that at one time glaciation was more extensive. A short-age theory must account for this. Some individuals attempt to develop theories for the mechanism that would initiate an ice age after the worldwide flood,[26] implying that conditions at that time were ideal to produce such an event.

Could the extensive volcanic activity during the Cenozoic have caused the ice age? Some scientists have considered the possibility. But if the Cenozoic covers a period of sixty-four million years before glaciation (fig. 10.1), these eruptions would be too spread out in time to significantly affect world climate. However, if the time span was much shorter, all of this volcanic activity might have created an adequate volume of ash in the air to reduce the sun's radiation and bring on an ice age.

Abundant paleontological evidence indicates that the earth used to be warmer and more uniform in climate than it is now. That evidence is found in Mesozoic and Paleozoic deposits. Even mid-Cenozoic deposits include tropical animal and plant fossils in the arctic.[27] After that, the earth cooled down. A short-age theory proposes that the earth was warmer before the flood and cooler after that event. If the earth began to cool off, compounded by extensive volcanic activity, perhaps the setting would be ideal to generate an ice age.

How long would it take to generate the ice age? No one knows for sure, but short-age theory predicts that continuing study may indicate that it did not require long ages. We can suggest that a state of unsteady climate after the global catastrophe could initiate such an event. J. R. Bray, in an article titled "Volcanic Triggering of Glaciation," states the following:

> An instantaneous glaciation theory for the formation of the large Pleistocene ice sheets has been proposed by Flohn and by Ives et al. It depends on the sudden

> buildup of a permanent snow cover over sub-Arctic plateaus. . . . The crucial event in this sudden snow buildup is the survival of snow over a large area for a single summer which then results in a series of feedback reactions leading to the establishment of permanent snowfields and subsequently, icefields. I suggest here that such a survival could have resulted from one or several closely spaced massive volcanic ash eruptions.[28]

Bray is not proposing a worldwide flood as the cause of such an event. His suggestions indicate that at least some scientists feel there is room for discussing how rapidly such an event could begin. There are other lines of evidence that are a problem for short-age theory, and much more study is needed, especially the presumed series of Pleistocene climatic cycles with multiple glaciation events[29] and the long series of laminations interpreted as annual layers in Arctic and Antarctic ice cores.[30] However, there apparently are considerable difficulties in interpreting the ice core records.[31]

Stratigraphy: The Geologic Column

The result of the processes we have examined is a sequence of rock formations called the "geologic column"

Glaciation processes

DATA

Observations of active modern glaciers and the evidence they leave behind. Evidence in rocks that matches modern glacial evidence and appears to be from former glaciation. Study of other, nonglacial processes that can produce features similar to glacial evidence.

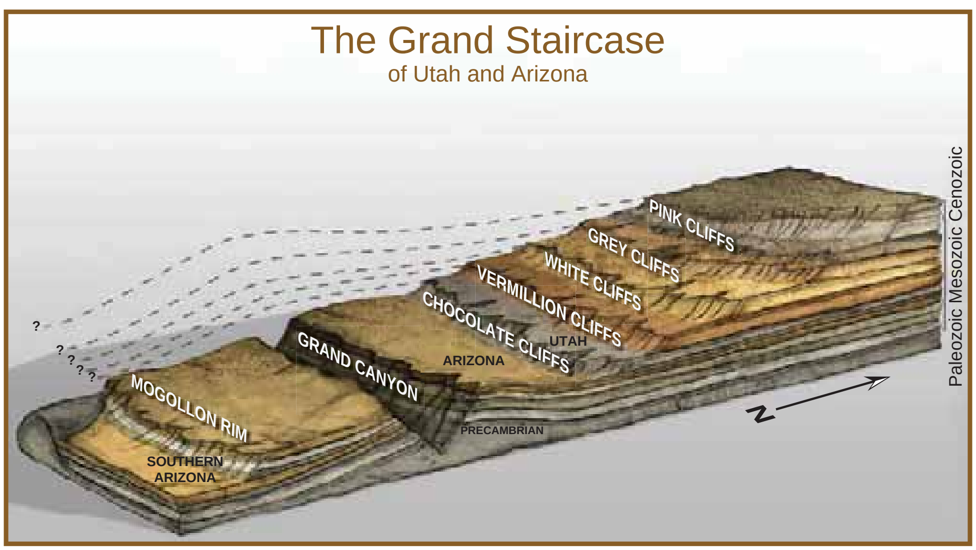
INTERPRETATION

The interpretation process will be similar in both worldviews, but naturalistic science will have less motivation to challenge glacial interpretation in questionable cases.

(fig. 10.1; 11.14). Although there is no one place on the earth where rocks representing every part of the geologic column are found in the same location, one above the other, a reasonably good sampling of the column can be observed at a number of places in different parts of the world. One of these areas is in Arizona and southern Utah (fig. 14.20). The rocks visible at the bottom of the Grand Canyon, in the inner gorge, are Precambrian. In the central region of the Grand Canyon, the layers at the top of the inner gorge are the first Cambrian rocks. Beginning with the Cambrian, Paleozoic rocks everywhere contain a great diversity of fossils, including all major phyla of easily fossilized animals. Most Cambrian fossil animals are marine invertebrates, but the first fish also are from the Lower Cambrian.[32] The Ordovician and Silurian also contain fish and invertebrate animals, but fish are first abundant in the Devonian, which is sometimes called the age of fishes. Trilobites are a widespread, very diverse, and unique part of the fauna of the Paleozoic sediments.

Above the Cambrian formations in the central Grand Canyon is a gap with no Ordovician or Silurian and only a little Devonian (sediments representing the missing section are present farther northwest in Utah and Nevada). Above this, there are formations representing the

Figure 14.20. North-south cross-section through the Grand Staircase in northern Arizona and southern Utah, showing the sedimentary rocks that form the geologic column in that area. Figure by Doug Oliver.



Mississippian, Pennsylvanian, and Permian. Pennsylvanian and Permian formations contain more invertebrates, amphibians (first found in the Devonian), reptiles (represented by their fossil footprints), and fossil land plants.

All the Grand Canyon rocks are Precambrian or Paleozoic. But north of the canyon, where the Paleozoic deposits dip down toward the north, Triassic deposits are present on top of them. These include the red-brown Moenkopi Formation and the very colorful Chinle Formation in the Vermillion Cliffs. The Triassic deposits contain dinosaurs and other fossils not present in the Paleozoic rocks. Just a little farther north from there, Jurassic rocks appear on top of the Triassic. The Navajo Sandstone is a prominent Jurassic formation, beautifully exposed in Zion National Park, forming part of the cliffs up to two thousand feet high. Above that are other Jurassic and Cretaceous layers. Dinosaurs and a number of other extinct reptiles are found only in Mesozoic strata. In some places, the first mammal and bird fossils are also found in the lower to middle part of the Mesozoic. Mesozoic bird and mammal fossils are not common and all represent extinct groups. Of course, the Mesozoic also contains many invertebrate and plant fossils, and the first flowering plant fossils occur abruptly in the Middle Cretaceous.

Above the Cretaceous layers in Utah, a portion of the Cenozoic is represented, including the Eocene Claron Formation that forms the colorful cliffs and ridges in Bryce Canyon National Park. The most recent sediments are localized Pleistocene and Holocene (recent) deposits.

Cenozoic deposits, including the Claron Formation, contain many fossils of plants, invertebrates, and vertebrates (including birds and mammals), representing types not found lower down. Human fossils are found only in Pleistocene deposits at the top of the geologic column.

Some general trends are seen in the fossil record in the Grand Canyon and elsewhere. On the continents, the Paleozoic (especially Lower Paleozoic) represents predominantly marine environments, the Mesozoic is a mixture of marine and terrestrial, and the Cenozoic represents mostly terrestrial environments. A high percentage of fossils in the Paleozoic are in extinct groups, with the percentage of modern groups increasing toward the upper part of the fossil record (fig. 11.14). Trends also appear in the abundance of rock types. For example, limestone is abundant in the Paleozoic and Mesozoic, but drops off higher in the column. Little limestone of this type is forming today.

Figure 14.20 is a cross-section through the Arizona-Utah area showing the layers dipping down to the north. Each layer extends underneath the next exposure above and to the north of it. The order of rock layers evident in surface exposures is confirmed by oil wells. When an oil well is drilled, bits of rock or cores are brought up from the well. Study of these fragments reveals that the rock layers are underground just as would be predicted.

In the Grand Canyon region and in other places, the major parts of the geologic column are exposed in order, layer upon layer. In still other places, only a part of the column is present. Where large portions of the column are represented, the layers with their fossils are found in a consistent sequence, unless faults and folds have caused layers to be moved around. In locations where only a portion of the column is present, its position in the geologic column is determined by the types of fossils present and by radiometric dates.

The sequence of fossils in the rocks apparently is real. Whether we prefer short-age geology or conventional geology, the geological column is still a valid description of nature's history book. In fact, the original study and description of the divisions of the geologic column were done largely by creationists. Later, as scientific theories changed after the work of Lyell and Charles Darwin, the original description remained essentially correct. What changed was the interpretation of how the rocks and fossils got that way.[33] Conventional geology says that the Phanerozoic part of the column (Paleozoic, Mesozoic, and Cenozoic) is the record of 541 million years of geological activity and biological evolution, from the bottom of the Cambrian to the present. The short-age geologist says that, at least from the beginning of the Cambrian, the geological record has formed very rapidly, not over the long evolutionary time scale. Part of it is a record of activity during a global catastrophe.

Fossils: The Record of Life

How do fossils get preserved? Why do some organisms decay and disappear, while others become fossils? In the ocean, many organisms (including mollusc shells, coral, fish, and floating hard-shelled plankton) die and fall to the ocean floor. Other organisms die in lake, stream, or terrestrial environments. If sedimentation occurs and covers them quickly enough, they are likely to be preserved as long as that sediment is not eroded away again. The sedimentation that buries them must be rapid since most animals or plants decay and disintegrate if not quickly preserved. Even if they are in an environment with no oxygen, anaerobic bacteria cause decay unless the specimens are buried rapidly.[34] Fossils of soft-bodied animals or plants do not form unless they are covered and mineralized within hours or a few days. How soon after death

Interpreting stratigraphic relationships in the geological column

DATA

Description of each rock layer, its fossils, and its relationship to other rock layers.

INTERPRETATION

Conventional science: The assumption of naturalism requires that the fossil sequence represent an evolution process producing the organisms from Cambrian to recent, over millions of years of time.

Interventionism: Most of the fossil sequence resulted from some processes other than macroevolution. Some parts of the sequence may be from microevolution and speciation after (and maybe before) the global flood. Seek to devise ways to infer the difference between sequences from flood processes and post-flood evolution.

fossil organisms were buried can be estimated from the nature of the fossil.[35] A vertebrate animal with its skeleton still articulated must have been buried before decay progressed far enough to separate the body parts—at least within weeks or months, depending on the animal and the conditions. Most fossils that have soft tissues preserved must have been buried within hours after death. Fossils of intact but scattered bones indicate that the animals decayed and the bones were transported from their original location before burial, but they were not subject to extensive weathering or physical damage. Bones or shells that are badly broken or abraded indicate lengthy exposure and/or transport.

The study of the processes between death and fossilization of organisms is called taphonomy. The basic processes are agreed upon by everyone, no matter what their philosophy. The better preserved a fossil, the more quickly it was taken out of the biotic environment by burial and/or rapid mineralization. However, a short-age model suggests there are so many fossils because much of the geological record formed during a rapid and catastrophic sequence of events, in contrast to the slow and gradual processes that occur today.

CHAPTER 15

Why Does It Matter What We Believe about Geological Time?

Overview

If Christians accept millions of years of geological time, does this matter for their theology? When we examine the nature of Christian theology, especially in relation to the origin and cause of evil and death, it matters a great deal whether we accept long ages of evolution. It determines whether God is responsible for evil or evil resulted from human rebellion. This is one important reason why the topics in this book are worth discussing. And if we make modern science the standard for determining our theology, this brings the likelihood that science will move on with new discoveries and our theology will be left without a foundation.

Evolution, the Great Controversy, and Evil

If the evidence tells us that macroevolution won't happen through natural means, does that say that God must have been involved to make the evolution of all life forms work? If so, that has implications about who God is—what kind of a person He must be.

Wouldn't it be easier just to accept the long geological time scale and fit creation into that scenario? Probably. That is what the majority of Christian theologians and other scholars are doing.[1] But the main reason for proposing an alternative theory is to maintain internal consistency in the informed intervention worldview, especially in explaining the stratigraphic distribution of a number of groups of fossils in the fossil record (fig. 11.14), including the vertebrates, and in maintaining theological coherence. The Bible does not say how many years it has been since creation, but we will show why we believe that Bible history is compatible with a time span since the creation week of only thousands rather than millions of years.

Before coming to the issue of how much time the fossil record represents, we will consider some foundational topics that affect the time question. If the life forms resulted from evolution over millions of years, this comes into conflict with the Bible and Christian theology.[2] For one thing, if the Genesis creation is not literally true, then what logical reason would there be to think that salvation and the Second Coming are true (2 Peter 3:3–7)? Perhaps they are also just allegories. Exodus 31 states that God wrote the Ten Commandments in stone with His own finger, including the part that says life was created in six days. Is that true? If not, can we trust the rest of the Bible? It is also evident that many Bible writers in the New Testament, and also Jesus, accepted an actual creation and flood, so the issue is much broader than whether we can trust the first part of Genesis.

Second, Christianity is based on a series of connected events (the Great Controversy between Christ and Satan). A very intelligent and capable created being, Satan, rebelled against God. Since God desires His created beings to serve Him out of love and not fear, Satan was allowed to show whether his ways were superior to God's ways. Humans were created sinless and perfect in their love and trust in God. They chose to believe Satan's lies and also fell into a sinful state of rebellion against God. The result of their fall would have been death, but Jesus came to earth to live among us and die in our place (Rom. 5). If we break the divine law by sinning, that law cannot be set aside to keep us from reaping the result. But Jesus's death was a substitute for our just penalty, and it allows Him to redeem us for eternal life.

If life has evolved over hundreds of millions of years, then humans were not created sinless but evolved from other primates. If that were so, then there was no original sin and no fall. And if there was no fall, then salvation from sin loses its meaning. To take this to its logical conclusion, if Jesus did not die to save us from our sin, then Christianity has no meaning. Also, if humans are the result of evolution, then the consistent biblical explanation for the origin and meaning of evil is destroyed. Charles Darwin and others in his day had great difficulty explaining the evil in this world.[3] How could a good God allow such evil to exist? That remains to this day an important, unanswered question for many people.

Conservative biblical theology, with the Great Controversy between Christ and Satan, provides the only satisfactory answer to that age-old question. According to the Bible, God created the earth and humans perfect. There was no sin or evil in this new creation until Adam and Eve chose to disobey. After their sin, Satan claimed and usurped the right to rulership of this earth. He could then tempt humans, who are not nearly as clever as he is, to sin and do evil things (moral evil). Satan also then had the freedom (and has the power) to influence nature in ways that resulted in natural evils like accidents, diseases, tornados, and many other calamitous events. Evil was not in God's plan or in His original creation—it resulted from Satan and sin. Evil was not punishment for sin but the natural result of sin, just as death is the natural result of jumping off a cliff. Understanding this may not keep us from mourning the death of a loved one, but this explanation does make sense, and we can look forward to the end of evil that God promises.

On the other hand, if life forms, including humans, resulted from evolution through vast ages, then that explanation for evil disappears. If evolution was God's means of creating (as in theistic evolution), then pain, suffering, disease, predation, and death were all a part of God's plan, and God is responsible for them. The fossil record contains abundant evidence of disease,[4] and predation and death were everywhere. In this scenario, evil could not be the result of human sin because humans did not appear in the fossil record until very recently, after more than five hundred million years of evil. A number of theologians who accept science's evolutionary explanation for the origin of life and humans candidly discuss these theological implications.[5] Their explanation for evil is that God allowed nature to "make itself" through evolution, and both good and evil were a natural part of the process, which even God could not prevent.[6] Their god may be sympathetic with us, but he was powerless to prevent evil, pain, and suffering. In contrast, the biblical story of creation, the fall, and redemption is a consistent, meaningful answer to the cause and the ultimate, sure end of evil. It is an integrated Christian worldview, whereas theistic evolution or similar concepts are the mixing of a few isolated Christian concepts into a secular worldview that does not logically hold together.

So far, we have considered the relationship between human origins and theological ideas, but what does that have to do with geological time? To answer that, we have to think about the explanation for the sequence of fossils. At the beginning of the Phanerozoic, the record contains mostly invertebrates. Then the land vertebrates appear, one group at a time, in what is generally interpreted as an evolutionary sequence, with humans evolving at the end of geological history. If we question the evolutionary explanation for the origin of the major groups of animals and plants, we must provide an alternate one. That alternative may be feasible if the fossil record was formed rapidly, following the creation event described in Genesis, because then there are possibilities for explaining the sequence of fossils in the record as the result of sorting processes that buried some groups of organisms before other groups.

The two internally consistent approaches are (1) macroevolution over millions of years of time (along with a philosophy that does not take the Genesis account seriously) and (2) literal biblical creation and short-age geology. There are both religious and scientific reasons for thinking that the second option is worth pursuing seriously. It is consistent with acceptance of Scripture as authoritative in theology, science, and history when it addresses such topics.[7] Can it also be consistent with the physical evidence? That is a primary topic in the coming pages. The short answer is that it can be more consistent than is often thought, but we still have many unanswered questions.

Chimpanzee Genes and Theological History

By 2005, the human and chimpanzee genomes had been sequenced, and it became evident that chimp genes and human genes were 98 to 99 percent similar among genes that were compared. We are hardly any different from a chimpanzee, and this was interpreted to mean that humans and chimps had obviously descended from common ancestors. How could we argue against the evidence? Even before the final chimp genome was available, books were being published dealing with the implications of this 98 percent similarity.[8] How should a Bible believer relate to this? It is an instructive case study in our response to troublesome evidence. Many Christians accepted this as further evidence against biblical creationism.

Sometimes it is wise to deal with such evidence by just waiting to see what will be found next because science often has surprises for us. That was a wise approach in this case. The first clue comes from considering the context of that 98 percent similarity. The genomes of animals contain a large amount of noncoding DNA, sometimes called silent DNA—silent because it does not seem to do anything. It doesn't code for proteins—provide instructions for the amino acid sequence in the protein. The human DNA is about 98 percent noncoding DNA, and the fact that it is silent was interpreted to mean it did not seem to have a function. It was interpreted to be "junk DNA," functionless, inactive old genes left over from the evolution process. Only about 2 percent of human DNA codes for proteins, or we could say it provides the "bricks" to build our bodies. That 98 percent similarity refers primarily to the protein-coding DNA. Of course if 98 percent of our genome was functionless junk, then the 2 percent coding genes would be all that is important.

Over the years, scattered research papers appeared reporting that some parts of the "junk DNA" did have a function, as part of the regulatory system that controls the activity of coding genes. Some of these regulatory genes were involved in managing the biochemical differences between humans and chimps.[9] Then in September of 2012, a massive genetic research project was completed and published, reporting that at least 70 to 80 percent of the human noncoding genes were not junk but had a function.[10] Many of these are now known to be part of a massive regulatory or control system with its complex of proteins and various types of RNA, with epigenetic tags, that direct the activity of protein-coding genes. These genes tell when, where, and how much of each protein is to be produced and how they will connect to each other to make the parts of cells and of animal bodies. How naïve of us not to have realized long ago that such a control system was essential. The naïveté was the direct result of naturalistic thinking. If life had no intelligent Designer, we would not expect such overwhelming complexity.

The same bricks can be used to make a dog house or a palace, and proteins can be used to make a human or a chimpanzee or a mouse, depending on the instructions provided by the regulatory genes. This would probably be true even if our protein coding genes were 100 percent similar to chimps, which they aren't. More study of chimp and human genes reduced the level of similarity, and more research has yet to be done. In particular, the human male sex chromosome (Y chromosome) differs radically in sequence structure and gene content from the chimp Y chromosome.[11]

There is a significant lesson in this for theology. In 2005, we could decide, based on the current genetic evidence, that our theology must accommodate human and chimp evolution from common ancestors. Or we could base our theology on the Bible, stay with the Genesis creation account, and predict that new scientific discoveries will answer more of our uncertainties.

If we make contemporary science our standard for theology, science is likely to move on and leave our theology sitting on shifting sand, as it did with chimp DNA. That is what happened, for example, in Darwin's day when Christian thinking about fixity of species was an idea based not on the Bible but on Greek science. Of course, in understanding human origins, we are still waiting for adequate understanding of a group of fossils interpreted as links between apes and humans. Perhaps it is wise to continue to wait for better answers to that evidence also, to keep our theology out of the shifting sand.

Is God Deceiving Us?

There are people who argue that if the Bible really intends to say that life on earth is young (only thousands of years) then God is deceiving us. They would go on to say that multicellular life is actually millions of years old, and God gave us false information in the Bible. We suggest a different way to think of this issue. Whatever your personal beliefs about the age of life, imagine for now that the Cambrian explosion was thousands of years ago, then later there truly was a global flood catastrophe. Imagine that in order to accomplish this, God interacted with the earth in ways that left evidence (e.g., radioactive materials in rocks) that will be confusing to us and difficult for us to explain. Consequently he told us what he did so we wouldn't be misled. If this is so, then the problem isn't that God deceived us. The problem is that we don't believe what He told us.

CHAPTER 16

Two Geology Theories

Overview

First of all, we briefly describe the conventional geology theory of earth history. Then a tentative theory is described for the events and processes of the global flood catastrophe. What would this event be like? We cannot know for sure, but the biblical insights in combination with existing geological evidence helps form an outline of a general theory for this event. Based on this evidence, we describe factors that likely influenced the formation of the fossil record and the rocks in which it is contained. These include what we can know about the original earth, how and why it changed, how the land could have been inundated and later reappear above water, and the sequence of changes after the catastrophe. The crust of the earth was completely changed. New mountains appeared and former mountains vanished, early continent-wide geological processes gradually gave way to local processes, and the earth became drier and more like its current state. We end with suggestions for research.

Multiple, Even Outrageous, Hypotheses

This chapter describes an interventionist short-age theory of earth history and compares it with the conventional long-age theory. For us, the reality of the global flood is not just a theory, but our geological ideas of how it happened do comprise a theory, and that is the spirit in which we present the following material. Here we present both the philosophical/theological concepts that support this unconventional theory and the scientific concepts and sequence of events that the theory must account for. Chapters 17 and 18 will summarize the most significant types of evidence that favor each of these theories.

In 1926, the president of the Geological Society of America published an insightful article titled "The Value of Outrageous Hypotheses."[1] Any new idea is apt to seem outrageous when first suggested, but "we may be pretty sure that the advances yet to be made in geology will be at first regarded as outrages upon the accumulated convictions of today, which we are too prone to regard as geologically sacred."[2] We are broadening Davis's concept even more to suggest that short-age geology is also a useful "outrageous hypothesis" for those willing to question naturalism.

These outrageous hypotheses in short-age geology, as long as they are also responsible ones, can improve the chances of finding explanations that are consistent with both revelation and geology. We are following the approach of multiple-working hypotheses recommended by Thomas Chamberlin,[3] himself a geologist. If we propose all the hypotheses (or theories) we can think of for a particular phenomenon, we are less likely to settle too quickly for the first one that seems satisfactory. Here, we compare a conventional long-age theory with a short-age theory, dealing only with very broad, global aspects of geological processes. Any details that we suggest for short-age geology processes should be taken as hypotheses to be tested.

It is especially important to note, in fairness to the authors cited in these three chapters, that many of these authors do not interpret the data in terms of interventionist or short-age theory. References are cited for specific data or concepts. We are seeking a different interpretation that is still consistent with the data.

The Precambrian

Geological processes have been in operation on neighboring planets and on Earth and its moon since they were created. Meteorites have crashed into the moon and made craters of various ages. Some have eroded, irregular rims; others have very sharp, smooth rims indicating they must be of more recent origin. Some of the old, eroded craters have young, uneroded craters within them. This evidence indicates a sequence of geological events but does not tell us the length of time involved.

The Precambrian deposits on Earth also contain evidence of geological processes, including sedimentation, cementation, metamorphosis, meteorite impacts, folding and twisting from the formation of mountains, and subsequent erosion of those mountains. Dynamic geological processes have left their marks on those earliest rocks, processes that scientists generally interpret as taking billions of years.

The same basic types of sediment make up the Precambrian and the Paleozoic deposits, but the obvious difference is the near absence of fossils in the Precambrian whereas the Paleozoic contains an abundance of fossils of structurally complex organisms. We will not discuss the Precambrian further but focus on the Phanerozoic (Cambrian to recent) because rocks that contain remains of complex life are of more significance to the theological issues raised in this book. We will now introduce two very divergent theories.

Conventional or Long-Age Geology Theory

In this theory, the formation of geological deposits and their alteration and erosion have been under way throughout earth history. The earth was not always the same but varied as to where the continents were, how much of our existing continents were covered with water, the type of climate, and other factors. However, the basic geological processes described in chapter 14 have always been in operation.

The beginning of the Cambrian was about 541 million years ago. Just before that, the first complex life forms, the Ediacaran fauna, were preserved. Then in rocks of the Early Cambrian are found the first fossils of almost all the phyla of organisms with hard parts that could be readily fossilized—the Cambrian explosion. There must have been some history of the evolution of these phyla before that, but we first find their fossils in this Cambrian explosion. The origin of the first living cells occurred much earlier, about 3.8 billion years ago, with some bacteria being preserved in the Precambrian rocks.

In the process of plate tectonics, the continental plates have been slowly shifting their positions on the earth from that time until now. The nature of original rocks forming the early ocean floor is not known, since the oldest existing ocean floor is only about one-third as old as the Early Cambrian. Rates of sediment accumulation, mountain formation, erosion, and so on have been very slow, punctuated by times of catastrophic activity. The overall theme has been slow and steady.

For many millions of years, the continents were mostly or partly covered by shallow epicontinental seas, producing the abundant marine invertebrate fossil deposits now found on our continents. Gradually the earth changed. Through the Mesozoic and into the Cenozoic, the continents became more and more exposed above the ocean. During the time of expansive glaciation, the Pleistocene ice age, the ocean level was about three hundred feet lower than at present, and finally reached its current level after glaciation.

As the geological processes progressed, animals and plants slowly evolved with the unpredictable accumulation of chance mutations, adapting to changing earth conditions and evolving new adaptations to move opportunistically into new environments. New taxa evolved and others went extinct all through this history, but at several times during the Phanerozoic (Cambrian to recent), there were catastrophic crises resulting in the extinction of significant percentages of different groups of organisms.

The slow, usually steady geological processes and biological evolution continue to the present day.

Short-Age Geology Theory

Introduction

The earth was created as a wonderful life-support system, with engineering features we can only try to imagine. Then a few thousand years ago a global catastrophic flood tore this system apart, probably beginning with the initial plate tectonic movements of continents. Then in quick but surprisingly orderly succession, continents moved, mountains were destroyed, sediments above the igneous basement rock were removed and redeposited elsewhere, and new mountains formed. Meanwhile meteorites struck the earth, volcanoes spewed ash, and lava flowed as massive new deposits called flood basalts. As events unfolded, many animals and plants were buried and fossilized, not

Evaluation of two geology theories

DATA

Discrete measurements, readings from instruments that, for example, identify minerals or quantify isotopes. Fossils and their geographical location of origin and the specific rocks they came from. Observable geometric relationships among rock units, faults, fossils, and so on. For interventionists, biblical statements about origins are data.

INTERPRETATION

General: Since we did not observe ancient historical events, virtually any description of how or when such events occurred is an interpretation.

Conventional science: The assumption is that methodological naturalism (MN) is accepted by faith and dictates that all interpretations must deny any event or process that implies supernatural actions or influences. Even if biological evidence seems to say that macroevolution does not work, this predicts that evidence will be found to show how macroevolution does work through geological time. This also interprets the data in ways consistent with MN and predicts that processes will be found to explain the entire geological column as formed over the radiometric time scale.

Interventionism: The assumption is that the biblical creation and history of life on earth for a few thousand years is accepted by faith and provides a few key concepts on which to build a geological theory. Short-age concepts are used in interpreting data and predict that future discoveries will alter the meaning of radiometric "dates" and will provide better interpretation of geological data.

all at once, but sequentially as the process drew them in. This sounds very chaotic, but the evidence indicates orderly sedimentary deposits and frequent intervals with low water level or bare ground with some animals leaving footprints or even laying eggs before being carried off again. Finally the drama gradually slowed to a more animal-friendly state and life was resumed on and in the new land and water bodies. The rest of the chapter will flesh out parts of this story.

The Earth after Creation Week

During creation week, the surface of the earth was prepared for life, with dry land and bodies of water designed for maximum efficiency in supporting life. Then the new environments were filled with life forms representing all the phyla, classes, and probably many families of organisms that are alive today or are known as fossils. At that time, there was a richer variety of habitats than exist now, and habitats now extinct seem to be represented by the many extinct groups of Paleozoic and Mesozoic organisms.

What was the surface of the earth like after creation week? We have no direct evidence to answer this question. But the few clues available from the inspired writings and geological evidence suggest the following ideas.

If we look at the world around us, we observe that living things are very intricately designed with all of their parts beautifully appointed to carry out their intended functions. However, the crust of the earth and its life-support system seem almost haphazard in certain respects. Huge areas of the earth have inadequate rain and can support only a small amount of life. The earth does not look well designed. It appears that the earth in its current changed state is the wreckage of a drowned planet—the remains of what was left after a geological catastrophe.

Perhaps, after creation week, the crust of the earth was almost as intricately designed as current living things are, creating a more uniform climate and superior life-support system. The rich fossil record can be interpreted as indicating that before the catastrophe, life on earth was much more abundant than what earth can support now. The fossils indicate that even in the mid-Cenozoic, tropical animals and plants were living much closer to the polar regions than they do now,[4] supporting the idea that the earth had a more uniform climate earlier in its history.

Catastrophe

The catastrophe on earth really began soon after creation, when Adam and Eve, perfect, created beings, fell from their sinless state, essentially giving Satan permission to exert his influence over them and over the earth as part of his rebellion against God. Life began to change because of mutations and perhaps other types of genetic alterations. Human culture became increasingly violent and rebellious, until Satan's plan to eliminate all God-fearing humans and claim mastery of earth was dangerously near success. God then foiled his plot by bringing a sudden geological catastrophe on the earth. To many people, this may seem unscientific, but Scripture describes a very real event, a real live cosmic conflict between intelligent personal beings that is being played out on this planet. God chose an elegantly designed boat as the means for saving the human and animal remnant.

Unfortunately Noah was not taking notes during his epic journey, so we don't know details of what was happening, geologically, during that time. Our only approach is to seek to learn a part of the story by geological research.

Hypotheses of Flood Dynamics

What would have to happen to bring on a global geological catastrophe and then to restore the earth to a habitable condition afterwards? How is the crust of the earth made? Where would the water come from? Where would it go? How would the fossils get to the places where they are now? We will suggest answers to these questions, based on what is known about the earth.

Figure 16.1 illustrates the relationship between the continents, the ocean floors, and the mantle underneath the crust. The land surface stays above sea level for the same reason that corks float on water. We do not often think of rock as floating, but look again at the diagram of the earth's crust. The continents all have a granitic foundation with a density of about 2.7 compared with the density or specific gravity of 1 for water. Basaltic rocks that form the floor of the ocean (a density of about 3) and the mantle below them (a density of about 3.3) are much denser.[5] The continents, formed of lighter rock, float on the denser basaltic ocean floor underneath. This well-balanced system explains why our continents do not sink and become covered by water.

Source of Flood Water, Its Post-flood Destination, and the History of Continents

If a global-scale geological catastrophe occurred on this earth, how could the water have covered the highest mountains? There is not enough water to do that unless the structure of the earth's crust was altered considerably. Even allowing that the mountains on the pre-flood earth may have been lower than some of the present mountains, earth's existing water would only be able to cover the land if the continents sank in relation to the ocean floors. It also appears likely that pre-flood mountains were destroyed, and the mountains we see today were formed during or after the catastrophe. Because the old mountains were being eroded away, this may partly explain how they could have been covered by water. During this process, new mountains may have risen in some areas, while old mountains were still above water in other places.

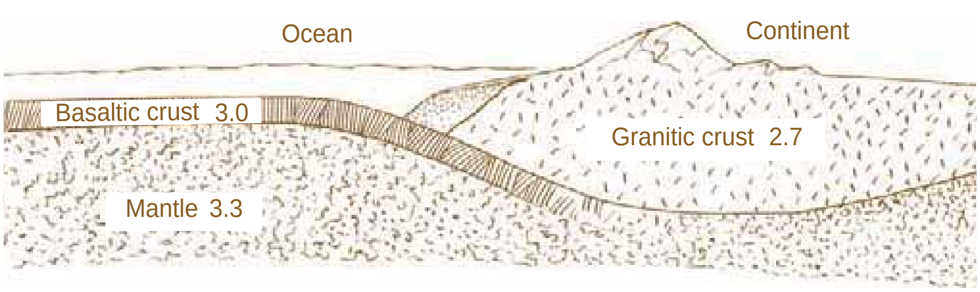


Figure 16.1. The structural relationships between continents and oceans. Numbers indicate density of the rocks (after Hamblin and Christiansen 1995). Figure by Robert Knabenbauer.

Flood models

DATA

Documented composition of ocean floor and continental rocks. Relative ages of existing ocean floors and continental rocks as indicated by radiometric dates. Presence and distribution of marine and terrestrial fossils in the sedimentary rocks. Many other types of observable, measureable factors in rocks and fossils.

INTERPRETATION

Conventional science: The assumption is that the Bible is a collection of myths, and there was no global flood.

Interventionism: The assumption is that the Bible presents a literal, factual record of earth and biological history but does not give geological details.

There are multiple working hypotheses of flood processes. Below are numbered models—some of the ideas that have been proposed. The authors of this work are not tied to a specific model, but we have examined these and present the concepts that we now believe are most consistent with the available evidence. We invite readers to make their own evaluation.

1. Most or all of the Paleozoic and Mesozoic and earliest Cenozoic formed during the flood. The rest of the Cenozoic formed after the flood. This concept is commonly accepted and is closest to our view.
2. Some, perhaps part of the Paleozoic, formed in the oceans before the beginning of the flood events described in the Bible. The rest of the Phanerozoic formed during and after the flood, perhaps as described in model 1 above.
3. Almost all the Phanerozoic, up to part of the Pleistocene, formed during the main event of the flood. The last of the Pleistocene came after the flood.
4. The flood formed some minor part of the Phanerozoic record.
5. Other variations have been proposed.

Removing the water from the land after the catastrophe also depends on changes in the earth's crust. The water could not just evaporate. The atmosphere could hold only a small fraction of the water needed to inundate the entire world. Some global process, such as the rising of continents and/or sinking of ocean basins, is needed for the flood water to flow into the new ocean basins.

If a catastrophic global flood occurred today and carried away the soil and other loose material on the earth, where would it be deposited? On the land or in the oceans?

Intuitively, it might seem that most of the sediments, especially the marine sediment, would be deposited in the ocean. But the largest volume of fossil-bearing sedimentary layers (including massive amounts of marine deposits) are found on the continents. So it is clear that the present continents were once covered by water (Gen. 7:20). Conventional geological theory proposes an explanation for that evidence. Any short-age theory also has to account for the same evidence.

The bulk of the sedimentary rocks, including marine deposits, are on the continental crust. And the sediment in the present ocean basins is all Jurassic or younger. Three possible explanations could be given for these observations (perhaps all three are true): (1) large areas of the continents must have been at low elevation during the catastrophe, forming depressed basins where the sediment was accumulating, and these sediment-filled basins rose after the flood to form land, with new mountains; (2) the rock composing existing ocean floors was not formed until late in the flood; or (3) the oldest ocean floors were subducted into the mantle. Looking back from our stable world with oceans that stay in the same place century after century, it is difficult to visualize or understand changes of this magnitude.

Perhaps the dramatic changes at the initiation of the flood involved plate tectonics, the breakup of part of the earth's crust with rapid subduction of some old continental areas, as suggested by John Baumgardner,[6] or the loss of continental area by some other process. Maybe the destruction of some pre-flood terrestrial continents was the primary event of the flood, and we find little or no trace of their fate in the geological record. You might wonder how that could happen and not leave any evidence behind. That may not be as difficult as it seems. The oldest existing ocean floors are generally no older than the Jurassic. What was there before the Jurassic? There is abundant room for large-scale mysteries, beyond our current understanding, to be hidden in those ancient subducted crustal masses. Our present earth is the meager remains of a shattered planet. There is evidence for huge slabs of rock deep down in the mantle that are much too cold (3000 °C colder than surrounding mantle material)[7] to have been there for millions of years.

One other objection to the subduction of continents must be answered. Continents now have a foundation of granitic rock, which is too light to sink down into the denser basaltic material under them. Does this negate the possibility that previous continents could have been subducted into the mantle and that seas once existed on what currently is continental crust? Perhaps not, if at least some of the original continents were composed of vesicular basalt with abundant pore spaces for water movement, resulting in a net specific gravity lower than solid basaltic rock. Recall that pumice, an extreme example, which floats in water, forms from basalt that has a foamy consistency because of trapped gases. Only a slight porosity (about 20 percent) would be sufficient to reduce basalt's specific gravity below that of granite. A continent of this composition could be light enough to stay above the ocean water level. But if the water system collapsed so that it became solid basalt, it could then be subducted into the mantle. That is speculation, but it seems within the realm of possibility, and it helps explain some of the geological evidence.

Relationship of Preserved Marine and Terrestrial Realms

Marine fossils are present in many of the Lower Paleozoic rocks of North America and elsewhere (fig. 16.2).[8] Because we are positing a rapidly accumulating sedimentary record, there is no time for plant and animal habitation to be newly established once the catastrophe has begun. Since the continents were first covered with marine sediments, in many places around the world, those places cannot be where the nonmarine fossils in the overlying layers lived, including the terrestrial vertebrates and plants we find as Mesozoic fossils in North America. Those organisms must

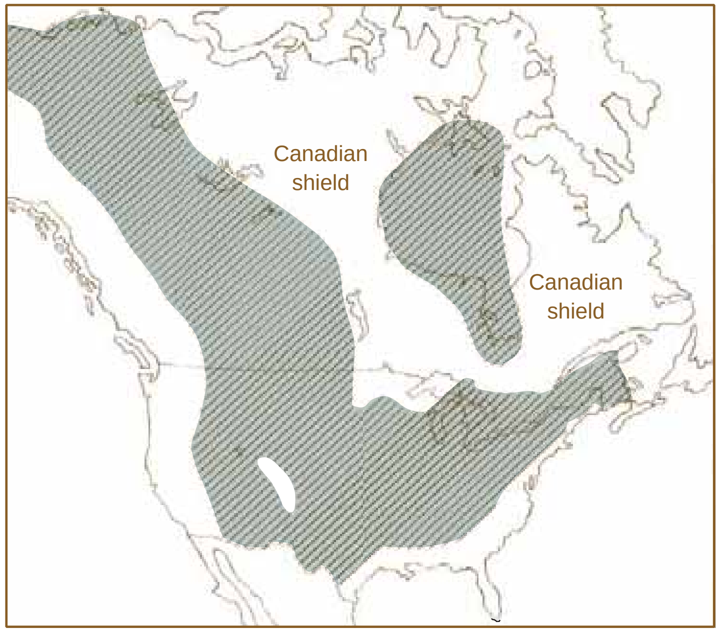


Figure 16.2. The area of North America that was covered by marine sediments (cross-hatched) by the end of the Paleozoic. The Canadian Shield consists of exposed Precambrian rocks. Figure by Leonard Brand.

have lived elsewhere. Yet we find their remains in layers overlying the mostly marine Paleozoic record. Reasoning from these data, we are led to conclude that a great deal of transport took place during the flood, bringing sediments and fossils in some cases across entire continents to deposit them on top of layers that have already been laid down. So where did the animals come from?

Paleocurrents (directional indicators preserved in the rocks) seem to suggest many of the sediments and possibly the contained fossils in the Paleozoic were derived from the east in North America, even though many of the marine forms may have been buried where they lived in various life zones in the ocean. But Mesozoic plant and animal fossils and the accompanying sediments were largely derived from the west. Presumably, somewhere to the west of the Rocky mountains is the land area where dinosaurs and other Mesozoic forms originated. One criticism of this idea is the difficulty of imagining dinosaurs and other animals transported that far in a flood with some of them still being alive long enough to make footprints in the sediment. Since we have never seen such an event, it is difficult to envision the process.

Relationship of continents and oceans and flood processes

DATA

Documented composition of ocean floor and continental rocks. Relative ages of existing ocean floors and continental rocks as indicated by radiometric dates. Presence and distribution of marine and terrestrial fossils in the sedimentary rocks.

INTERPRETATION

Conventional science: During much of earth history, sea level was high enough to cover the continents with shallow epicontinental seas, depositing marine sediments on the continents. The nature of pre-Jurassic ocean floors is not known. Why ocean floors during and after Jurassic do not have abundant marine fossils and sediments is not clear.

Interventionism: During the flood, the existing continents were the lowest area, and marine fossils were deposited in the new sediments on these depressed regions. Perhaps these areas were seas before the flood. The nature of pre-Jurassic ocean floors is not known. The existing ocean floors were raised above the existing continents during the flood. This is why existing oceans do not have abundant marine fossiliferous sediment during the Jurassic and for most of the time after the Jurassic.

Mountain Building and Overthrusts

In North America, the Rocky Mountains began to form in the Jurassic, but the process continued as the Cretaceous and Early Cenozoic deposits were forming. As the Rockies pushed upward, basins were formed between the mountain ranges (fig. 16.3). Sedimentation now occurred in these basins and in other localized areas rather than over vast areas as commonly occurred in the Paleozoic and Mesozoic (fig. 16.3A). During the uplifting of the mountain ranges, erosion removed the sediments that formed the tops of the mountains, exposing the granite that now forms the high peaks of the ranges. The remnants of these sedimentary rock formations that once covered the entire area are tilted up against the sides of the uplifted mountains (fig. 16.4).

In some places, a formation or series of formations evidently was broken at a fault zone and then the strata on

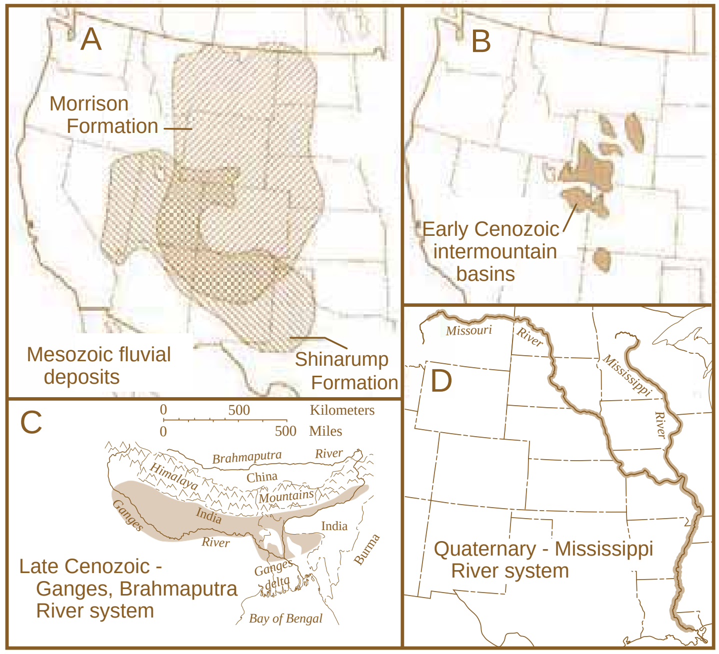


Figure 16.3. Distribution of (A) some widespread Paleozoic formations, (B) some of the Tertiary sedimentary basins of Wyoming (after Cook et al. 1975; Cooper et al. 1990; Dodson et al. 1980; Dubiel 1994), and (C, D) two modern river sedimentary basins. All to the same scale. Figure by Leonard Brand.

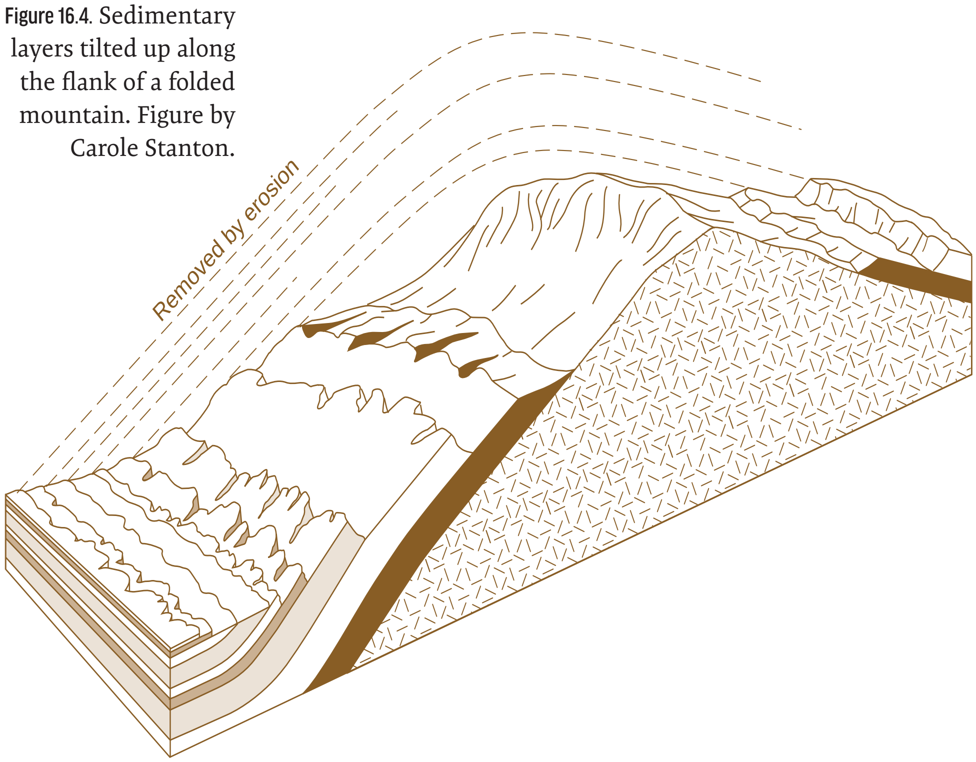
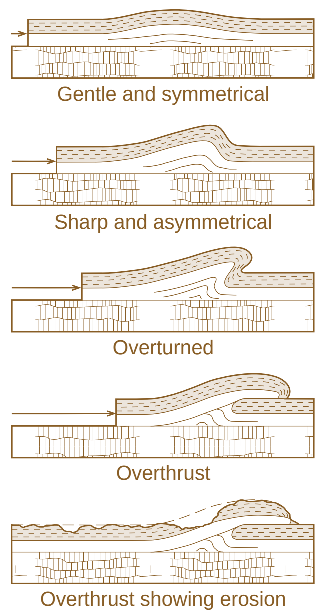


Figure 16.4. Sedimentary layers tilted up along the flank of a folded mountain. Figure by Carole Stanton.

one side were pushed up and over the top of the same strata on the other side of the fault (fig. 16.5) to form overthrusts.[9] One result of an overthrust is that older rocks are sitting on top of younger rocks. These exist in a number of places around the world, and a large part of the Canadian Rockies is a gigantic overthrust belt (fig. 16.6). In a global catastrophe in which continents are actually moving around the earth, it is no surprise that some rock strata have slid over the top of other rock for many miles. It seems easier for this to happen rapidly while the sediments are submerged as in a catastrophic model.

Figure 16.5. Cross-section illustrating the formation of an overthrust. The sedimentary layers are pushed from the left, buckle to form an overthrusted mountain, and erode to the modern form of the mountain (see fig. 16.6; after Eardley 1965). Figure by Carole Stanton.



Landscape Formation

During the transition period after the catastrophe, a lot of water was moving around on the earth. The newly formed landscape was not yet in equilibrium, and tremendous erosion could occur rapidly. Probably much of the present spectacular scenery—like the Grand Canyon, the San Juan River meanders, the Grand Staircase, and many other canyons and cliffs—was carved during the time after the main catastrophe. Steve Austin has proposed a hypothesis for the carving of the Grand Canyon by catastrophic draining of a large inland lake.[10] Experiments by John Koss and colleagues indicate that when a continental area is underwater and the water level drops to expose the land,

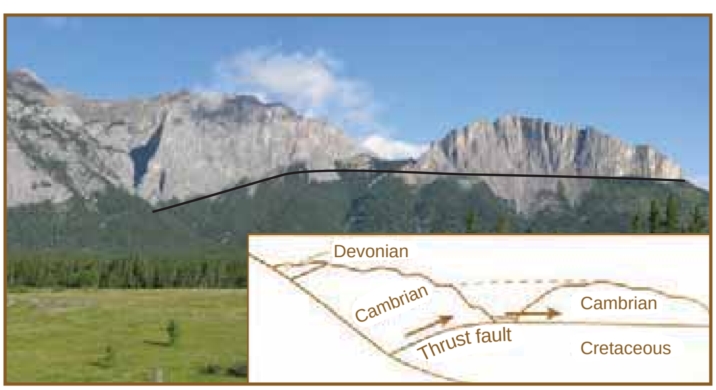


Figure 16.6. Photo of overthrusted strata in the Canadian Rockies. Sediments above the thrust fault have moved toward the right, over the top of younger strata below the fault. Subsequent erosion has removed part of the sediment, leaving these remnants. Figure by Leonard Brand.

one result is the carving of canyons or valleys.[11] They did not invoke a catastrophic theory in their discussion, but a global catastrophe would explain where all that water came from. Some of this erosion occurred after the major erosive events associated directly with the flood, since we find eroded surfaces in many places covered by more recent basalt flows. Where this is so, erosion that disrupts the continuity of the basalt flows must have happened subsequent to the flow and thus after the erosion of the surface on which the basalt rests. Erosional evidence in some places seems best explained by a second, later episode of erosion in connection with the Pleistocene glaciations farther north.

Sequence of Vertebrates and Plants in the Fossil Record

As we discussed in chapters 11 and 12, invertebrates and fish-like vertebrate fossils occur in the Early Cambrian, other fish appear somewhat later, then amphibians, reptiles, mammals, birds, and flowering plants, in that order. That fossil sequence comprises the data, and our goal is to interpret the data as a sequence of events during the catastrophe rather than as an evolutionary sequence. If a massive flood occurred today, we would expect, as a general rule, to see a succession of forms from different habitats buried in turn as sediments of the catastrophe filled in the marine basins and began to cover the land. For example, on a continental scale, we would expect the first deposits in the ocean basin to contain marine invertebrates, but not tetrapods (fig. 16.7). Other factors would also influence when each vertebrate group began to be buried (table 16.1). The three factors in the table tend to support each other. Since they all work together, it is somewhat more feasible to suggest that the combination of these three factors could contribute toward producing the general sequence we see in the fossil record.

The fossil record does follow this expected sequence of marine forms first, then sediments with an increasing

Figure 16.7. The ecological zonation model (or biome succession), showing the relationship between a hypothetical pre-flood landscape and the sequence in which the fossils were preserved in the geological column (after Clark 1946). Figure by Robert Knabenbauer.

percentage of terrestrial forms. However, there are difficulties that we must also consider. For example, why is there no flowering plant pollen below the Middle Cretaceous? Pollen is easily carried long distances by wind or water. Why are there not at least a few mice or sparrows in Paleozoic or Mesozoic deposits? In other words, why did animals and plants from "higher life zones" not mix with those in "lower zones" during the massive river and valley flooding that was presumably going on? Our current understanding of this model leaves many unanswered questions. But in broad strokes, it offers a beginning on which to build better answers.

Table 16.1. Factors expected to influence when the first examples of each vertebrate class were overcome by the global catastrophe

	Ecology	Behavior	Mobility	Mean
Birds	4	4	4	4.0
Mammals	4	5	3	4.0
Reptiles	3	3	2	2.7
Amphibians	2	2	1	1.7
Fish	1	1	—	0.7

Ecology = successive elevations in a hypothesized pre-flood ecology; behavior = intelligence and behavioral adaptability. Mobility of fish is not ranked because the mobility of aquatic and terrestrial animals cannot be directly compared in this context.

Other factors perhaps could have significantly influenced the time at which many groups met their demise. As the catastrophic destruction progressed, we would expect changes in water temperature; changes in the chemistry of seas and lakes, from mixing of fresh and salt water; and contamination by leaching of other chemicals into the water. Each species of aquatic organism would have its own physiological tolerance for these changes. The result could be a sequence of mass mortalities of different groups as the water quality changed. Changes in turbidity of the water, pollution of the air by volcanic ash, or changes in air temperature could have similar effects.

A great diversity of bird, mammal, and flowering plant fossils is found in the Cenozoic sediments (fig. 11.14). Perhaps these groups were largely inhabitants of upland regions that were not affected until late in the geological catastrophe. In the post-flood world, these groups were able to survive, but many other groups of animals and plants did not survive long in the cooler post-flood world.

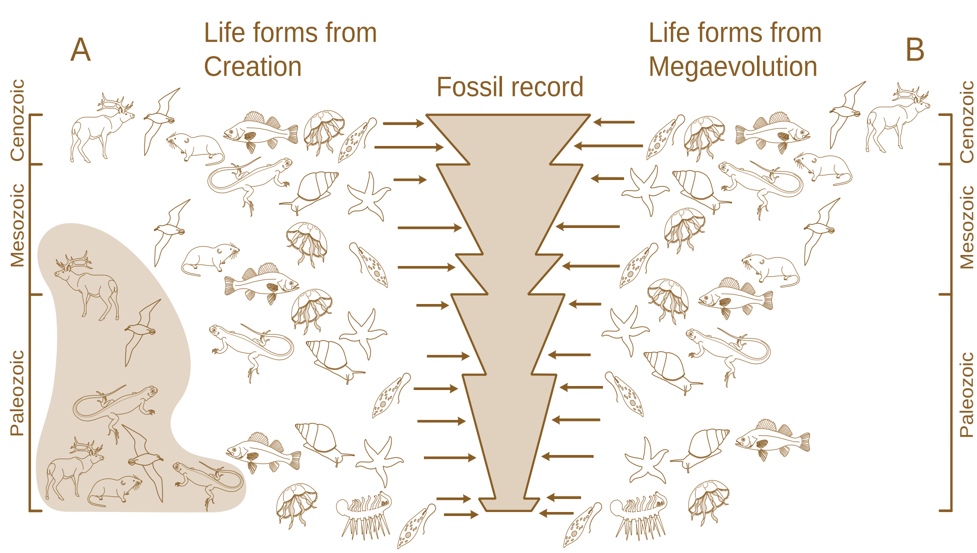
There are several major changes as we go up through the fossil record involving mass extinctions and new types of organisms entering the fossil record. At the top of the Permian was a mass extinction of many animals (fig. 10.1), and a whole different spectrum of animals and plants appeared in the Mesozoic fossil record. There are still marine invertebrates and vertebrates, but many new terrestrial forms are introduced, including reptiles, dinosaurs, mammals, and land plants. Finally in the Cretaceous, the flowering plants make their first widespread appearance in the rocks, but they do occur lower. A perfect angiosperm flower has been found in the Jurassic.[12]

At the end of Cretaceous rocks, another major extinction sees the terrestrial dinosaurs, and many forms of marine reptiles and cephalopods disappear from the fossil record. Above that, Cenozoic deposits record the great diversity of the mammals and birds, along with the flowering plants. In the marine realm are modern types of corals, echinoderms, molluscs, fish, and marine mammals in profusion. These Cenozoic plants and animals are the forms we are familiar with in our environments today. These changes in the fossils do not represent the appearance of newly created organisms. They resulted from the successive final destruction of some habitats and the death and burial of organisms from each of those habitats as the catastrophe unfolds. For data and interpretations, see "Interpreting the sequence of fossils in the rock record" on page 282.

A biblical model of earth history that begins with a literal creation and then evil introduced by human sin requires that humans and other modern animals existed from the beginning, even during early stages of the geological column (fig. 16.8). How could they have been there and not be found as fossils in those lower sediment layers?

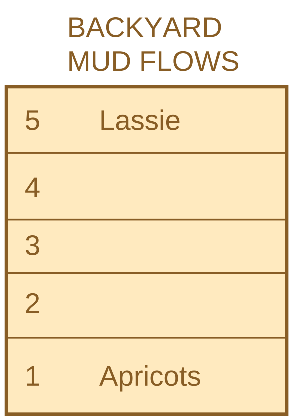
An analogy may help explain the concept.[13] A storm deposits a layer of mud in your backyard. This happens five times before you have time to clean it up. The five layers are a sequence in time, with the lowest layer formed first. You find some fascinating things as you dig through the layers. There are apricot pits, only in the lowest layer. There is also some doggie poop, but only in the fifth, uppermost layer. From these data, we can devise a theory to explain the sequence of events. There must have been at least one apricot tree, but only during the first storm. Using DNA, you trace the doggie poop to Lassie, a few houses down the street. Lassie must not have been there until the fifth storm.

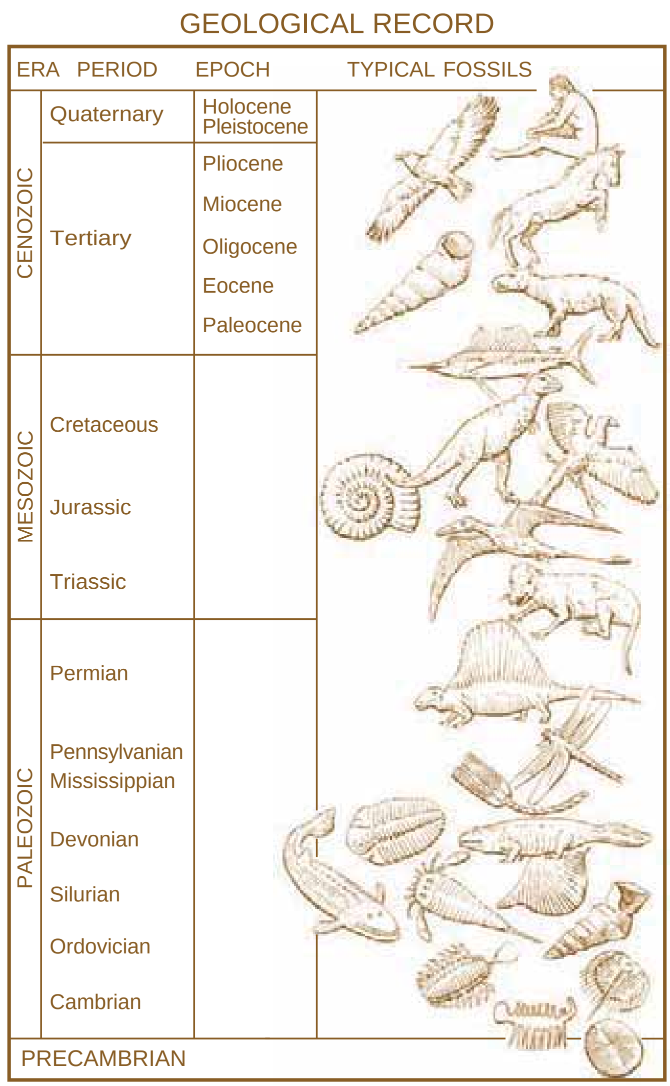
Figure 16.8. Representative types of animals, showing their theorized presence or absence at different times in earth history under (A) interventionist theory with all basic life forms present from the creation event and (B) conventional geological theory. Shaded area includes animal types present early in earth history but not preserved in the fossil record at that time. Figure is diagrammatic and does not imply that any given animal type was just the same all through history (Brand 2006a).



As we evaluate this theory, we have one advantage that is missing in normal paleontology research—we were there during the five storms and have access to a reliable record of what happened. We know there was indeed an apricot tree, and it was uprooted by the first storm. So far so good. However, we also know that Lassie was there during, and before, the five storms. How could the evidence have misled us so badly? More digging raises the neighbors' suspicions, but it answers our questions. We find that the fifth mud flow followed a little different path, and it was the only mud flow that went through Lassie's

Figure 16.9. Five backyard mud flows and the geologic column. Figure by Robert Knabenbauer and Leonard Brand.





yard. Lassie was there during the first four mud flows, but not in a situation that could preserve evidence of his presence.

The fossil record is like our five backyard mud flows but much larger (fig. 16.9). During the Paleozoic, Mesozoic, and Early Cenozoic, the humans and other modern types of animals must have been living someplace where fossils were not forming. This is somewhat analogous to the coelacanth fish that were thought to have been extinct for sixty-five million years until live specimens were caught in 1939. They were not living in situations conducive to fossilization during the Cenozoic.

The only way to get fully trustworthy answers to our questions of when and where humans were living through history would be from an eyewitness account, as in the Lassie study. In the study of the fossil record, we were not there, so we don't have access to eyewitness evidence. The only source that claims to provide such evidence is the Bible, but most scientists don't accept this as evidence. It comes down to this: Do we have more confidence in God's Word, inspired by One who observed the formation of the fossil record, or do we have more confidence in the opinions of humans, who were not there?

Another feature of the fossil record is the detailed sequences of different types of some organisms in the record, like foraminifera (one-celled marine organisms), ammonites (fig. 16.10), and trilobites in marine deposits. They occur in a series of zones, with slightly different species in each successive zone. Short-age geology proposes that these zones—at least in the Paleozoic and Mesozoic—resulted from a sorting process in the flood rather than from evolution. For example, as the flood waters reached progressively higher ecological zones (or biomes), they killed and fossilized the differing types of organisms found in each ecological zone. An alternative is that changing water chemistry or temperature or turbidity could have killed different types of organisms at different times.

See "Interpreting the sequence of fossils in the rock record" (p. 282) for an evaluation of this issue.

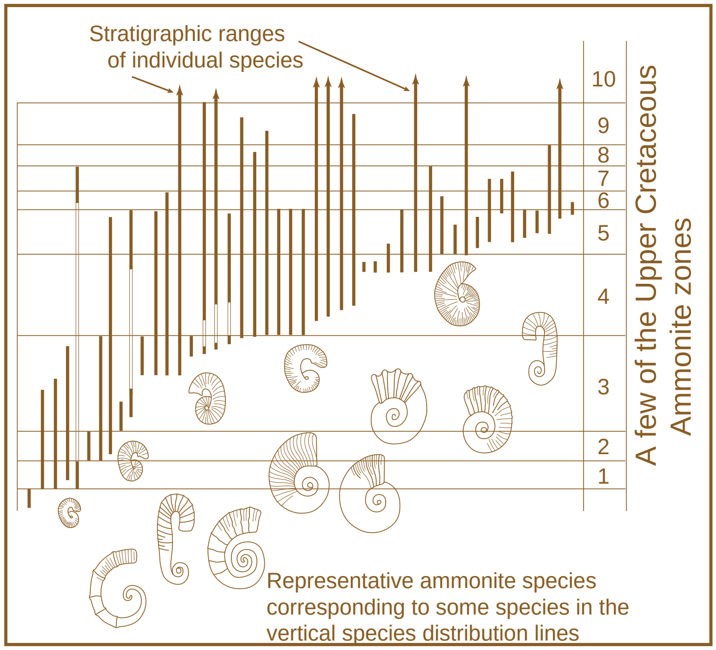


Figure 16.10. An example of fossil zonation: several arbitrarily numbered ammonite zones in the Upper Cretaceous. The vertical lines are species ranges, showing the beginning and end of the range of that species in the fossil record. The lines with arrows at the upper end are species whose stratigraphic ranges extend into higher levels. Each zone is characterized by the presence of one or more specific ammonite species and the absence of other species (after Cobban 1951; Wiedmann 1969; and Kauffman et al. 1993). Figure by Leonard Brand.

Flood Survival and Post-flood Biogeography

At some point during the deposition of the Cenozoic formations, animals began spreading over the earth and establishing themselves on the new landscape. How did they get where they are now? Did they all leave the ark and find their way to new homes? This topic includes significant challenges that short-age theorists must address. First, we should recognize that the story of the ark involves only a small portion of the animals, specifically the air-breathing terrestrial animals. The spread of plants apparently depended on seeds that were carried far and wide by the water and then landed, sprouted, and survived in areas where the environment was right for them. It could be that some seedlings or other plants also survived long enough in the water or on floating debris to settle in the mud and grow.

Marine animals had to make their own way. They were in the water, their own element, and survival and geographic spread depended on their ability to tolerate such conditions in the water as turbidity, chemical changes, temperature changes, and destruction of critically needed breeding grounds.

Fresh-water organisms faced a different type of challenge since it appears that some suddenly found themselves in a body of salt water. There is a process in the modern world that may have reduced this problem for them. As fresh water from large rivers spills out onto the ocean today, the less dense fresh water does not mix quickly with the salt water. During the flood, fresh water may have remained on top long enough to provide a temporary refuge for fresh-water organisms. Perhaps, too, many animals have a greater potential for adaptation to changing water conditions than we have recognized (or did at that time).

The terrestrial invertebrates probably had more options for survival. An enormous amount of floating plant debris, perhaps even floating islands, would mean that animals could live for a long time during the catastrophe until they landed on a newly emerged land surface. This would be especially true for upland invertebrates whose environments were the last to be uprooted during the catastrophe. The groups of organisms affected last during the flood spent the shortest time in the water before finding new homes. These would be the groups most likely to survive into the new post-flood world.

The sequence of events in the geological record suggests that new mountains were appearing before the old land surface was all destroyed. The flood was a complex event. Thus even though the pre-flood mountains were covered (and no doubt destroyed), we cannot necessarily assume that all the land was covered at the same time. This would favor the survival of many invertebrates that could find shelter on the available land.

The biggest questions involve the terrestrial vertebrates. These seem to be the animals described as surviving the flood on the ark and then being released on the post-flood earth. Did modern biogeographic distributions of the terrestrial vertebrates result from the spread of all of these groups from the ark in Asia Minor to their present location? It would not be too hard to explain the horses, elephants, rabbits, and a variety of other animals, but what about the kangaroos and numerous other marsupials of

Australia, the tree-dwelling sloths of South America (they cannot walk effectively on the ground), or the pocket gophers that live only in North America? Did the complex of closely related rodent families found only in South America all stick together as they avoided other continents and made their way to, and only to, South America? This situation is complicated further by the fact that their fossil relatives also are found only in South America.

A large number of mammal families have a fossil record and modern distribution limited to only one continent. Did they travel from the ark and return only to their original home without even leaving any fossils along the way? This could happen by chance for a few families, especially if their home was a continent readily accessible to Asia Minor. However, fifty-nine families of mammals fit this pattern (table 16.2), and the continents with the highest percentage of endemic families (unique to one continent) are Australia and South America, two continents that are farthest removed from Asia Minor and the most difficult to reach from there. This enigma is considerably reduced if all or most of the Cenozoic fossil record formed after the flood, but it is one of the biggest unanswered short-age geology questions.

How animals and plants have been distributed to their present locations was at one time mostly explained by

Table 16.2. Number of endemic mammal families in six paleogeographic regions (compared with total number of mammal families)

Paleogeographic region	Total families	Endemic families	
		No.	% of total
Neotropic (South and Central America)	39	24	62
Australian	16	14	88
Nearctic (North America)	23	2	9
Ethiopian (Africa)	37	13	35
Oriental (Southeast Asia)	31	4	13
Palearctic (Europe and Asia)	32	2	6
Total	**101**	**59**	**58**

vicariance biogeography. According to this theory, their distribution is explained by the movements of continents, carrying groups of organisms with them. In this way, for example, the New World primates became separated from Old World primates and the two groups diverged.

However, since about 2004, biogeographers have been willing to acknowledge that vicariance biogeography doesn't explain present distributions. Much of the evidence can only be explained by rafting across oceans on floating debris.[14] This explanation is very compatible with flood geology, since a huge amount of floating plant debris would be expected during and after a global flood catastrophe. Floating islands have been known in modern times, and these also could have been common.

Recovery from Catastrophe: After the Flood

From Very Widespread Geology to Localized Deposits

The geological catastrophe is not likely to have ended suddenly but rather with a transition to less catastrophic conditions, progressively more like the relatively stable

Biogeography: The spread of organisms over the earth

DATA

Documented geographic distributions of living animals and plants. Geographic distribution of fossils and their verifiable location in rock units.

INTERPRETATION

Conventional science: Geographic distributions of fossil organisms was the result of their movements as they evolved and adapted to different habitats over millions of years. Modern distribution of organisms is just the latest result of the process described above.

Short-age geology: Geographic distribution of at least Lower Paleozoic marine fossils probably indicates original living place. Geographic distribution of many other fossils resulted primarily from transport processes during the flood. Biogeographic processes after the flood were essentially the same as in conventional biogeography, but over a shorter time period. Spread of animals and plants by rafting is known to be important in conventional biogeography and would no doubt be even more important in and after a global flood catastrophe.

earth we know. There was also a gradual change from large-scale to smaller-scale geological processes. Paleozoic and Mesozoic sedimentary deposits generally cover very widespread areas, with individual deposits extending over 150,000 square miles or more. Then, in the Cenozoic, there is a change to more local basin-fill deposits between the newly forming mountain ranges (fig. 16.3). In modern times, the size of depositional areas are much smaller yet, as in river valleys instead of extensive fluvial deposits.

Volcanism

A lot of volcanic activity occurred during and after the flood process. The volcanoes produced ash deposits, lava flows, or deposits of volcanic breccia. Yellowstone National Park contains primarily deposits of volcanic breccia and ash. During the Eocene, the trees of the Yellowstone fossil forests were being buried by breccia flows.[15] Perhaps they were deposited while this area was still under water, or at least while there was enough rain and standing water to produce mudslides down the sides of the volcanoes, burying the trees as has happened at Mount St. Helens.

In other areas, extensive amounts of molten lava flowed from long fissures and formed enormous deposits called flood basalts, forming plateaus (table 16.3).[16] A notable example is the Columbia River Basalt, a series of thick basalt layers covering eastern Washington and Oregon (fig. 16.11). This enormous deposit of lava dwarfs

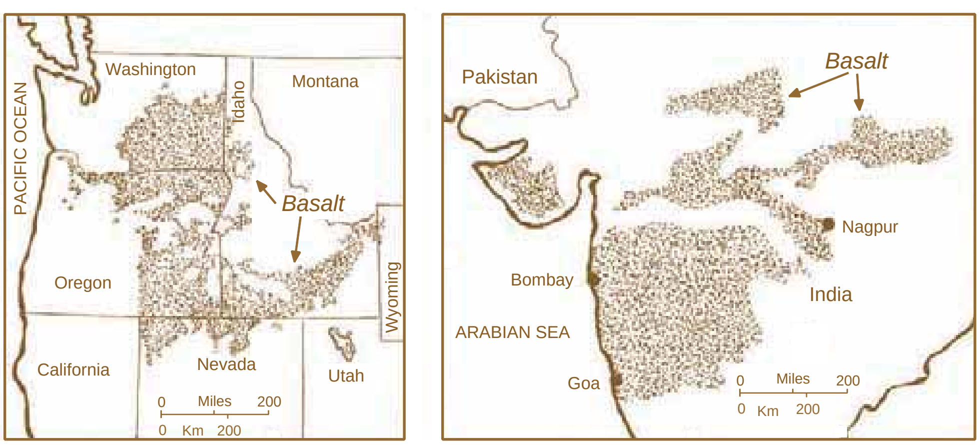


Figure 16.11. The distribution of (left) the Colombia River Basalt in the northwestern United States and (right) a large basalt field in the Deccan Plateau in India (after Longwell et al. 1969). Figure by Robert Knabenbauer.

Table 16.3. Basalt plateaus (flood basalts)

Basalt plateau	Area (km^2)	Average thickness (m)
Snake River Plain, Idaho	50,000	
Columbia River Basalt, NW United States	164,000	1,000
Deccan Traps, India	500,000	650
Parana Plateau, Brazil	1,200,000	650
Karroo Basalts, South Africa	2,000,000	700
Siberian Platform, Russia	2,500,000	360
Northern Australia	400,000	1,000
Great Lakes region, United States and Canada	100,000	Up to 5,000

Data from Monroe and Wicander 1992

anything we see happening today but is small compared to some other flood basalts. The only area where this type of deposit is still forming is in Iceland.

Shrinking Lakes and Mineral Deposits and Drying Deserts

The trend from very widespread deposits to more local deposits can be seen in lake deposits. There is compelling evidence for many large basin-filling lakes in the time following the flood, which later dried up. An example is ancient Lake Gosiute in Wyoming, which formed the Eocene Green River Formation in Wyoming, Utah, and Colorado, with its limestones and millions of fossil fish, shoreline reefs formed by stromatolites, and other fossils (fig. 16.12A).[17] Meanwhile fine-grained volcanic sediments and coarser sediments eroded from adjacent mountains were forming the Wasatch and Bridger Formations, the flood-plain deposits associated with Lake Gosiute (fig. 16.12B). Finally this entire depositional system changed to the dry valleys now existing there.

Later there was a Pleistocene episode of temporary large lakes in western North America. In Utah and surrounding areas, the giant Pleistocene Lake Bonneville was one such lake. At its peak, Lake Bonneville covered most of the western half of Utah and parts of Idaho and Nevada.

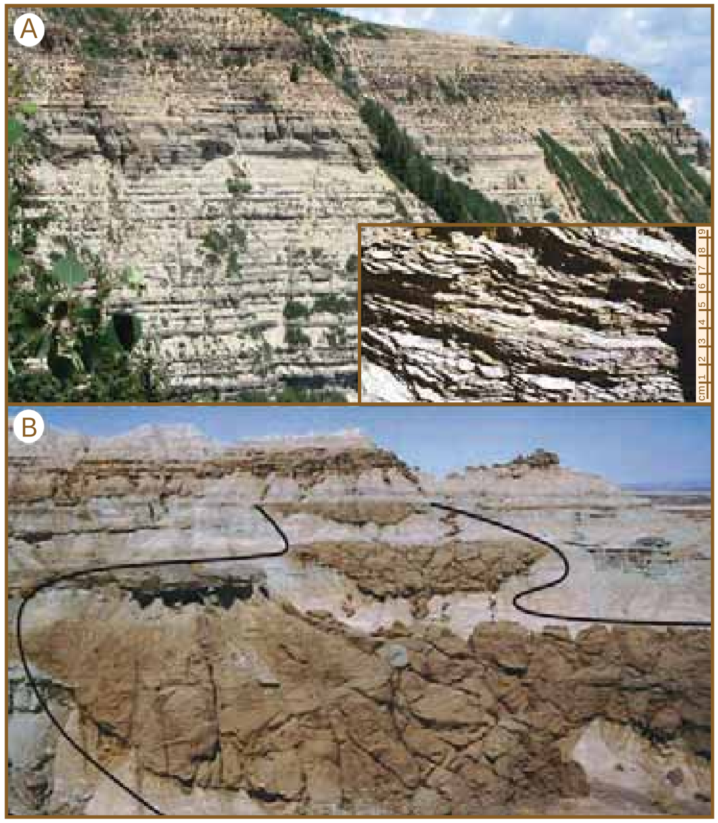


Figure 16.12. (A) The Eocene Green River Formation, consisting mostly of finely laminated lake sediments, containing millions of fossil fish and other vertebrates. Inset: Close-up of laminations (scale in cm). (B) The Eocene Bridger Formation in Wyoming, which contains numerous vertebrate and invertebrate fossils. The curved lines outline the approximate boundaries of an ancient river channel. Three cross-sections of the channel are still in place, surrounded by flood plain deposits. Figure by Leonard Brand.

It was 325 miles long and more than 1,000 feet deep in the central portion. Its ancient shorelines are prominent features in many parts of central Utah today. Apparently, at some point during the Pleistocene, the lake broke through a dam of boulders and debris in Idaho and emptied out catastrophically. At peak outflow, its emptying rate equaled the combined flow of all the rivers in the world. Today, by contrast, all that remain are Great Salt Lake and nearby Bear Lake, near Salt Lake City. Many desert valleys in California, Nevada, and Utah were also filled with water (fig. 16.13).[18] In eastern Washington State, the Channeled Scablands resulted from the rapid draining of another lake, Pleistocene Lake Missoula (fig. 14.14). All these lakes shriveled in size or ended as dry salt pans in desert valleys. In review of this section, note that there are two times when ancient lakes occupied part of the western United States—first the extensive Eocene lakes depositing the Green River Formation and later the large Pleistocene lakes farther to the west.

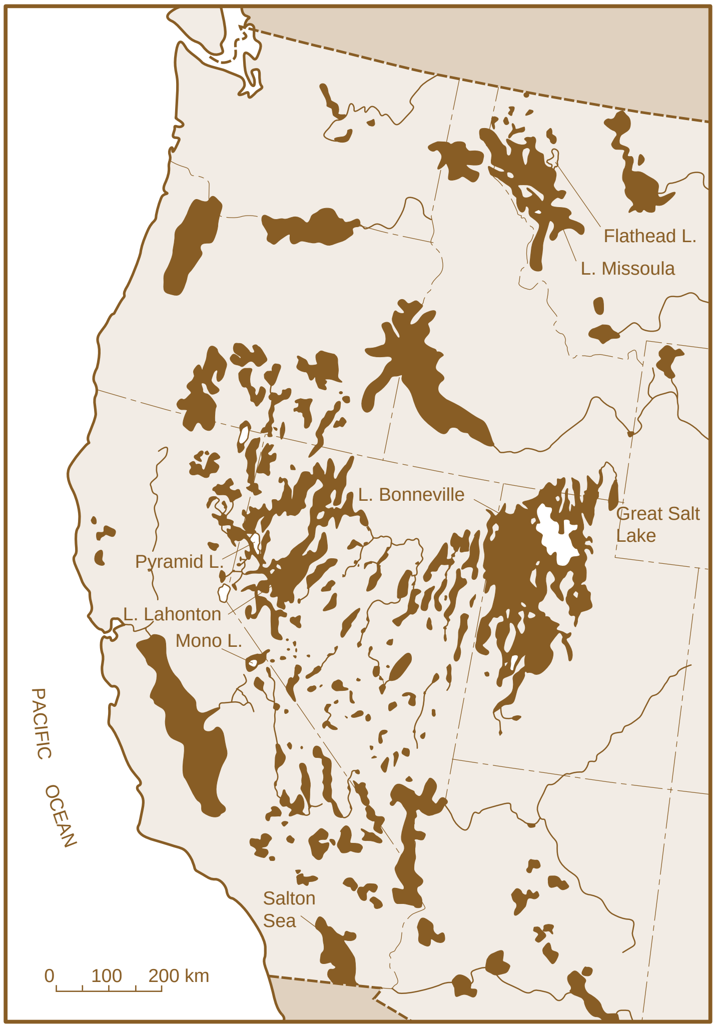


Figure 16.13. Pleistocene lakes that filled basins in the western United States at the end of the ice age (after Foster 1969). Figure by Carole Stanton.

A mineral spring deposit in Death Valley, California, illustrates on a smaller scale the same trend to more and more local deposits at the end of the Cenozoic (fig. 16.14). In the Pleistocene, a sheet of water from a large mineral spring flowed over a wide stretch of hillside, depositing layers of tufa (fig. 16.14A). Through time, the spring dwindled, while part of the original tufa eroded away and a much reduced flow of water from the same spring deposited tufa over a smaller, lower hill (fig. 16.14B). Today more of the tufa deposits have been eroded away, and the small remaining spring has regressed down into a newly eroded ravine (fig. 16.14C). The small stream from the

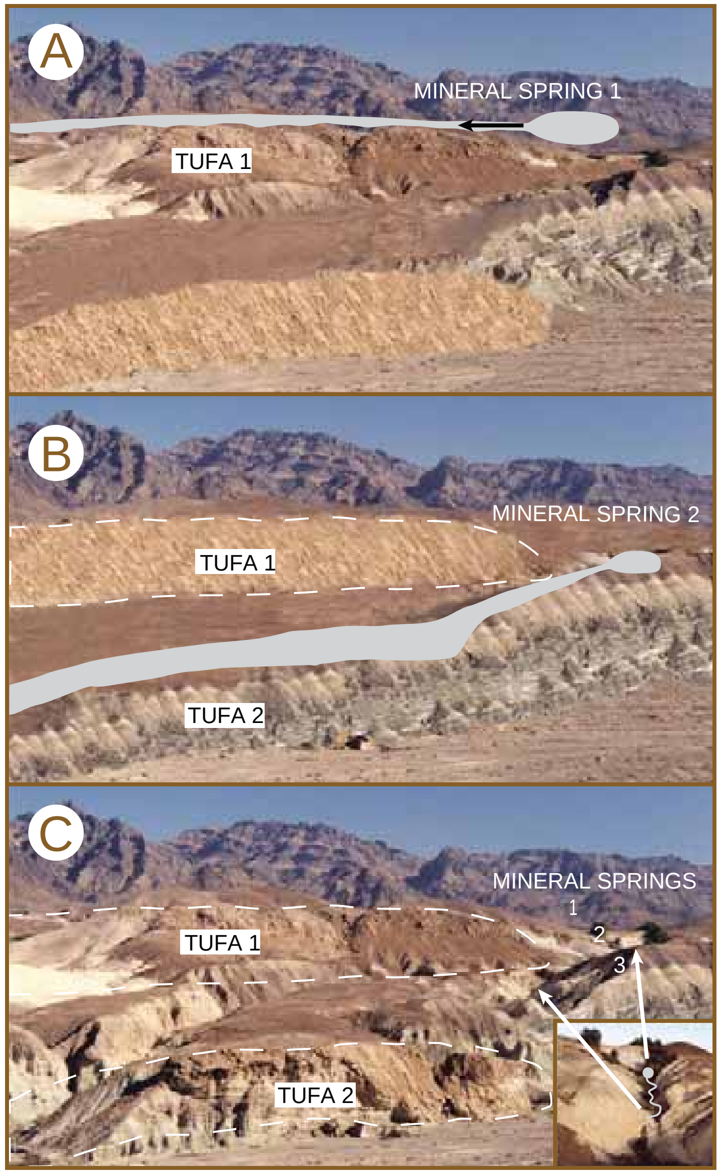


Figure 16.14. A mineral water spring in Death Valley National Park, showing (A) its size in the Pleistocene; (B) its smaller size at a later time, forming a second tufa deposit at a lower elevation; and (C) its very small size today, forming only mineral deposits along a small stream in a new gulley and on the stream-side vegetation. The first two tufas have mostly eroded away. Photos in A and B have been altered to reconstruct the estimated extent of tufa deposits at early stages. Photo C shows the actual remaining deposits today. Stage A probably had several other springs feeding the developing tufa deposit. Figure by Leonard Brand.

spring coats plants and rocks with the same mineral that formed the large tufa deposits.

During the Pleistocene, the Mojave Desert in southern California gradually changed from a mesic pinyon pine and juniper woodland to the desert we know today. This change is documented in sequential fossil deposits and in the pollen, plant debris, and bones found in ancient desert woodrat middens. The area has gone from enormous lakes to watered deserts to today's dry, desolate deserts.

Vertebrate Fossils and Trackways

While the Cenozoic processes were moving toward smaller, more localized deposits, the sediments they deposited contained abundant and diverse mammal and bird fossils, which were rare in the Mesozoic. The Upper Cenozoic also holds more direct evidence of bird and mammal activity that must have been post-flood. Many types of mammal footprints are found in Cenozoic deposits (especially the Upper Cenozoic). Almost all of them were made by carnivores, ungulates (hoofed mammals), or elephants but also include corkscrew-shaped burrows of extinct giant beavers. Fossil bird footprints are not as common as mammal prints, but the majority of those that have been found are also in Upper Cenozoic deposits (fig. 16.15). Many of these footprints probably can be interpreted as post-flood

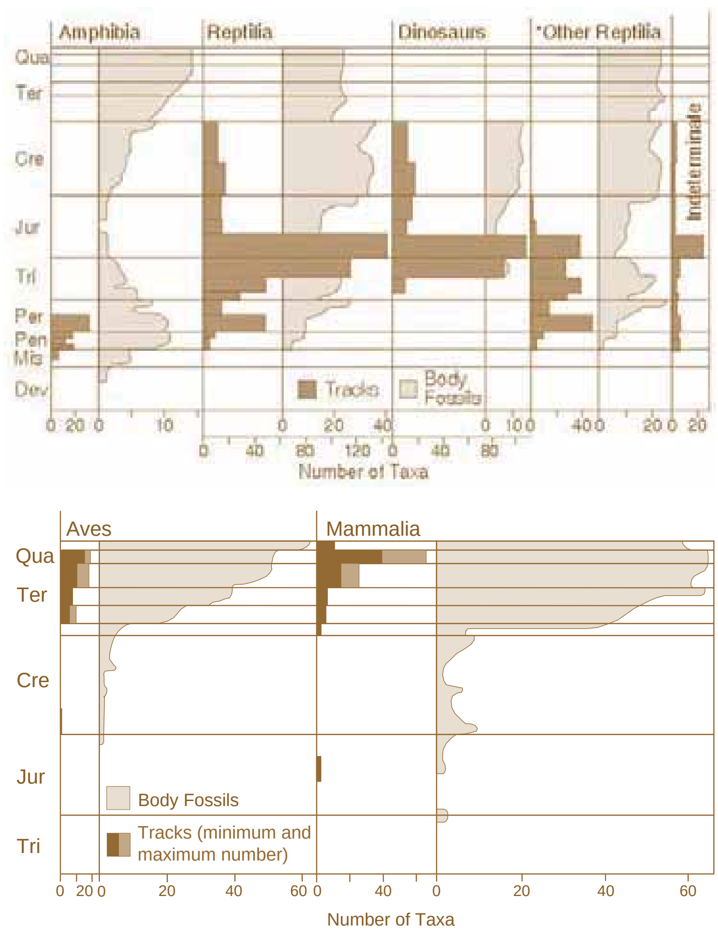


Figure 16.15. Stratigraphic distribution of fossil bird and mammal tracks and body fossils (from Brand and Florence 1982). Figure by Leonard Brand.

fossils. One might ask why there are not at least a few mammal and bird tracks in flood deposits lower in the geologic column. Perhaps there are. Some bird and mammal tracks are found in Mesozoic deposits, and at least two papers in the paleontological literature report fossils that look just like bird tracks (fig. 16.16). However, since they are found in Paleozoic formations, they are labeled merely as unidentified tracks.[19]

Post-flood Glaciation

The Pleistocene clearly represents events that occurred after the flood. Something happened to change the climate, bringing on the Pleistocene glaciation (fig. 14.19). After that episode, earth's climate warmed up again and the ice melted back to expose more land. It appears that there may have been a few cycles of retreat and advance of the glacial front. When all the ice was on the land, enough water was frozen up in the glaciers to lower ocean levels as much as three hundred feet.

It was during and after glaciation that the large lakes, mentioned above, developed in western North America (fig. 16.13). The shorelines of these Pleistocene lakes can be seen in the desert basins in Nevada and especially in Utah along the Wasatch Mountains (fig. 16.17) from Salt Lake City south to Provo and beyond. Interventionists sometimes cite these old shorelines as evidence of the receding waters of the flood. But the flood waters certainly

Figure 16.16. Two bird-like tracks from Paleozoic sediments (after [A] Sternberg 1933 and [B] Gilmore 1927). Figure by Robert Knabenbauer.

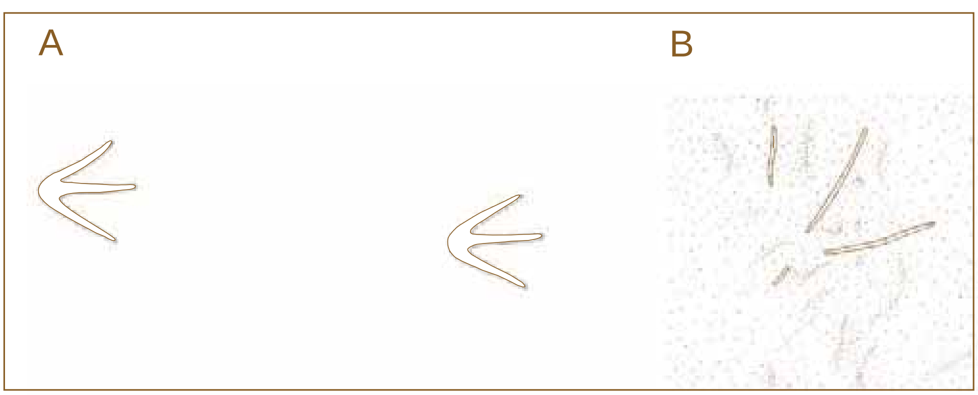


Figure 16.17. Old shorelines (arrow) of ancient Lake Bonneville, north of Salt Lake City, Utah. Figure by Leonard Brand.

must have been gone before glaciation, and these shorelines are likely from the receding of the glacial waters.

At the same time, the earth's crust was readjusting after glaciation. The tremendous weight of the ice pushed the earth's crust down. As the ice melted, the land rebounded, rising to a new stable position. Also it seems there were other crustal movements resulting from causes other than glaciation. In some places, a significant elevation change took place, even in the last two thousand years, as can be seen in Italy (fig. 16.18). The ruins of a Roman market, within a few blocks of the ocean, are now partly under water. These buildings were above sea level in the second century A.D. Then they sank slowly until during the Middle Ages when marine, boring animals made their burrows in the stone columns eighteen feet above the floor level of the structure. Before A.D. 1500, the area began to rise again. Now it is under only a few feet of water.[20] These ancient buildings in Italy provide evidence of continuing adjustments of the earth's crust long after glaciation. The adjustments are still occurring. In the last one hundred years, parts of Scandinavia have risen about a meter (3 ft) and part of Romania has sunk about a meter. Many parts of the earth move up or down one or a few centimeters per year.

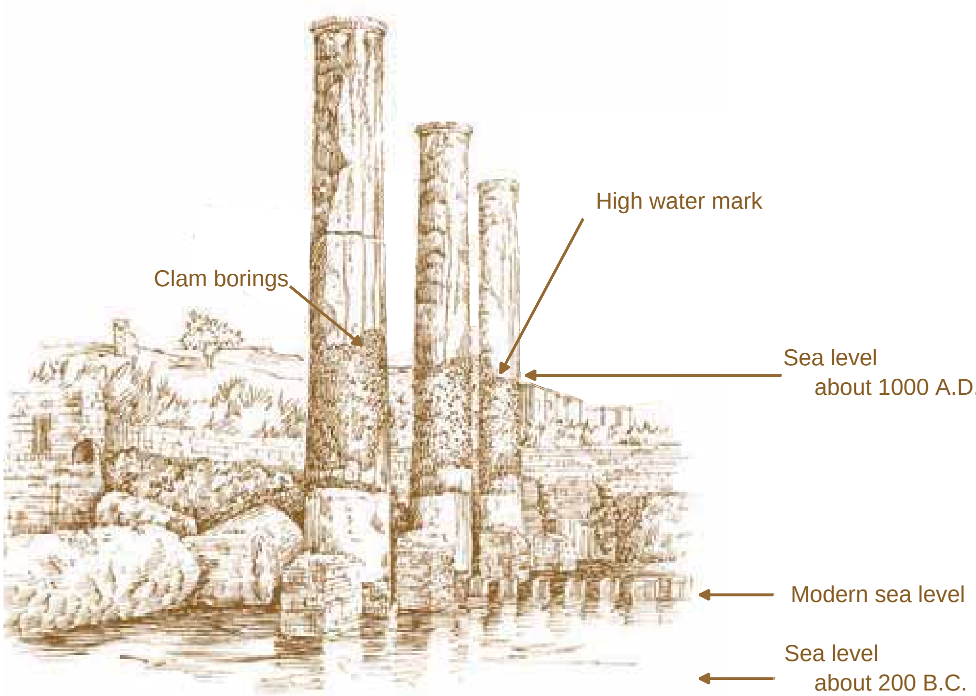


Figure 16.18. Roman ruins near Naples, Italy, showing evidence of submergence and more recent rise above sea level (after Longwell et al. 1969). Figure by Robert Knabenbauer.

Glaciation had a profound influence on the climate in the northern hemisphere. When northern Europe and North America were covered with ice, the rest of Europe and eastern North America were covered mostly by tundra and coniferous forest. As the glaciers melted, the plant communities moved north until today tundra is found only in the far north and on mountain peaks. The coniferous forest is in the mountains and in northern Canada. Most of Europe and eastern North America are covered by deciduous forest (fig. 16.19).[21]

The changes in climate were accompanied by changes in the distributions of animals. In North America, the muskox and a very small animal, the arctic shrew, are found now only in the northern part of Alaska and Canada. Pleistocene fossils of muskox and arctic shrews from glacial times can be found much farther south in the central United States (fig. 16.20).[22] It appears that since the glaciers disappeared, the climate has changed accordingly. The life zones have all moved northward. Conventional geology and short-age geology agree on this basic sequence of events, but short-age

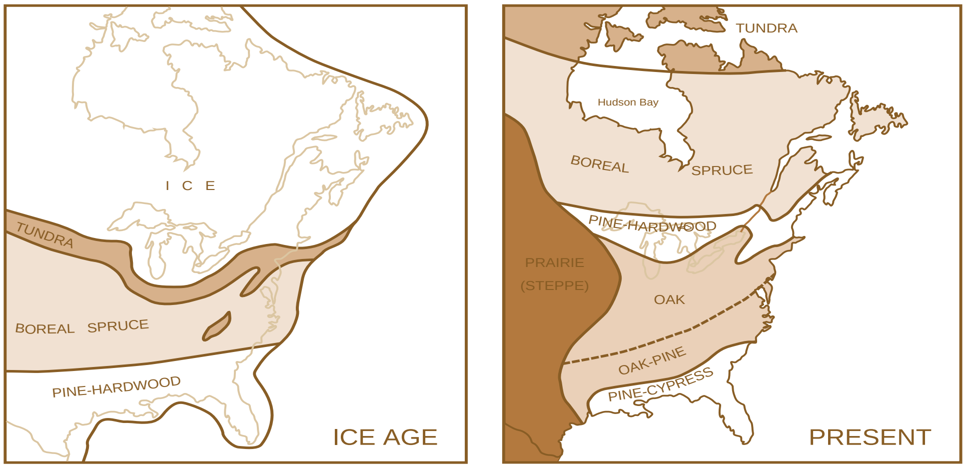


Figure 16.19. Distribution of vegetation types in eastern North America during the ice age and current distribution (after Dott and Prothero 1994). Figure by Carole Stanton.

geology proposes that they occurred over a much shorter time span.

One feature of the mammal fossil record during this time of substantial climate change is difficult to reconcile with the evolution theory. Changing climate is expected to initiate microevolutionary change in animals. However, mammal fossils do not show any such change during the cycles of glaciation. The La Brea Tar Pits in southern California show shifts from dry chaparral shrub to snowy pinyon pine forests during the peak of glaciation twenty thousand years ago and then back to dry chaparral. Yet none of the common ice age mammals and birds showed any change over the last thirty-five thousand years of geological time.[23]

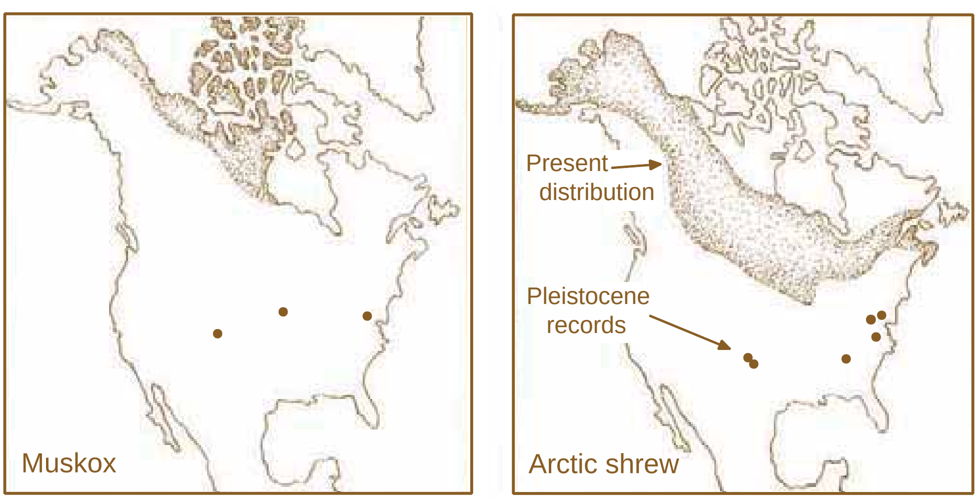


Figure 16.20. Modern and Pleistocene distribution of the arctic shrew and the muskox (after Hibbard et al. 1965). Figure by Robert Knabenbauer.

Post-flood Humans and Other Fossils

In North America during the Pleistocene, a fauna of large game animals comparable to the type of fauna that now exists in Africa populated the land. At that time, the Los Angeles region looked quite different from today. Mammoths, mastodons, wild horses, lions similar to African lions, wolves, saber tooth cats, huge ground sloths, dire wolves, camels, and other exotic, wild mammals were roaming the area.[24] A variety of birds lived there also, including vultures and a type of condor larger than our modern condors. An impressive accumulation of skeletons of these animals was preserved in the tar pools now called the La Brea Tar Pits.

All of these large animals lived in North America post-flood. It is not known why they went extinct. The climate has changed, and also mastodons or other fossil animals have been found with arrowheads stuck in them. Other evidence also implicates humanity in their death.[25]

All known human fossils have been found in the Pleistocene or recent. One human fossil site called Mummy Cave is east of Yellowstone National Park, near Cody, Wyoming. Apparently, ancient Native Americans camped at this spot during their travels, and charcoal from their campfires and artifacts such as arrowheads were left behind. Sediment covered these areas, and other traveling parties camped at the same site on top of the new sediment. In this way, a sequence of fossil-bearing layers was produced over a period of perhaps several thousand years. On one level, a mummified person was found, giving the cave its name. Some believe that the deposits at Mummy Cave accumulated over a period of nine thousand to ten thousand years. We can propose that it did not take that long and that after the flood the climate was wetter and sediments were accumulating more rapidly than they do today. The layers still represent the passage of time associated with changes in the human cultures that left their artifacts behind. For instance, the arrowheads definitely change as we explore upward through the layers.

Many unanswered questions about ancient humans still remain. Why do no human fossils appear in deposits considered to be flood deposits? Were there so few humans that they escaped burial? Did the antediluvians all escape long enough to decay on the surface after the flood? Or have we not found any ancient humans because they perished completely with a subducted continental plate? Perhaps future discoveries will help answer these questions.

Biological trends in the Cenozoic follow a persistent pattern of change in the whole ecosystem. For example, group after group of mammals are small in size in the Early Cenozoic and become larger through time. Among others, this includes horses, rhinos, elephants, whales, camels, primates, and carnivores. They not only grew larger but adapted to drier and more open habitats as forests gave way to more grasslands. Some interventionists think this is all evolutionary change within created groups as post-flood climate and habitats changed. But if humans did not evolve from other primates, how do humans fit into this pattern?

Others suggest that most of the Cenozoic, up into the Pleistocene, is still flood deposits, with the sequence of fossils resulting from some aspect of the pre-flood distribution of these fossils. The following is one argument in favor of that view. At the time of the biblical patriarch Abraham, it appears that horses, camels, sheep, and goats looked just like they do today. This means that, if the Cenozoic is post-flood, all the apparent microevolutionary change in the Cenozoic, along with the geologic deposits of most of the Cenozoic, must have occurred in the few hundred years between the flood and Abraham. Short-age geology also must explain why humans and any items that can be readily dated by carbon 14 do not appear until the Pleistocene if the flood ended early in the Cenozoic. Some would argue that since human fossils and artifacts, radiocarbon datable items, and domesticated animals appear in the Pleistocene, then the post-flood period must not begin until in the Pleistocene. These questions all offer opportunities and challenges for further research.

Post-flood Evolution

After the geological catastrophe, conditions would have been ideal for rapid speciation. The earth was largely empty with many niches to be filled. The animals were spreading over the earth and becoming isolated in ecological pockets in valleys, in mountain ranges, and on new islands. New species were forming rapidly as animals and plants adapted to changed conditions on the earth, and modern biogeographic patterns—modern distribution of species and higher groupings—were established at this time. Some populations of animals moved into caves and became adapted to that environment—even becoming blind because their eyes were useless in a dark cave.

The volcanic islands of Galapagos and Hawaii apparently formed after the flood. Several groups of animals have traveled to these and other islands, perhaps on massive amounts of floating debris on the oceans. Speciation then occurred on the islands.

The chipmunks (fig. 9.2) spread over Asia, where one species still lives today, and to North America (or the reverse). The chipmunks scattered over North America and developed into separate species in different mountain ranges and other ecological pockets (fig. 9.3). The voles, like the chipmunks, speciated simultaneously in many places (figs. 9.4–9.6). A large number of species and even genera resulted through the operation of microevolution and speciation processes in these and other animal groups.

How much evolutionary change has occurred within created groups of animals? Modern understanding of rapid microevolution perhaps make it realistic to suggest that many changes seen in the Cenozoic mammal record represent actual post-flood evolution. Perhaps the sequence of horses is, at least in part, an example of this process (fig. 11.19). A number of other groups of mammals illustrate the same trend from small, generalized forms early in the Cenozoic to larger, more specialized animals toward the top of the Cenozoic. Do these groups represent post-flood evolution? Such changes probably would not require any new genes or new structures and may be realistic possibilities, facilitated by epigenetic processes and potential created in the beginning.

However, some mammal groups represent diverse patterns. For example, compare the fossil record of bats and whales. The earliest known fossil bats, from the Eocene Green River Formation in Wyoming and the Messel in Germany, differ from living bats only in minor details. In contrast, the sequence of fossil whales, discussed in chapters 11 and 12, includes two quite different types of whales and some terrestrial and semiaquatic forms claimed to be ancestral to whales. Also, a fossil with skull characters of baleen whales has teeth like the toothed whales.[26] It is not clear just how much evolution has occurred within the created groups of whales.

Reefs

After the catastrophe, coral reefs apparently began to grow. Some of these reefs, such as Eniwetok Atoll in the Pacific Ocean, have a depth of 4,600 feet (1,405 m) from the basaltic rock of the ocean floor to the top of the reef. Can a reef grow that much in a few thousand years? Coral does not grow if it is more than 165 feet (50 m) below the ocean surface. So the Eniwetok reef must have begun growing when the ocean was quite shallow and continued growing as the ocean bottom gradually subsided. These would be ideal circumstances for rapid growth of coral, perhaps even adequate to grow the Eniwetok reef in 3,400 years.[27]

Orderly Deposition

Even today, when a storm is creating havoc at the water surface, well-ordered deposits of sediment are being produced under the water. This important feature of the sedimentation process is needed to explain the geological record. The geological catastrophe did not wash the sediments into the ocean and dump them in a chaotic fashion. The entire geological column is composed of orderly deposits laid down in consistent sequences.

This can be illustrated by comparing some modern sedimentary deposits with the fossiliferous rocks in the Phanerozoic record. Today, sand dunes form in the ocean, in deserts, and in other environments. These modern dunes form cross-bedded deposits, and cross-bedded sandstone deposits have some characteristics similar to modern deposits. When sand dunes get too steep, the sand slumps (fig. 16.21A). The same types of slump structures can be seen as fossil slumps in sandstone (fig. 16.21B). In either underwater sand dunes or desert dunes, the water or air currents may produce ripple marks (fig. 16.21C). These features are preserved as ripple marks in the rocks (fig. 16.21D) and sometimes cover extensive rock surfaces. Turbidity currents produce characteristic deposits today. In the geologic record, the discrete layers formed by turbidity currents are widespread.

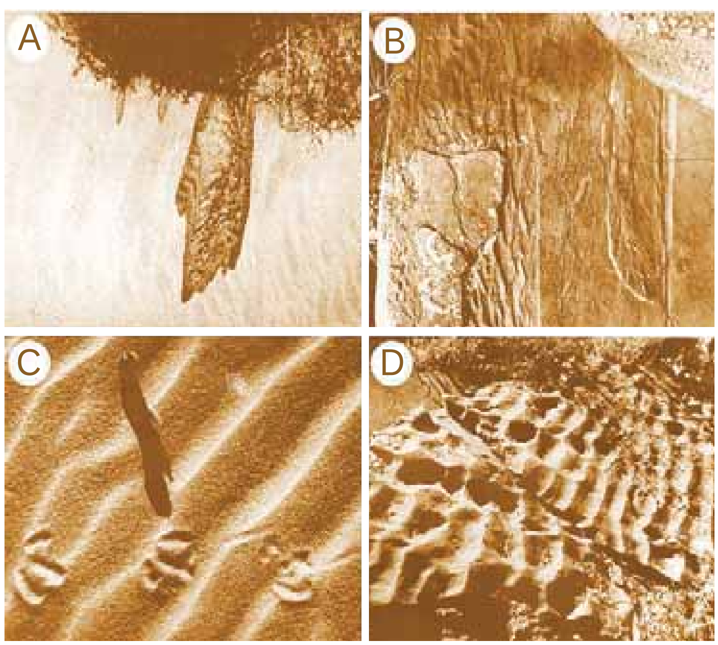


Figure 16.21. (A) Slump on modern desert sand dune and (B) ancient slump in sandstone; (C) modern ripple marks and (D) ancient ripple marks in sandstone. Figure by Leonard Brand.

From this orderly deposition, a geologist can study the rock and tell in what sedimentary environment it was deposited. We could expand this concept to include many ways in which modern analogues help us interpret ancient features of rocks and fossils. However, there are limits to the application of modern analogues in explaining ancient rocks. Many geological features and rock formations do not have adequate modern analogues, and both short-age and conventional geological interpretations have difficulties. The difference between a short-age and a conventional theory is largely a matter of time and scale. How rapidly did the geological events occur? What was the magnitude of these events? In the next chapters, we will further develop the comparison of these theories.

Modern Processes and the Study of Ancient Rocks and Fossils

When the catastrophe was over, the earth went through a long period of readjustment. The earth's crust eventually came much closer to being in equilibrium. The geological processes of erosion and sedimentation slowed to more gradual or sporadic rates. Mountain-building processes and other major readjustments of the earth's crust are no longer occurring at rates noticeable to us unless measured with high precision GPS units.

Today, rivers slowly cross the landscape, carving out wide meanders and then cutting them off during storms, leaving oxbow lakes (fig. 16.22). Windstorms blow dust and sand and produce new sedimentary deposits, including desert sand dunes. Ocean waves round off pebbles and grind them smaller, finally producing sand, and the waves and currents shift the sand and make new sedimentary deposits. The coastline erodes, and we can measure how fast it erodes. Earthquakes occur, and their strength and location can be measured. Volcanic lava flows and other types of volcanic eruptions are observed. They do not occur on a scale that they have in some cases in the geological record (fig. 16.11), but the basic processes are the

Figure 16.22. A meandering river in Bolivia, with former meanders that now form oxbow lakes. Courtesy of Chris Hadfield.

same. We can all watch on television as prime residential areas in California slump into the ocean and flash floods in the desert slowly add more sediment to the alluvial fans along the hills.

These processes (modern analogues) help us understand the past, but they also have all been studied during the recent, relatively stable, part of earth history (according to short-age theory). As a result, they introduce a strong bias toward the interpretation that ancient rocks were deposited slowly, over very long periods of time. It is possible also that some natural bias exists against deeper water sedimentary processes, since it is more difficult to study the details of modern deep-water deposits than shallower water or terrestrial deposits. The study of modern analogues yields many helpful insights into geological processes, but short-age geology interpretations differ mainly with the rates of geological processes determined from such analogues and suggests that much faster rates, on a vastly larger scale, were the norm during much of geological history.

In recent decades, the data have led science to recognize that the deposition of the rocks involved much more catastrophism than was previously thought. Short-age geology, which does not make the *a priori* assumption of millions of years of time, predicts that continued research will indicate still far more rapid geologic processes than have been currently envisioned. Researchers who accept or are at least open to a short age for the Phanerozoic record will, we predict, ultimately be more successful in understanding earth history.

The basic concepts of this short-age theory suggest a series of events that could have happened. Many questions still lack answers, just as other scientists are also without some answers. This provides opportunity for research. It will be interesting to see how the accumulating data will change and improve our short-age theories in the coming years, making them more effective in explaining the geological events of the past.

Research Suggestions and Testing Short-Age Geology Theories

Theories or hypotheses, including those proposed here, are only useful to science if they encourage research that improves our understanding of the subject. A useful scientific theory will make predictions of what will be discovered if the theory is correct. If these predictions stimulate discovery through research that would likely not have been done otherwise, the theory has become a productive scientific theory. The possibilities go beyond making a few minor improvements on our current understanding. "Large intellectual struggles cannot be won by success in easy and simple skirmishes. . . . A new theory must meet and encompass the hardest and most apparently contradictory cases head on."[28]

Research can be directed toward two different issues: the improvement of the short-age theory and attempted tests between specific hypotheses derived from short-age and conventional theory. Many areas of research can contribute to the development of short-age theory when it is entered with a willingness to use that theory to suggest hypotheses and test them and with a mind-set willing to challenge the scientific status quo. Some central topics of research that come to mind include (1) a study of any indicators of sea level at various stages in the geological past; (2) a study of the sequence of paleoenvironments, one geological basin at a time, for comparison with different versions of short-age theories; (3) a development of a three-dimensional model of the movement of sediments and organisms during the flood process; (4) a quantitative study of the extent and nature of unique and widespread deposits on a global scale; (5) continued study of paleocurrents over large areas; (6) an analysis of indicators of animal activity in relation to sedimentation; and (7) a study of taphonomy to evaluate such things as which fossil deposits were formed rapidly. Austin and colleagues suggest additional research questions to solve.[29]

It would be useful to study fossil reefs to evaluate the strength of the evidence that they are true reefs and are buried in their original growing position. It probably would be valuable to analyze the geographic and stratigraphic distribution of fossil reefs in relation to theoretical reconstructions of pre-flood oceans to determine which of these fossil structures could have grown before the flood. Further analysis of the origin and distribution of stromatolites and other apparent indicators of the passage of time (independent of radiometric dating) is also needed, along with more quantitative analysis of the time gaps in the rock record and of evidence for large-scale erosion and its distribution in the geologic record.

Some creationists assume that the geological processes such as erosion, sedimentation, mountain building, and changes in sea level did not begin in any substantial way until the beginning of the global flood of Genesis 6 through 8. In this view, the first flood deposits are approximately at the base of the Cambrian. There are variations on this theme. For example, it is often suggested that the Paleozoic and Mesozoic formed in the flood and the Cenozoic formed post-flood, but some would include everything from Cambrian through Pleistocene in the flood. Some are willing to have some sediments accumulating before the flood in the oceans. Others have also begun to think along similar lines.[30]

One advantage of considering new, biblically compatible ideas for comparison with traditional flood geology is that we are not limited by unnecessary constraints but have options to test. Testing these ideas will not happen quickly, as it will require considerable effort to gather field evidence to evaluate which parts of the geological column formed during, after, and maybe before the catastrophe.

There will be additional research suggestions and predictions at the end of chapter 18.

CHAPTER 17

Evidence for Long Time

Overview

Can the geological and paleontological evidence really have such divergent explanations as thousands of years versus millions of years for the history of life on earth? This chapter presents lines of evidence that challenge short-age geology theory and suggests alternate explanations for them. The most significant one is radiometric dating and a few other dating methods. Other phenomena with time implications are cyclic sedimentary structures and paleontological feature such as reefs and stromatolites. The striking sequence of organisms in the fossil record is discussed and also the rate of cooling of laccoliths. Short-age geology needs an explanation for plate tectonics and the slow modern rate of movement of drifting continents.

Challenges and the Search for Understanding

The two geologic theories we are comparing—short-age geology and conventional geology—use the same data and research methods. They agree on many basics of geological theory and even on a lot of catastrophic geologic activity. One difference stands out in bold relief: the amount of time proposed for the Phanerozoic record—thousands of years compared to 541 million years. How could the data allow such an enormous variation in interpretation?

Many say the data unquestionably point to hundreds of millions of years of geologic time for the fossil record. Nevertheless, others predict that as our understanding of the geologic record improves, the balance will shift until the short-age theory is better able to explain the evidence. Even now, the evidence, as generally interpreted, offers serious challenges to conventional geologic theory as well as to short-age geology. If we had all the evidence, it would point clearly in one direction. The data available now do not, indicating that many significant discoveries yet await us. Short-age theory will succeed in a scientific sense only with continued diligent scientific research and honesty in dealing with the evidence as the theory is utilized for developing testable hypotheses.

This chapter presents evidence that seems to indicate a very long time for earth history. We will discuss this, and then the next chapter looks at the other side—evidence more compatible with a short-age geological time frame.

Radiometric Dating

The most serious problem faced by the short-age theory is radiometric dating with its 541 million years of time for the Phanerozoic.[1] Before discussing the implications of these dating methods, let's review the basic principles involved in radiometric dating. All radiometric methods depend on the fact that some isotopes (particular forms of an element with differing numbers of neutrons) are unstable. Over a period of time, the radioisotope (the unstable parent element) breaks down to form some other element (the daughter product). The rate at which this radioactive decay occurs can be determined experimentally and always follows the same type of decay curve (fig. 17.1). For example, potassium (^{40}K) decays to argon (^{40}Ar) and in a particular length of time, called the half-life, one half of the ^{40}K decays to ^{40}Ar (10 percent) or ^{40}Ca (90 percent). Intuitively, we might think that in the second half-life the rest of it will decay, but not so. In the second half-life, half of what is left will decay and so on, producing the decay curve shown in figure 17.1. The half-lives of different unstable isotopes vary from fractions of a second to billions of years. Those with short half-lives are not useful for dating purposes. The half-life of carbon 14 (^{14}C) is about 5,730 years; for ^{40}K (potassium), it is about 1,300,000 years. If we can determine the ratio of parent to daughter isotope in a rock sample (horizontal bars in fig. 17.1), we can determine where that ratio fits on the decay curve. That position indicates the age of the rock, if the assumptions of the method are correct and if the rock meets the conditions for valid use of the dating method.

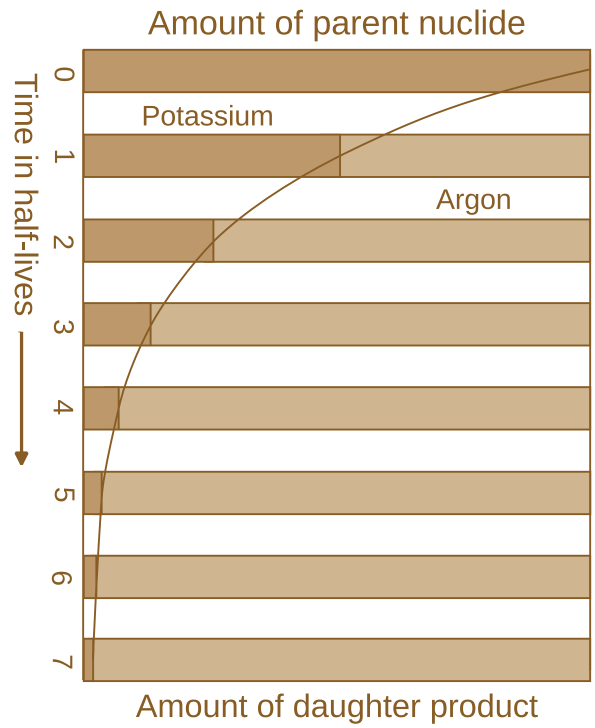


Figure 17.1. The radioactive decay curve, illustrating the concept of the half-life. The vertical bars show the parent/daughter isotope ratios, which are interpreted as indications of age of the rocks. Figure by Robert Knabenbauer.

^{14}C dating is different in some important ways from the other methods. Most carbon is ^{12}C, which is stable and is not the source of ^{14}C. ^{14}C originates in the upper atmosphere when cosmic rays strike nitrogen molecules, leading to a change of nitrogen atoms into ^{14}C, some of which combine with oxygen to form carbon dioxide (CO_2). These molecules circulate down into the lower atmosphere (fig. 17.2). Over time, the ^{14}C, including the atoms that are part of CO_2, decay back to nitrogen. The production and decay of ^{14}C are close to equilibrium, so that the ratio of ^{14}C to ^{12}C in the atmosphere is now relatively constant. When plants take in CO_2 and use it to synthesize new molecules and plant tissue, they incorporate both the ^{14}C and ^{12}C. Animals eat the plants, and as a result, all live plants and animals contain ^{14}C. A plant or animal no longer takes in fresh ^{14}C after it dies, so the amount of ^{14}C that it contains gradually diminishes as it decays to nitrogen. If we measure the number of radioactive disintegrations per minute in a standard amount of dead tissue, compare it with the decay curve for ^{14}C, and make certain assumptions, we can determine the length of time since the organism died.

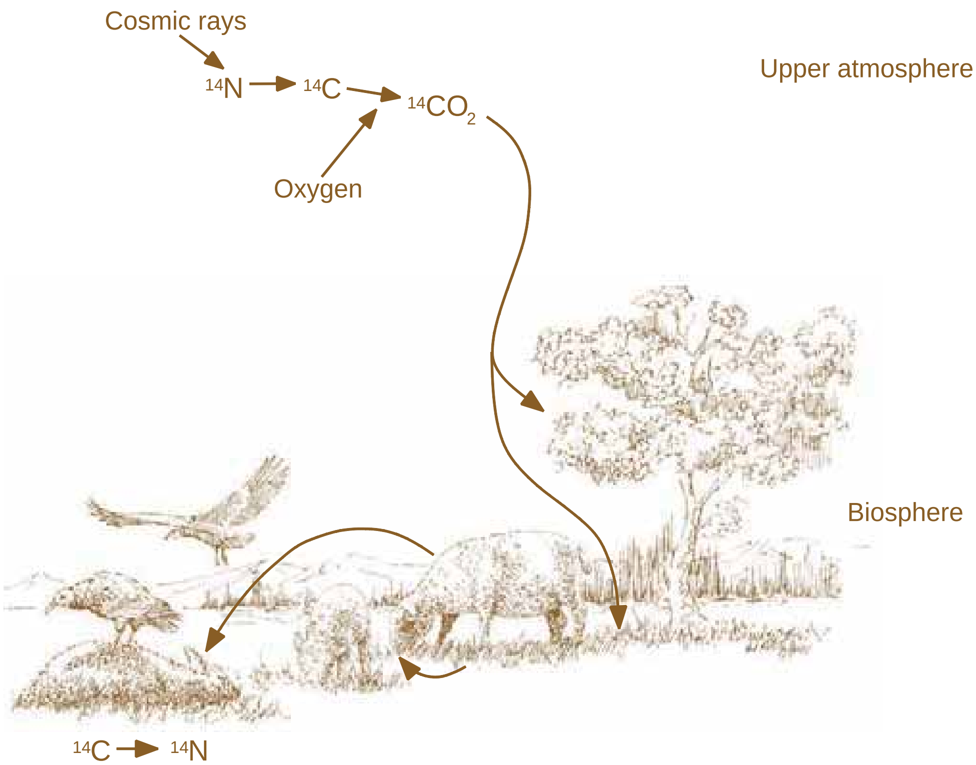


Figure 17.2. The process that produces ^{14}C and incorporates it into plants and animals. Figure by Robert Knabenbauer.

The nature of this method places some limitations on how it can be used. Since it depends on the presence of carbon incorporated from the atmosphere into plants, it is used only for dating plant and animal remains, not rocks or minerals. It can be used only if the organic matter has not been replaced by minerals. Also, because the half-life is only 5,730 years, it can be used only for dating fossils with a ^{14}C age less than about 50,000 years old. In other words, it only can date fossils in Upper Pleistocene or younger deposits, not fossils older than Pleistocene.

All the other radiometric dating methods utilize radioactive elements that are found in minerals, not in plant or animal tissue. So they can date certain minerals, but most fossils can only be dated with these methods by dating a layer of lava or other igneous rock near the fossil and using that date to estimate the age of the fossil-bearing sediments. Also, the half-lives of some of these elements are millions or billions of years long, so they are used for dating older materials than can be dated by ^{14}C. Three of these methods are argon-argon, uranium/thorium-lead and rubidium-strontium.[2]

Many fossil-bearing rocks do not contain the correct minerals for precise dating with radiometric dating methods. The age of these Phanerozoic deposits is determined primarily by biostratigraphy. This means that the fossils in the rock and in the formations above and below them are compared with the sequence of fossils in other locations to see where they fit in the sequence. Of course, the fossils found in rock can only be used for comparing the sequence of rocks in different locations and do not indicate the age of the rocks in years. Radiometric methods are used wherever possible to date minerals near the fossils and to provide a time calibration for the biostratigraphic scale. Radiometric dates can be uncertain by several percentage points, even for the more reliable dates. But if the assumptions these methods depend on are correct, they indicate that the Phanerozoic record occupied well over five hundred million years.

Assumptions and Analysis of Dating Methods

Whether any dating method yields correct dates is dependent on the accuracy of certain assumptions. The date is determined by the processes of radiometric decay, but also by other factors like the history experienced by the rock. The assumptions for carbon 14 are a little different from the other methods because of the unique source of ^{14}C.

Carbon 14 Dating

The accuracy of carbon 14 dates is dependent on several assumptions:

1. The decay rate has always been constant. (The available evidence seems to support this.)
2. The amount of CO_2 in the atmosphere has been constant. Since ^{14}C is produced from nitrogen, not carbon, its production is independent of the amount of carbon in the atmosphere. Consequently, if the

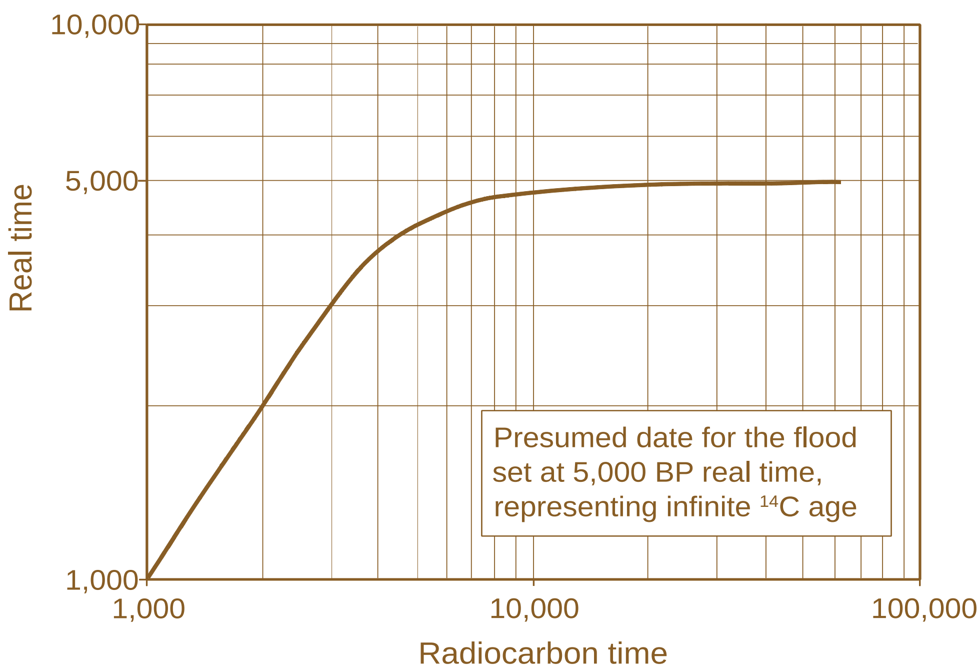
amount of CO_2 was higher in the past, it would have diluted the ^{14}C, and fossils would date older than they actually are. It is quite possible that CO_2 was more prevalent in the past, making this a possible source of error.

3. The amount of cosmic rays entering our atmosphere has been constant. Possibly the earth originally had a lower rate of cosmic ray bombardment of the upper atmosphere due to a stronger magnetic field and, perhaps, more moisture in the upper atmosphere (although this would have a limited effect), making this another possible source of error in ^{14}C dates.[3]
4. Many plants take in ^{14}C and ^{12}C unselectively, without preference for ^{12}C. Some plants do selectively prefer ^{12}C, but it is possible to determine this and correct for it.

Short-age geology predicts that only a small amount of ^{14}C was in the atmosphere before the global catastrophe. This is based on a theoretical consideration and an empirical observation. The theoretical consideration is the destructive effects of mutations in organisms caused by radiation. Because of this, it seems likely that the original created biosphere experienced little or no cosmic ray bombardment. Even if that problem has some solution other than a reduction of ^{14}C production, one other factor must be considered—coal and oil, which should have no ^{14}C in the long age model, seem to yield ^{14}C dates of about forty thousand years. This requires some ^{14}C in the atmosphere when the organisms lived that produced the coal and oil, if the short-age geology time scale is correct. R. H. Brown has developed a model for relating ^{14}C dates to real time based on this short-age theory.[4] According to his model, at the time of the global catastrophe, the concentration of ^{14}C in the atmosphere began to increase primarily because of a reduction in the amount of total carbon in the atmosphere. After a transition period, the level of ^{14}C reached equilibrium at approximately the level observed today (fig. 17.3). Organisms living during the transition period would date older than they actually are with immediate postcatastrophe ^{14}C ages being in the forty-thousand- to seventy-thousand-year range. Organisms that died after the curve reached equilibrium would yield ^{14}C ages that are fairly accurate. (One implication of this model is that if someone claims to have wood from the biblical ark and it has a ^{14}C age of five thousand years, it is not from the ark. Anything that lived before or immediately after the catastrophe will have a ^{14}C age of about forty thousand years, even though it is actually only a fraction of that age.)

In evaluating these radiometric dating methods, one should think of the entire process including the history of the rock and the laboratory methods and analysis. The ^{14}C cycle begins with the altering of ^{14}N into ^{14}C, which becomes mixed with the ^{12}C in the atmosphere. The ratio of ^{14}C to ^{12}C depends on the cosmic ray influx and the amount of ^{12}C in the atmosphere. The result is some proportion of ^{14}C in the tissues of plants and animals, which die and become preserved. The scientist collects a sample, determines the number of disintegrations per minute (or in the Accelerator Mass Spectrometry (AMS) method, counts the

Figure 17.3. Model of the changing level of ^{14}C in the atmosphere and its effects on the apparent age of organisms (from Brown 1990). Figure by Leonard Brand.



number of ^{14}C atoms), and interprets an age from the number of disintegrations per minute. The scientific procedures for collecting and analyzing samples may be precise and accurate, but the accuracy of the date still depends on the correctness of the assumptions that go into the interpretation of the data. Testing those assumptions would require that we know the composition of the atmosphere and the rate of cosmic ray influx during the Pleistocene. Of course, we cannot go back and measure those.

It is intriguing that many samples from throughout the Phanerozoic contain ^{14}C, even though most of these samples should not contain any ^{14}C, because the radiometric time scale would provide more than enough time for all the ^{14}C to be lost through decay. If this is correct, it indicates these samples are all younger than seventy thousand years.[5] This deserves more study.

Other Radiometric Dating Methods

Common dating methods that are used include potassium-argon, uranium/thorium-lead, and rubidium/strontium. The accuracy of these methods depends on five assumptions:

Interpretation of ^{14}C dates

DATA

Measured amount of ^{14}C in all samples. Measured ^{14}C decay rate.

UNKNOWN

Ancient amounts of ^{12}C in the atmosphere. Ancient cosmic ray levels and other possible influencing factors.

INTERPRETATION

Conventional science: This assumes the ^{12}C concentration and rate of formation of ^{14}C have remained approximately constant. This concept is required by the naturalistic worldview.

Interventionism: This assumes the ^{12}C concentration and the rate of formation of ^{14}C were not constant but very different in the past. This assumes that ^{14}C gives relative age but not actual age. These assumptions are required by a conservative biblical worldview.

1. The decay rate has always been constant.
2. The rock has remained a closed system with no chemical exchange with the surrounding medium.
3. The radiometric clock was set to zero when the rock was deposited in its present location. All previously existing daughter products escaped at that time (or the initial amount of daughter products can be estimated, based on mathematical calculations from the data).
4. The parent-daughter ratios (indicated in fig. 17.1) were caused only by radioactive decay of parent to daughter over time.
5. There are other factors that we may not know about yet.

In evaluating dating methods other than ^{14}C, one should consider the entire process, which begins in the earth. The magma at any given point below the earth's crust has some ratio of parent isotope to daughter product, depending on its history. When that magma comes toward the surface to form a new deposit, it must not mix with older rock, because that could change its apparent age. Also, no exchange of parent or daughter elements can take place with fluids moving through the rock or its "clocks" will be inaccurate because the parent/daughter ratio will be the result of something other than the amount of time that has passed. The researcher collects a sample, goes through the laboratory procedure to determine the ratio of daughter and parent elements, attempts to determine if the above assumptions have been met, and interprets the date of the rock.

There do not seem to be reasons to doubt the theory of the decay process, the pathways of decay from one isotope to another, or the accuracy of the laboratory procedures for measuring the parent and daughter isotopes. But there are other issues where the dating process seems more uncertain. Several questions need better answers before radiometric dates are convincing to those of us who view radiometric dating as a hypothesis to be tested rather than as a given truth.

One question for potassium-argon is how sure we can be that the clock has been set to zero by loss of all argon before the new rock formed. If some percentage of old daughter products were not lost when a new rock formation was deposited, the clock would not be set to zero. In that case, the rock will date much older than it really is. Is there a truly independent method for determining whether a "date" is accurate or inherited? That determination must not be based on evaluating whether the date agrees with the already accepted time scale, or circular reasoning comes into play.

For most methods other than ^{14}C, the daughter products are not lost when a new rock forms, but the amount of such inherited daughter products can be determined by plotting an isochron (fig. 17.4). The isotopic ratios from many samples of a given rock are plotted on the graph, and a line is drawn through them. If the data points fall on a straight line on the graph, it is called an isochron. The slope of the line and the position where it meets the vertical axis are entered into a formula that gives the presumed age of the rock at the time it was deposited.

But if the dated rock formed by mixing of magma with the host rock into which it flowed, the ratio of isotopes will be the result of the mixing process. If this has occurred, the plot of isotopic ratios may look like the isochron in figure 17.4, but it is a mixing line, resulting from the mixture of differing rocks, and is not an isochron. A mixing line does not indicate the age of the rock.[6] If other lines of evidence indicate the radiometric age is not correct, the apparent isochron may be recognized as actually being a mixing line.[7] Most scientists involved in determining these geologic ages are confident they can identify which plots are mixing lines. However, some short-age geologists question whether many radiometric "dates" could actually represent mixing lines and thus are not true ages. Perhaps there also are other important questions about radiometric processes that we have not yet pondered.

In spite of the above problems or questions, radiometric dating methods apparently give a generally consistent sequence of dates. There are questions about precision,[8] and not all dates come out right, but there is at least an approximate correlation between published radiometric dates and the position of a rock in the geological column. Cambrian rocks yield Cambrian dates, not Eocene dates. Those who do this dating are convinced it is generally evident why some dates do not come out right.

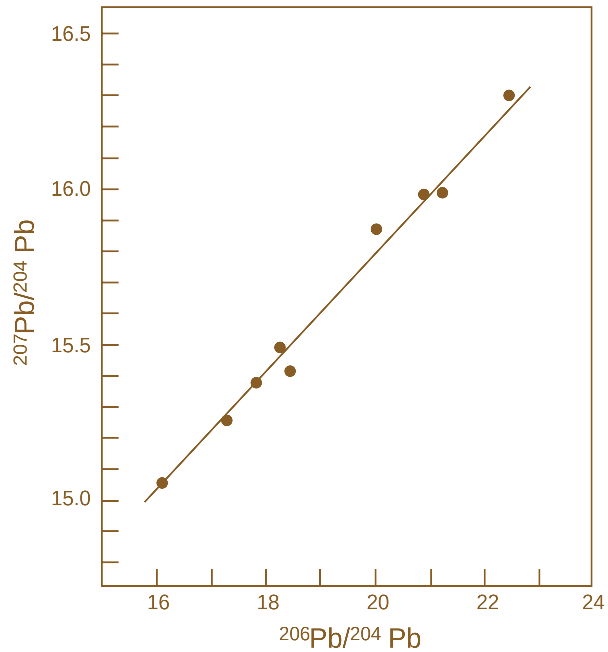


Figure 17.4. Graph of isotopic ratios used to plot an isochron line. Each dot is from an individual measurement. If the points fall on essentially a straight line, as they do here, the isochron line is then drawn through the points and extended to the vertical axis. Figure by Leonard Brand.

However, another way to present this issue is to point out that when radiometric dating equipment analyzes a sample, it does not directly give a date but yields a ratio of parent/daughter isotopes (fig. 17.1). Repeated sampling from different parts of the geological column yields a fairly predictable sequence of ratios. What caused this sequence of ratios? If the rocks were here long enough, time would produce such a sequence, and most scientists assume that is what happened. But perhaps it is possible that the rocks were not here long enough for time to do this, and the sequence of ratios was produced by some other controlling factor. If that is true, then that other factor would explain why there is the predictable sequence of isotope ratios as we go up through the geologic column, and time had nothing to do with it. Our challenge is to understand what factor could have had this controlling influence on the isotope ratios.

Because of the predictable sequence of ratios, radiometric dates seem to be at least a reliable method for *relative* dating—indicating which rocks are older than which others. Rocks in North America with a radiometric “age” of fifty million years are probably the same age as rocks in Africa with a radiometric "age" of fifty million years and are older than rocks that yield dates of forty-five million years. Thus the isotope ratios appear to be a suitable method for age correlation between different rock formations, irrespective of what the researcher believes about absolute time. The bigger question is whether the dates in years are correct or whether all the rocks are much younger than radiometric dates imply, giving only relative, not absolute, ages. Interventionists are working on answering this question[9] because the answers we have at this time are not adequate.

It is known that laboratory measurements of decay rates vary according to the distance from the earth to the sun at the time the measurement was made. This variation is small because the variation in the distance from earth to sun is small.[10] However, this variation in decay rates does demonstrate that decay rates are not absolute or intrinsic to the specific isotope but affected by some external factors. This suggests there is more to learn about radioactivity, but belief in a short-age geological model is still based mostly on faith in the Bible account as accurate history.

Interpretation of radiometric dates other than ^{14}C

DATA

Measured decay rates of each specific isotope. Measured parent/daughter isotope from rock samples.

INTERPRETATION

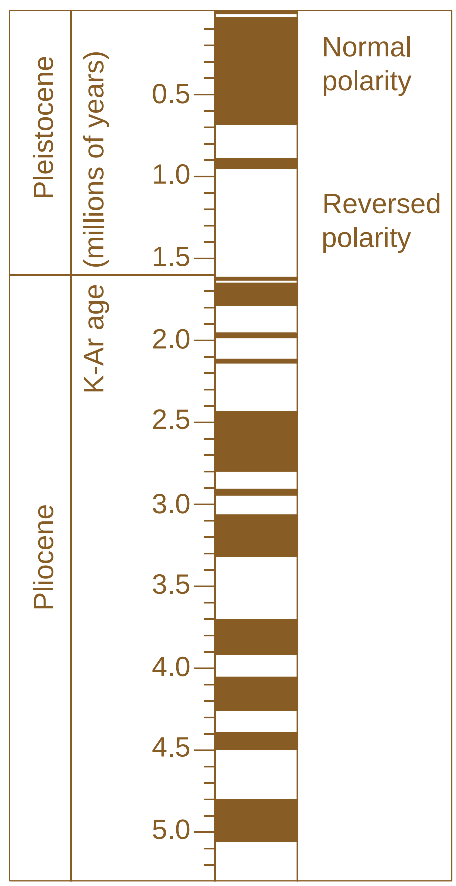
Conventional science: Evolutionary origin of life forms is assumed, and this requires very long time spans. This requires that the radiometric time scale be at least roughly correct. This also gives no incentive to seek other interpretations of the radiometric data.

Interventionism: This assumes a much shorter time frame. It also predicts that the conventional assumptions are wrong or that there are other discoveries to be made. It gives incentive to search for better explanations for the data.

Magnetic Stratigraphy and Amino Acid Racemization

Two methods were not discussed above since they are not independent dating methods. Magnetic stratigraphy is the analysis of evidence for magnetic reversals in fine-grained sedimentary rocks.[11] Magnetic particles in rocks are oriented according to the earth's magnetic field when the rock formed. The earth's north and south magnetic poles have apparently reversed many times in the past, and rocks can be classified as having normal or reversed magnetic polarity (fig. 17.5). Magnetic reversals have no potential to independently indicate the age of rocks; therefore, the magnetic reversal scale must be calibrated by radiometric dates. Magnetic reversals are important for refining relative age assignments of rocks in sequences of sedimentary beds with few units that can be dated by radiometric methods.

Figure 17.5. Magnetic reversals in Late Cenozoic rocks (after Lemon 1993). During times of normal polarity, the north and south magnetic poles are in the same positions as today. During reversed polarity, the positions of the north and south magnetic poles were reversed. Figure by Leonard Brand.



David Humphreys has proposed a mechanism for rapid reversals of the earth's magnetic field during the global catastrophe.[12] Some evidence confirms that such reversals can occur within a few days.[13] The relation of this research to short-age geology was discussed by Andrew Snelling.[14]

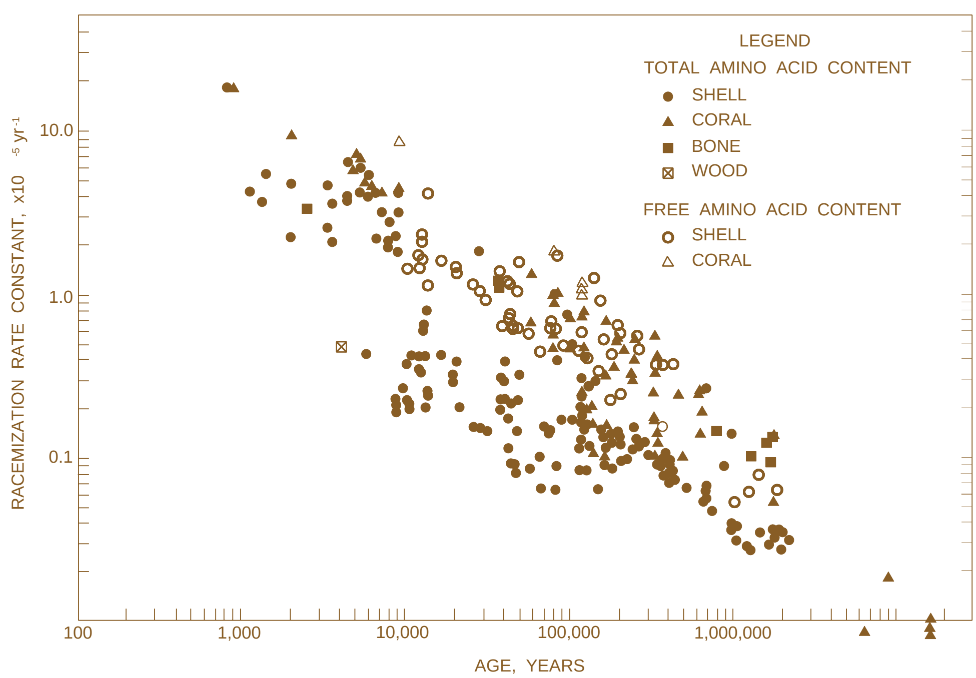
Paleomagnetic data are also used in another way, not for dating, but to determine the position of continents during each stage of continental drift. The magnetic inclination (variation from the horizontal) of particles in rocks depends on the latitude at which the rocks formed. We can determine that latitude by measuring the angle of inclination in the rocks.

The other method is dating by amino acid racemization. When an organism dies, its amino acids slowly change (racemize) from all L amino acids to a 50/50 mixture of D and L forms. Measurements of the amount of racemization have been used in dating Pleistocene fossils, but the method also is not independent of radiometric dates but must be calibrated by ^{14}C. The rate "constant" used in calculating ages from amino acid data is not constant. It changes progressively with the age of the fossil by three orders of magnitude (fig. 17.6)[15] because the process is affected by temperature and moisture conditions and these conditions cannot be known with certainty for prehistoric samples. If the rate "constant" is kept constant, the method gives dates in the range of a few thousand years.[16]

Cyclic Sedimentary Features That Seem to Require Time

Figure 17.6. Isoleucine racemization rate constant versus associated fossil age as published in the literature (from Brown 1985). Figure by Leonard Brand.

Some sediments contain what are described as tidal cycles (one lamina deposited with each high tide), and if this is correct, they may represent a time frame consistent with short-age geology. Discovery of these tidal cycles has changed the interpreted time for deposition of some rocks from thousands or millions of years to a few years—in other words, three or



four orders of magnitude faster than previously thought.[17] This is still a challenge to explain within a one-year event but fits well if it occurred in a portion of the geological record that formed over hundreds or a few thousand years.

Many other finely laminated sediments are not tidal but are sometimes interpreted as varves (one lamination formed per year). Such deposits often contain many thousands of laminations, and short-age geology theory predicts that these "varves" do not represent annual deposits. Some evidence already challenges the varve interpretation.[18] In addition, exquisitely preserved fossils in "varved" sediments, as in the Eocene Green River Formation (fig. 17.7), seem to require very rapid burial.[19]

Other cyclic sedimentary processes are recognized in the geological record, and some of these are interpreted as sedimentary cycles (Milankovitch cycles), resulting from a rising and lowering sea level over many thousands or tens of thousands of years. To understand the true time implications of these sedimentary cycles requires that we understand the mechanisms that produced them. Some may be actual cycles of sea level change, but other mechanisms should also be considered, including possible mechanisms

Figure 17.7. Fossils from the Eocene Green River Formation. Upper right: fly larvae and fish fry from shallow water environment; lower right: crocodile coprolite (fossilized dung), surface and cross-section views; lower left: one of the oldest known fossil bats. Figure by Leonard Brand.

not yet discovered. Cyclic sediments and some "varved" deposits are more easily explained if they occurred within a few thousand years rather than in the part of the record that formed within one year. However, there still are important questions for which we need answers before such cycles can be explained by any short-age theory.

The reports of ice cores extracted from glaciers in Greenland and Antarctica having hundreds of thousands of annual layers have often been raised as an objection to short time.[20] While the ultimate answers are not in, there are substantial reasons for rejecting the ice lines as annual. We will review a few of these.[21]

The assumption of one layer of ice per year has been challenged by observations of "many hundreds of layers of ice" in the ninety meters of ice covering planes abandoned forty-six years earlier on the Greenland ice sheet during World War II. Clearly the "one year per lamination" construct is false in this case. But more important, it calls into question the annual nature of the laminae. Perhaps laminae could result from individual storms or other climate shifts (fig. 17.8).

Figure 17.8. Layers of snow in Great Basin National Park, representing individual storms in one season. Figure by Leonard Brand.

Since the visible, countable ice laminae disappear at depth because of compression, scientists studying cores resort to other techniques to identify "annual events." These generally are isotopic or chemical signals or particles in the ice that can be recognized in the absence of visible bands. Layers of volcanic ash are easily recognizable in ice cores and can be analyzed for similarities to ash from known eruptions. These kinds of data seemed convincing until further work showed there were thousands of eruptions that could have satisfied the required sources, even in historic times. With about thirty eruptions per year worldwide, volcanic ash dating of cores is very questionable. Diffusion and migration of materials in liquid water within the ice core is a serious problem for other methods of attempting to extract annual signatures from the ice. As is the case in many other areas of historical science, ice core dating techniques are anything but objective and are model driven.[22]

Laccoliths and Sedimentary Features

Some mountains are formed by an enormous mass of molten magma intruding into overlying sediment, forming a body of igneous rock called a laccolith (fig. 14.13). How long does it take for the molten laccolith to cool after it has formed? You may remember from physics class that some materials gain or lose heat much more slowly than others, and rock cools very slowly.

In Hawaii, lava flows several years old are still warm because rock loses heat so slowly. Could those mountain-sized laccoliths already be cool if they formed only a few thousand years ago? This line of evidence has been argued to indicate a very long time for earth history. At least some laccoliths formed after some of the Phanerozoic fossil-bearing rocks were deposited (fig. 17.9). But Snelling and John Woodmorappe have studied the cooling of granitic magmas and concluded that the heat could dissipate within a time frame compatible with a young earth.[23] Thus this may not be the problem it

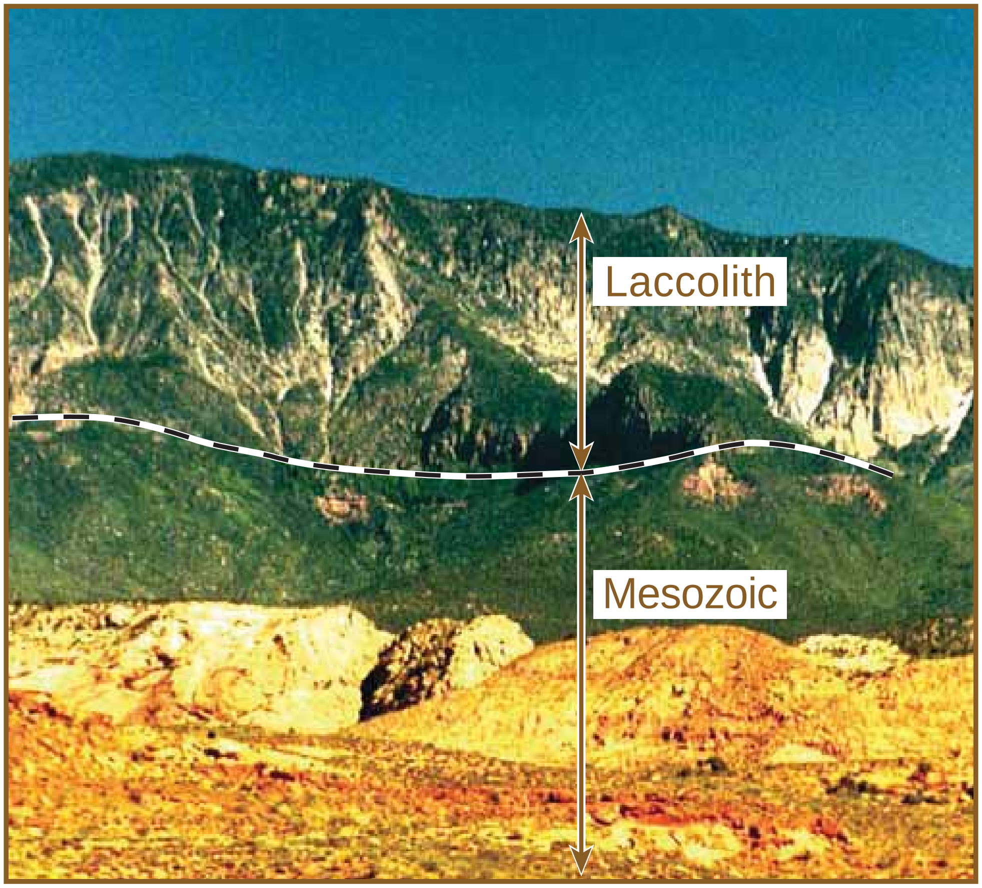


Figure 17.9. A laccolith north of St. George, Utah. Red Jurassic sediments (partly covered by trees) can be seen below the laccolith, which forms the upper part of the mountain. Figure by Leonard Brand.

seemed to be, especially if conductive (water flow) cooling is considered.

Features that also seem to require considerable time include the several advances and retreats of the Pleistocene glaciers.[24] More study is needed on this issue.

Most types of sedimentary rocks described in chapter 14 could be formed quickly, but the weathering process is more of a challenge. It appears that the reduction of old rocks to dissolved minerals and sand would be a long process. How, then, was the enormous volume of sand and clay in the sandstones and shales of the geological record formed in a short time? Possible short-age geology hypotheses could include the formation of much of this sand during the Precambrian or the creation of sand during creation week as an extensive component of the soil.

Plate Tectonics

Abundant evidence indicates that the continents were not always where they are now but have been drifting. Short-age theory must deal with the theory of plate tectonics.[25]

Earlier in earth history, the continents were apparently all close together. They spread apart until they reached their present positions on earth. The nice fit between the continents (at the edges of the continental shelves) on both sides of the Atlantic supports this theory (fig. 17.10). Also, a midoceanic ridge runs down the middle of the Atlantic Ocean, paralleling the contour of the continents on either side, which are moving away from that ridge.

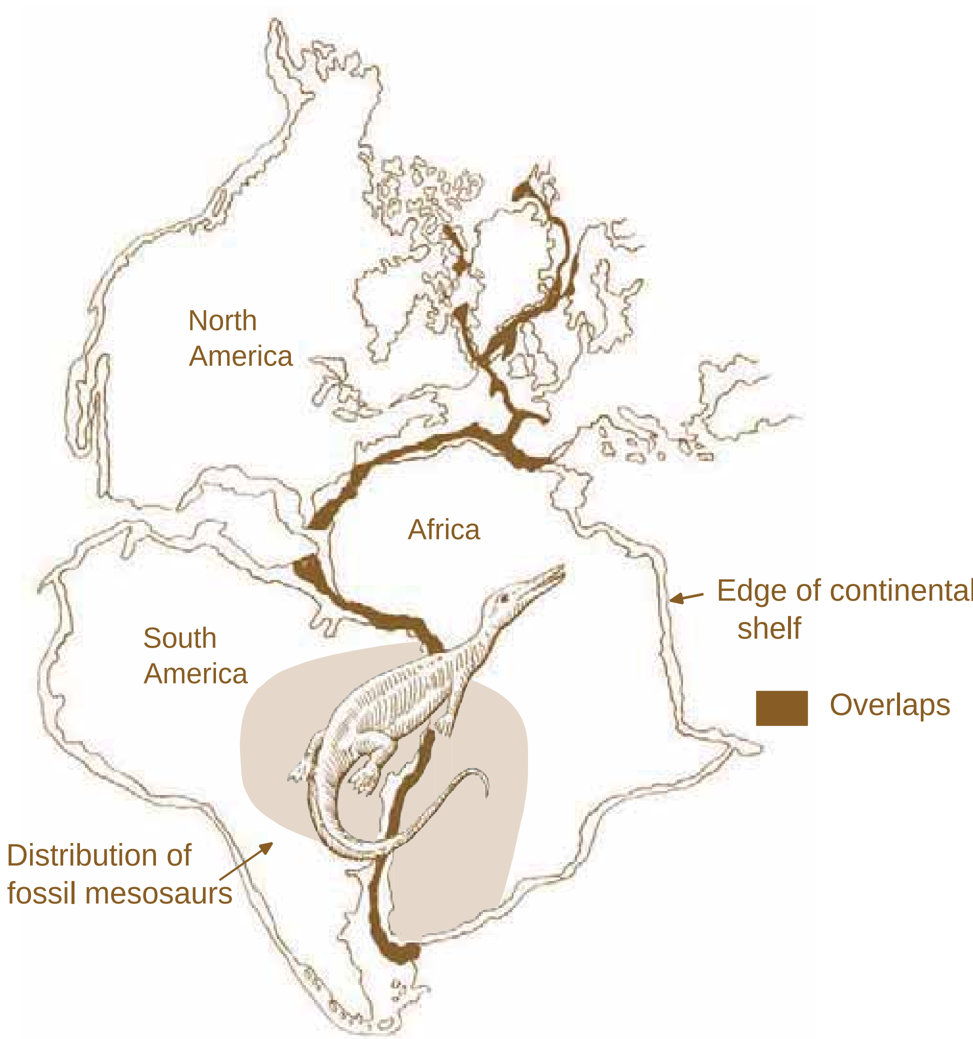


Figure 17.10. The fit between the continents before the formation of the Atlantic Ocean (after Monroe and Wicander 1992). Also shows the distribution of mesosaurs on both sides of the Atlantic Ocean (after Hallam 1972). Figure by Robert Knabenbauer.

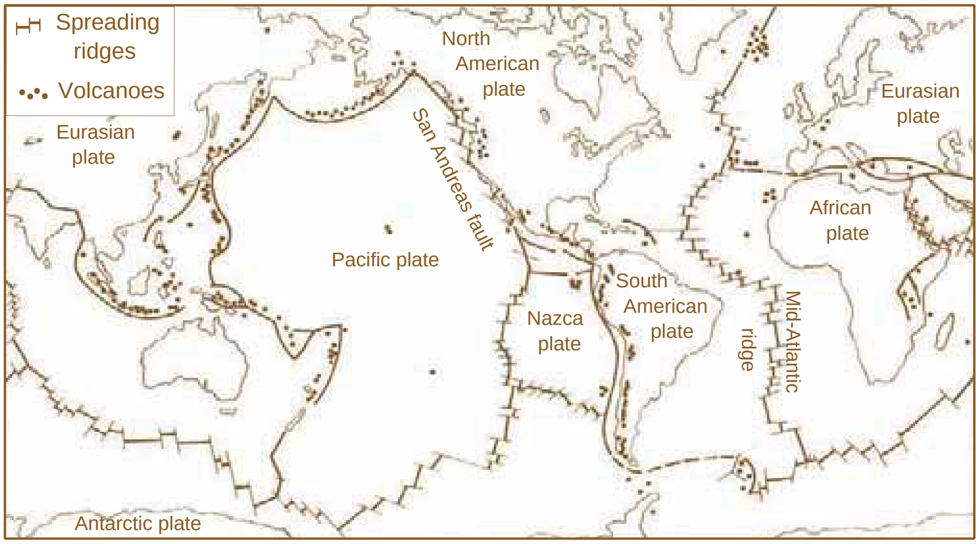
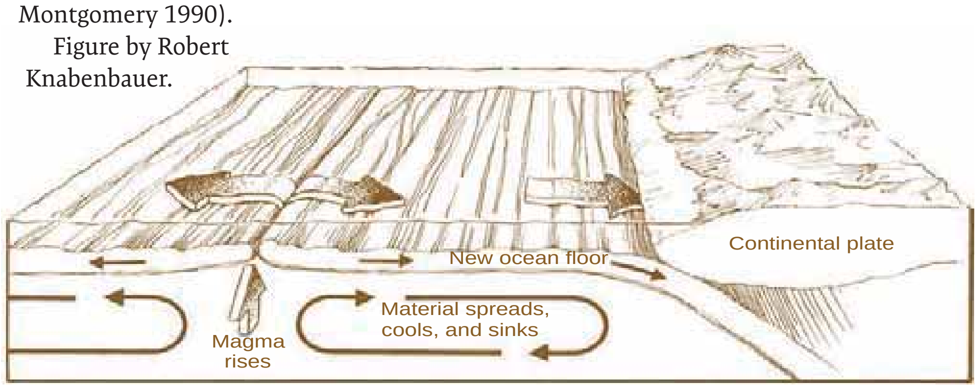


Figure 17.11. The continental plates and spreading ridges where ocean floor is forming (after Monroe and Wicander 1992). Figure by Robert Knabenbauer.

Figure 17.12. A cross-section through a portion of the earth's crust, showing the presumed movement of magma that moves the continents and produces new ocean floor (after Montgomery 1990). Figure by Robert Knabenbauer.

There are similar ridges in other oceans (fig. 17.11). As the continents move away from the ridges, hot magma flows up along the crack at the oceanic ridges and forms new ocean floor (fig. 17.12).

In places where two plates collide with each other, the theory says that if one of the plates is a continental plate, and one is an oceanic plate, the oceanic plate will be overridden and pulled down into the mantle. Just as the theory predicts, the deep oceanic trenches occur at places where oceanic plates are being pulled down into the earth by collision with a continental plate. Volcanoes and the epicenters of recorded earthquakes are clustered along the midoceanic ridges and in other places where plates are colliding (fig. 17.11). Also the match of fossils and types



of rock on adjacent continental plates supports the theory of plate tectonics (fig. 17.10).

Major mountain ranges are parallel to the edges of plates that are in collision with other plates—the Andes Mountains in South America, the Alps in Europe, the Rockies in North America, and the Himalayas in Asia. These mountains apparently formed as the earth buckled and folded because of plate collisions.

The continental plates are currently moving at a few centimeters per year.[26] A short-age geology model requires much faster movement in the past. An unanswered question is how the heat generated by this fast movement would be removed. A model for rapid plate tectonics during the flood has been proposed by John Baumgardner[27] and Steve Austin and colleagues,[28] but it has not yet explained how to deal with the heat generated by such rapid continental motion.

Paleontological Features with Time Implications

Reefs, extensive bioturbation of some sediments, fossil hard grounds (hard, cemented marine sediments that were home for living animals and were burrowed on the ocean floor before being covered by new sediments), and other features of biological origin seem to require some time, but not millions of years.

Deposits interpreted as coral reefs, algal reefs, and bioherms (similar to reefs) are distributed throughout the fossil record (fig. 17.13). This seems impossible to explain in a one-year flood because each stratigraphic level of reefs, if the reefs formed in situ (not transported or in the position where they were fossilized), would require several years to hundreds of years to grow. Wave-resistant carbonate reefs and accumulations of carbonate sediment that formed in situ, containing unsorted organic remains, are not usually interpreted as transported assemblages, although at least a few reefs were transported and deposited as megabreccias.[29] These transported reefs could have grown before the global catastrophe. Some deposits that once were interpreted as reefs have been reinterpreted as debris flows or other nonreef structures.[30] Other fossil reefs are still interpreted as reefs in position of growth. Ancient reefs are usually much smaller than our biggest modern reefs (e.g., those in the Pacific Ocean), and any that did form in situ would require some time and would seem to be indicators of a part of the record that did not form during the one-year flood. However, perhaps they could develop in a short-age time frame, but we don't know what processes would do this.

Stromatolites are mound-like structures formed by cyanobacteria that begin to grow on rocks or other objects and then form layer after layer as sediment collects on the sticky cyanobacteria (fig. 17.14).[31] These are also distributed throughout the fossil record. It presumably takes several years to grow an average sized stromatolite. Thus true stromatolites also seem to indicate that the part of the geological column containing them was not formed during the one year of the flood. A profitable line of research for short-age geologists is to carefully study stromatolites from different parts of the fossil record to determine if some of them have been seriously misinterpreted.

Figure 17.13. The total number of reefs reported in the scientific literature in each geological period (data from James 1983; Kiessling et al. 1999).

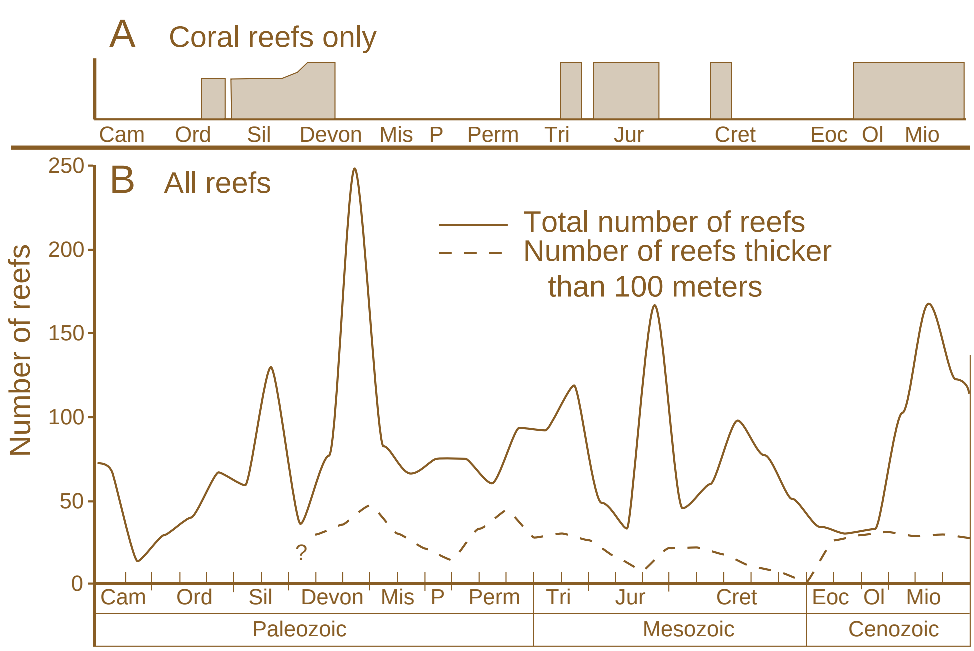


Figure 17.14. Cross-section through a stromatolite. The cyanobacteria began growing on the rock surface at the bottom of the photo and formed layer after layer on top of this. Figure by Leonard Brand.

Other areas that seem to require long time periods incompatible with the short-age model could be included in this section. For those of us who take this model seriously, each of these areas is both a challenge and an opportunity. With personnel, proper training, and adequate funding these opportunities promise an interesting and productive scientific future.

Interpretation of cyclic sediments, laccoliths, plate tectonics, reefs, and so on

DATA

Actual measurements of sedimentary features and identification of minerals and so on. Measurements of physical relationships of continents to each other. Measured rates of current continental movements. Measured size, geographic and stratigraphic location of reefs, specific structural features, and so on.

INTERPRETATION

Conventional science: This assumes that the naturalistic worldview is correct, and modern geological analogues are adequate for interpreting the ancient record. Observations will be interpreted in accord with this assumption. This view provides no incentive for seeking alternate interpretations as long as there is an interpretation that fits the naturalistic worldview. This can result in superficial interpretations.

Interventionism: This assumes the short-age time frame is approximately correct. Conditions in a global catastrophe are expected to be very different from the modern world, and thus modern analogues will not give trustworthy explanations for many ancient deposits. This gives incentive for deeper study of many geological features.

CHAPTER 18

Evidence for Short-Age Geology

Overview

Short-age geology faces some challenges, as we saw in chapter 17, but there are other types of evidence that point in the other direction—they are difficult to reconcile with the millions of years in the conventional theory. There are processes of erosion and sediment formation that work much too fast for those long time spans. Some are quite catastrophic and difficult to explain by processes observed now on the earth. On the other hand, there is not nearly enough volume of sedimentary rock to occupy the millions of years. Many geological deposits are so geographically widespread that they seem to call for catastrophic, even global explanations. The nature of specific rocks and their fossil deposits also seems to point to short time spans. Why does so much of the geological record occur as distinct layers, when such layers forming in the modern world are generally destroyed by animals burrowing through them? These and other evidences do not disprove the geological time scale, but they make it unsatisfying. A growing body of evidence raises doubts about conventional geology for those who are willing to question naturalistic assumptions.

This chapter lists several of the important types of evidence that are strongly supportive of or at least favorable to a short-age geological time scale. The objective is not to prove the flood or to disprove conventional geology but to further develop a short-age theory.[1] Some of the evidence is difficult to reconcile with deep time.

From Lyell's Uniformitarianism to Catastrophism

For a century after Charles Lyell, catastrophic interpretations of geologic data above the bottom two or three levels in figure 18.1 were not given serious consideration. Lyell reacted against the catastrophist geologists of his era, and his explanations of geology did not allow any catastrophic interpretations in geology. That restriction was dogma for a century, until accumulating data finally forced reconsideration, and the recent trend toward accepting more catastrophic interpretations moves in the direction predicted by short-age geologists.

The important question is whether the accumulating evidence will favor a continued strong trend in that same direction or will stop short of pointing to an extensive catastrophe on a global scale. Short-age geology does not rule out any of the possibilities in figure 18.1 and suggests that the data for some portion of the geologic record are best interpreted by the highest level of catastrophic action.

Geologist J Harlen Bretz's study of the Channeled Scablands in Washington State was a heroic episode that began to break the hold of Lyell's rigid gradualism in geology.[2]

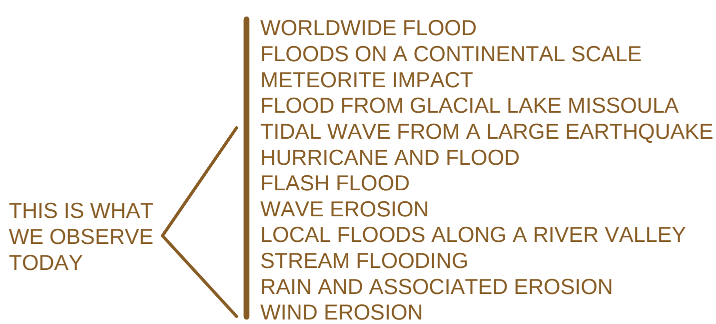


Figure 18.1. Sequence of increasing levels of catastrophic processes. Figure by Leonard Brand.

This network of channels in eastern Washington is carved up to nine hundred feet into the hard rock composing the Columbia River Basalt. Bretz saw evidence that this was the work of a cataclysmic flood. In spite of determined resistance to his hypothesis for more than two decades, it finally became clear that Bretz was right and Lyell was wrong. The channels of the Scablands were carved by the sudden draining of about five hundred cubic miles (over 2,000 km^3) of water from glacial Lake Missoula (fig. 14.14) when a glacial dam failed.[3] Acceptance of the reality of this event, the great Spokane flood, opened the way for the recognition of other catastrophic events in geologic history that previously had been overlooked.[4]

In 1966, near Iceland in the Atlantic Ocean, a new piece of land appeared as a volcano reached above the water and formed the island of Surtsey.[5] A geologist visiting the island soon after it was formed commented that processes usually taking thousands of years happened on Surtsey in days or weeks. The reason is at least partly apparent. The island formed in the ocean with wave action constantly at work, carving cliffs and beaches and other geologic features. Surtsey shows us how quickly some geologic processes can occur in the presence of an abundance of water energy and an abundant input of sediment, and this would be the case in a global catastrophe.

Density Flows

When an underwater mass of sediment becomes unstable due to oversteepening or perhaps triggered by an earthquake, the sediment begins to move downslope, and as it does, the particles of sediment become resuspended in the water column (liquefaction). At this point, the resuspended mass of sediment behaves as a dense fluid and flows rapidly downslope. Such a density flow is termed a turbidity current. The flow then travels out and as it moves, deposits a layer of sediment called a turbidite. Turbidites (fig. 18.2) are a common and important feature of the geological record.[6]

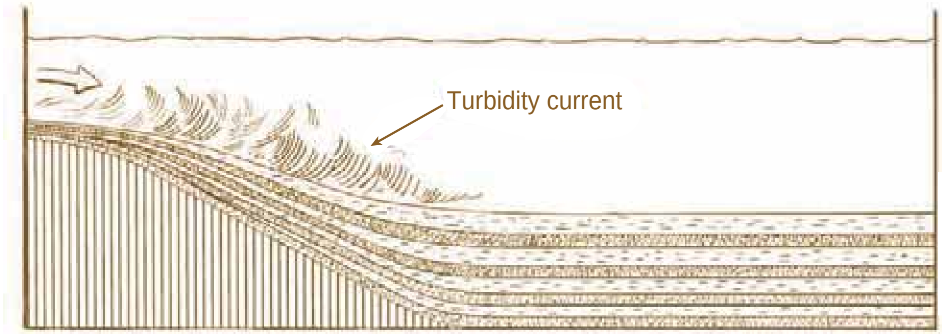


Figure 18.2. Cross-section through a turbidity flow and the resultant turbidite. Figure by Leonard Brand.

Turbidity currents can flow down very low angle slopes or even on the level after they develop momentum. These flows have produced modern submarine fields of turbidites covering thousands of square miles at the mouths of some large rivers. Submarine fans of turbidites and other sediment flows cover twelve thousand square miles off the mouth of the Mississippi River, eight thousand square miles at the Hudson River, and twenty thousand square miles at the Congo River, and a single turbidite covering nearly 3,600 square miles has been identified.[7] Since the discovery of turbidites, many thousands of sedimentary deposits have been reinterpreted as turbidites.[8] Turbidites are compatible with conventional theory and are also consistent with the rapid deposition expected in short-age geology.

Megabreccias are sedimentary deposits in which angular rocks (clasts) greater than one yard (1 m) in diameter occur in a matrix of finer material and smaller rocks, which may or may not be angular. Chadwick reviewed the literature on a number of very impressive megabreccia deposits—most readily explained by short-age theory.[9] Scientists believe most of these deposits occurred underwater where buoyancy could reduce the weight of the rocks by a third and thus reduce friction. Some sequences of turbidites have very large clasts, more than a meter in diameter, associated with them. These large clasts apparently moved by force of gravity.

Debris flows are slower, less fluid density flows that also do not require a steep slope and can carry clasts of apparently unlimited size. Table 18.1 lists a number of

Table 18.1. Large exotic blocks moved by debris flows or slides

Location	Stratigraphic position	Size of blocks
Peru	Eocene 1	10–15 m in diameter, 5,000 metric tons
Texas	Paleozoic	30 m in diameter
Oklahoma	Pennsylvanian	100 m in diameter
Venezuela	Tertiary	100 m in diameter, 30 m thick
		1 km long, more than 100 m thick
Timor	Miocene	800 m in diameter
Switzerland	Tertiary	500 m long, some overturned
Arabia	Cretaceous	1,600 km^2, 1,000 m thick
Australia	Devonian	Algal reefs up to 1 km across
Italy	Tertiary	Blocks up to 200 km^2, some upside down
Greece	Tertiary	Up to several km long, many upside down

impressive examples of such exotic blocks that have been moved long distances, often tens of kilometers and up to several hundred kilometers.[10]

Nothing Happens except in a Catastrophe

In 1869, geologist John Wesley Powell and his men were the first persons to travel by boat through the Grand Canyon. On a subsequent trip in 1871, they took many photographs. In 1968, another geologist, E. M. Shoemaker, made the same trip and relocated many of the same camera positions from which Powell took his photos. Comparison of the two sets of photos taken ninety-seven years apart indicate that in almost all areas very little change occurred during that time.[11] Most of the same rocks are in the same places with the same cracks they had in 1871. However, one particular pair of photos of the same spot in a branch of the Grand Canyon shows a dramatic change. A large volume of rock has been removed from along the river, and other large, new deposits appear. This change occurred recently during a single flash flood. These observations led Shoemaker to title a seminar presentation "Nothing Happens in the Grand Canyon except during a Catastrophe." This is just one example of a general recognition that many geological features form rapidly, but then little happens until the next catastrophe. Short-age theory goes further and suggests that, in parts of the geologic record, very little time intervened between these catastrophes.

Rates of Modern Erosion and Sedimentation

Ariel Roth presented data indicating that rates of sedimentation in the ocean and erosion of the continents are inconsistent with the geological time scale.[12] The amount of sediments being eroded from the continents and deposited in the oceans can be estimated from measurements of the sediment load in major rivers. Estimates range from eight thousand to fifty-eight thousand million metric tons per year. From this type of data, estimates of the required length of time to erode our continents to sea level vary from ten to thirty-four million years, with ten million years being a widely accepted figure in the geological literature.[13] The higher rates include adjustments for the assumed increase in recent erosion rates caused by human agricultural practices. Even the slower erosion rates are difficult to reconcile with current geological theory since our continents have never been eroded to sea level as they should have been many times in five hundred million years. Also, there are still mountain ranges like the Appalachians in North America that have been here for about three hundred million years, according to radiometric dates, enough time for them to have been destroyed by erosion many times over.

The suggestion that the mountains still exist because of continued uplift from below does not seem to be an adequate explanation.[14] If the uplift of the continents had been sufficient to support such a cycle of continued erosion and deposition, the lower parts of the geological column should have been destroyed, which is clearly not the case. On the other hand, if only the mountains had been continuously uplifting, the sediments deposited along the flanks of the mountains would show that, since they would be pushed up along with the mountains. The continuity of the geological record through the Phanerozoic seems to tell us that there has not been a series of cycles of erosion and uplift adequate to begin to account for the discrepancy between current erosion rates and the existence of the continents and mountains. If climates in the past had been much drier than at present, erosion rates would have been a little lower. But it seems more likely that the average conditions have been wetter in the past.

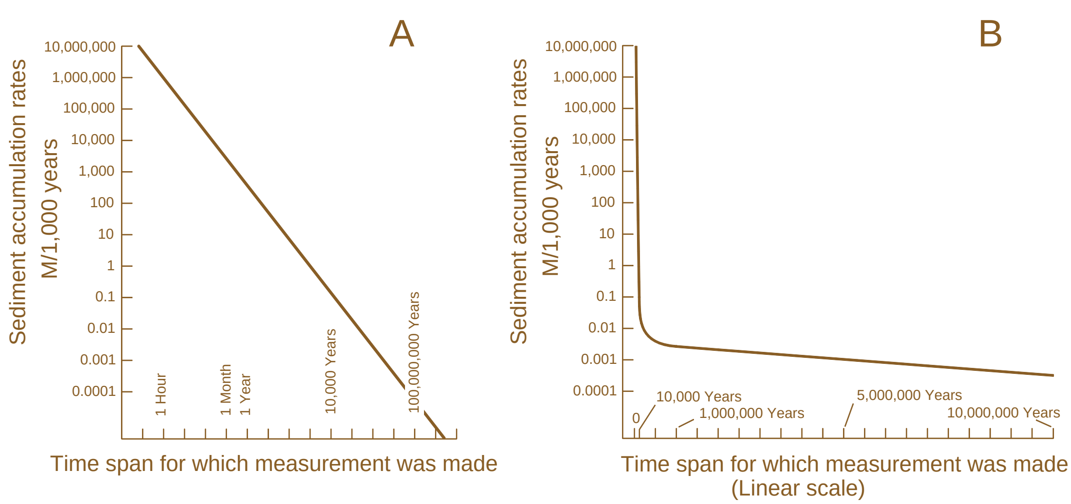
As the rivers erode the continents, the sediment ultimately ends up in the ocean. Conservative estimates of the amount of sediment reaching the ocean would lead to the ocean basins being filled with sediment in 114 to 178 million years.[15] That has not happened. In large areas of the ocean basins, the sediment thickness averages only a few hundred meters. Major river deltas are not nearly as large as they should be. One suggested solution to this problem is that the sediments are subducted into the deep ocean trenches and carried down into the mantle along plate margins, as proposed in the plate tectonics model. However, subduction does not occur fast enough to keep up with the sediment flow into the oceans. Also, the sediments from the earth's large rivers are not being deposited in basins containing subduction zones. The rates of erosion of continents and sediment accumulation in the oceans seem to fit better with a much younger Phanerozoic record than is currently accepted by conventional theory.[16]

Ancient Sedimentation Rates

The average thickness of Phanerozoic sediment on the earth is 4,900 to 6,500 feet (1,500–2,000 m), although it is much thicker in some places. If we use the larger figure (2,000 m) to calculate a sedimentation rate over the Phanerozoic, using radiometrically determined time, the depositional rate is 0.001 cm per year. That compares poorly with the sedimentation rates of about one cm per year in modern depositional basins. Why is the ancient rate slower than modern rates by three orders of magnitude? If the present is the key to the past, then sedimentation rates through geological history should have been of about the same magnitude as modern rates. If that were true, there should be many times as much ancient sediment as we find in the geological column. There seems to be far too little ancient sediment.

A classic study compared erosion rates over different time spans from a modern flash flood to ancient rates measured over millions of years (assuming radiometric dates).[17] The results indicate that sedimentation rates in the geological record are only a small fraction of the sediment that would be predicted from modern sedimentation rates averaged over a few years (fig. 18.3). Peter Sadler and others suggest an answer to this—much more sediment was originally deposited but most of it was eroded away before the next episode of sedimentation, or brief episodes of sedimentation were followed by long intervals of inactivity.[18] Brett and Baird's explanation of this theory for explaining the missing sediment is shown in figure 18.4 and represents the dominant solution by the geological community to this phenomenon.[19] They propose that many episodes of significant sedimentation occurred, but in each episode, the extra sediment was eroded away and thus not preserved in the rocks. If this repeated recycling process were correct, the actual ancient sedimentation rates could match the amount of preserved sediment and only *appear* to be unrealistically slow when measured over millions of years.

Figure 18.3. Relationship between sedimentation rates and the time span over which the measurements were taken. (A) A graph of the average sedimentation rates from Sadler (1981), on the same log/log scale that he used. (B) A graph of the same data, but with time plotted on a linear scale. Figure by Leonard Brand.



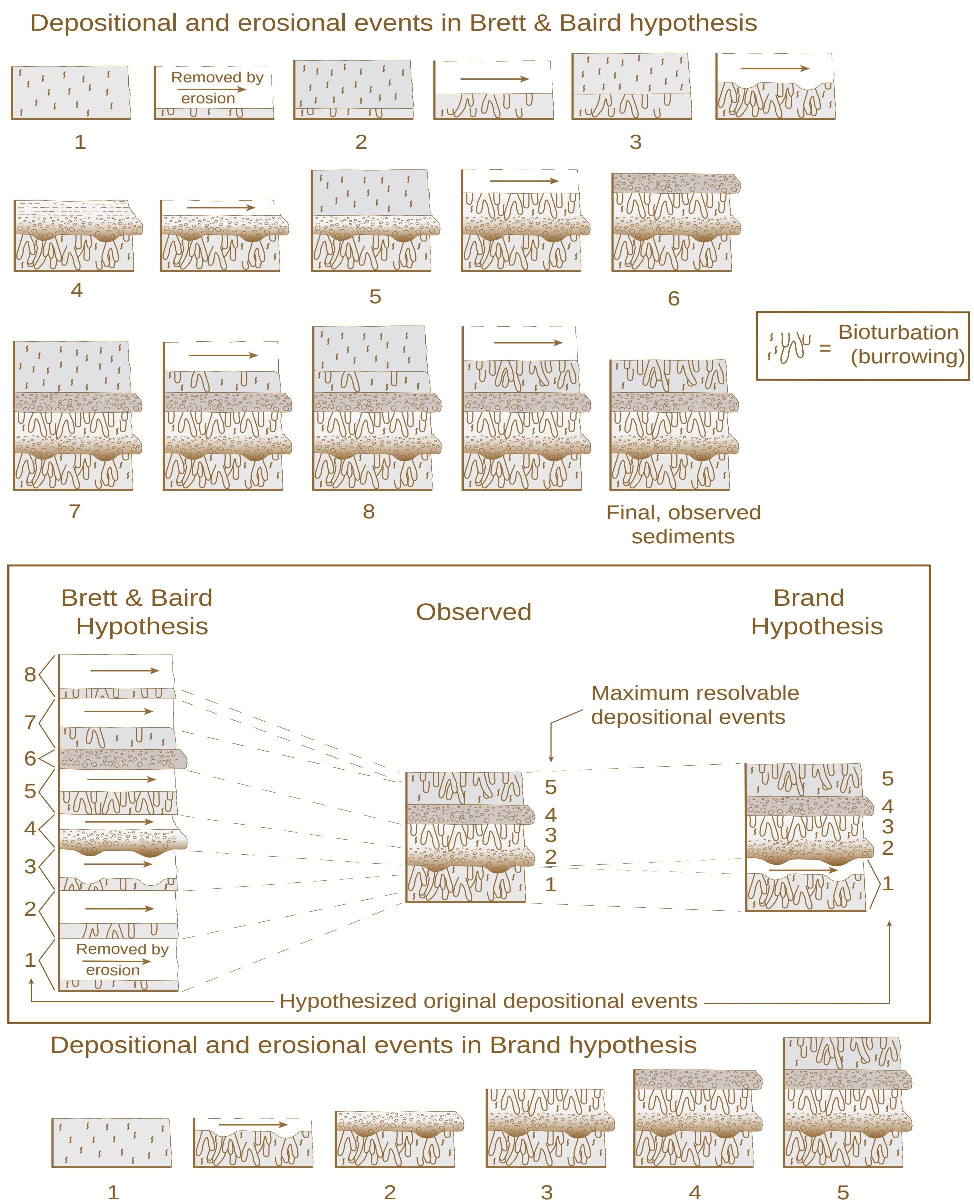


Figure 18.4. Comparison of two models to explain the shortage of sediment in the geological column. Diagrams in box portray the hypothesized original amount of sediment deposited for each model and (center) the observed sedimentary record. In the Brett and Baird model (diagram modified from Brett and Baird 1986), there were successive episodes of sedimentation followed by the erosion of part of the sediment before the next sedimentation event. Extensive burrowing by animals obliterated some contacts between sediment layers so that individual layers can't be distinguished. In the Brand model, no sediment erosion is assumed except where indicated by definite evidence of such. The sequences of drawings above and below the box portray the sequence of events in each model. Numbers indicate depositional events, and arrows indicate erosion of the sediment outlined with dotted lines. Figure by Leonard Brand.

But what if the time was not hundreds of millions of years? In that case, the calculated rates for the Phanerozoic, based on Sadler's data, would be wrong because the time is wrong. If instead of that long time span much of the sedimentary deposits accumulated in a yearlong global catastrophe and its slower aftermath, the ancient sedimentation rates would be perhaps two hundred thousand times faster than modern rates and would be consistent with the actual amount of existing sediment.

In the theory represented at the left in figure 18.4, the missing sediment is hypothetical (an ad-hoc hypothesis), required by the geological time frame but not indicated by physical evidence. This additional, hypothetical sediment is not necessary in short-age geology. We can suggest that the existing sediment is generally close to what was originally deposited, except when there is definite evidence of a significant erosional unconformity. This is illustrated at the right in figure 18.4.

The proposal of sedimentation rates two hundred thousand times faster than modern rates may sound absurd, but it is not necessarily so. Guy Berthault and colleagues have calculated the sedimentation rates necessary for certain ancient sediments to account for the processes that could move the sediments to their site of deposition and produce the sedimentary structures in the rock.[20] This requires rates that are two thousand to ten million times higher than rates calculated from radiometric dates. This is consistent with seriously catastrophic depositional events.

It seems to us, from the literature and from our own study, that some significant evidence in the rocks requires rates of geological processes that are much too fast for conventional theory based on the radiometric time scale. We will now summarize additional examples of this evidence.

Geological Time Gaps with Little or No Erosion

Now we will consider a different aspect of erosion in relation to the passing of large amounts of time. A given part of a continental surface is always experiencing one of

Ancient sedimentation rates

DATA

Ancient sedimentation rates, calculated from thickness of sediment divided by time as measured from radiometric dates. Ancient sedimentation rates, calculated in the same way using the biblical time frame. Ancient sedimentation rates, based on rate necessary to explain the sediment features.

INTERPRETATION

Conventional science: Begin by assuming radiometric time is correct. Since there is much too little sediment, propose a hypothesis to explain this (accepted hypothesis is numerous episodes of erosion, which have no evidence for their existence).

Interventionism: Since calculated sedimentation rate is close to the expected, no special hypothesis is needed. Hypothesize that sedimentation rates in the flood were as fast as modern flash flood rates.

two possible processes: it is either an upland area that is being eroded or a basin into which sediments are being deposited. Where erosion is occurring, it carves the land into irregular topography as water seeks the path of least resistance in its downhill journey. With this concept in mind, let's take another look at the sedimentation rates discussed above (fig. 18.4).

Tjeerd van Andel puzzled over why the hypothesized cycles of sediment recycling or inactivity typically leave no record that can be detected.[21] Some evidence of erosion, soil formation, or burrowing by animals should exist, yet the general lack of such evidence is typified by a deposit studied by him in Venezuela. Two thin coal seams separated by a foot of gray clay were, respectively, of Lower Paleocene and Upper Eocene age. "The outcrops were excellent but even the closest inspection failed to turn up the precise position of that 15 Myr gap."[22] Recall that those fifteen million years should have sufficed to erode an entire continent to sea level.

There are many known levels in the geological record that show evidence of erosion and/or uplift of sediments before the next layers are deposited. These are called unconformities. But van Andel's comments are directed to the significant lack of evidence for erosional gaps in the record that remains after the evident unconformities have been accounted for.[23] Acceptance of the standard geological time scale is what makes these data puzzling. If we are willing to make that time scale a hypothesis to be tested, the most straightforward, simplest explanation of the data presented by Sadler and van Andel is that there has not been nearly that much time in the geological record.

Data summarized by Roth greatly expand the nature of the above problem where gaps in the geological record believed to represent millions of years of time between two consecutive sedimentary formations show little or no evidence that erosion or deposition occurred during that time (paraconformities).[24] The Pliocene Ogallala Formation (2–5 million years old) lies directly on top of the Triassic Trujillo Formation (208 million years old) over an area of fifty-four thousand square miles (150,000 km^2) in the central United States. If two hundred million years had passed before the Trujillo Formation was covered, there should have been erosion of valleys, gullies, or even canyons besides soil formation and plant growth. In fact, as indicated above, the entire Trujillo formation and the rest of North America should have been eroded away. However, the contact between the two formations is very flat with only slight evidence of erosion despite the existence of soft units in the Trujillo that would have eroded easily.

If this phenomenon were rare, we might pass over it as an oddity that is not pertinent to explaining the record in general. However, the same type of evidence is found frequently in the geological column throughout the world.[25] Figure 18.5 shows the erosion that might be expected if long time periods had passed between sedimentary formations and compares it with the characteristic appearance of the geologic record, especially in the Paleozoic and Mesozoic, which displays minimal erosion between formations. Some erosional channels are evident, but the amount of relief is surprisingly small compared to

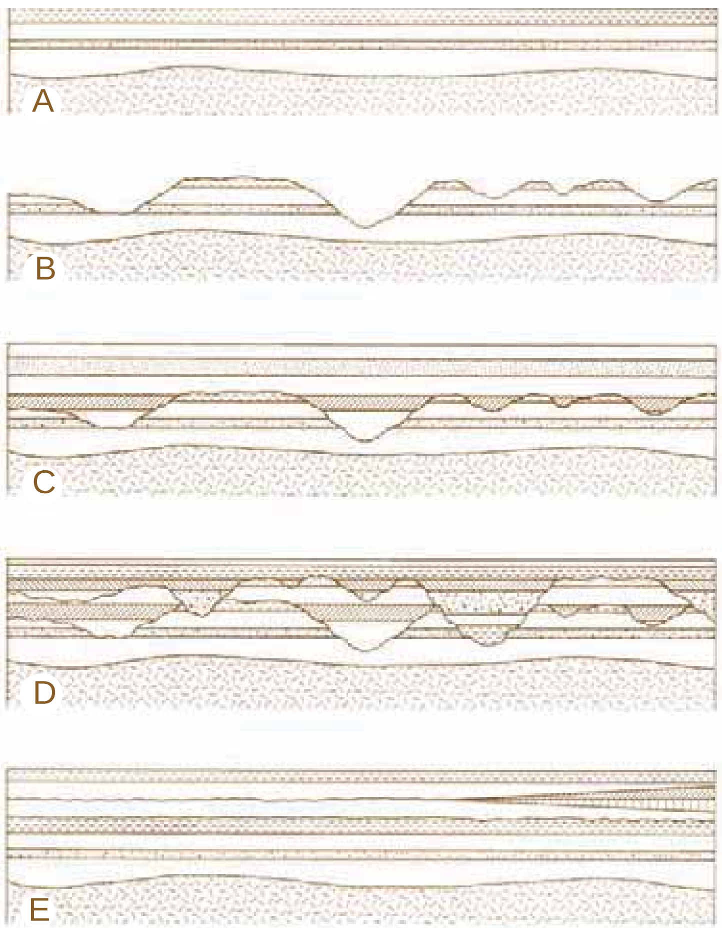


Figure 18.5. Expected (A–D) and actual (E) deposition and erosion patterns at time gaps in the geological record. (A) A series of successive sedimentary deposits. (B) Erosion occurs when the sediments are exposed to water drainage. (C) Sedimentation resumes, filling and preserving the old erosional channels. (D) A second cycle of erosion and deposition. (E) The more usual pattern seen in the geological record, without significant erosion at presumed time gaps. These are hypothetical diagrams with variable vertical exaggeration depending on the erosional conditions (from Roth 1988). Courtesy of Ariel Roth.

modern topography produced by erosion with the passage of time.

Figure 18.6 is a cross-section through southeastern Utah, illustrating how common these gaps are in a well-studied area. The presumed time gaps are shown in black. In reality, the formations lie on top of one another over large areas without significant erosion between them. They are relatively thin, widespread layers. Table 18.2 lists a number of additional examples of the same phenomena.

Theories that attempt to explain these uneroded layers below the time gaps have not stood up to careful study. Apparently no modern analogue exists for these very flat areas with little erosion.[26] For example, some very arid areas in Australia are quite flat and are

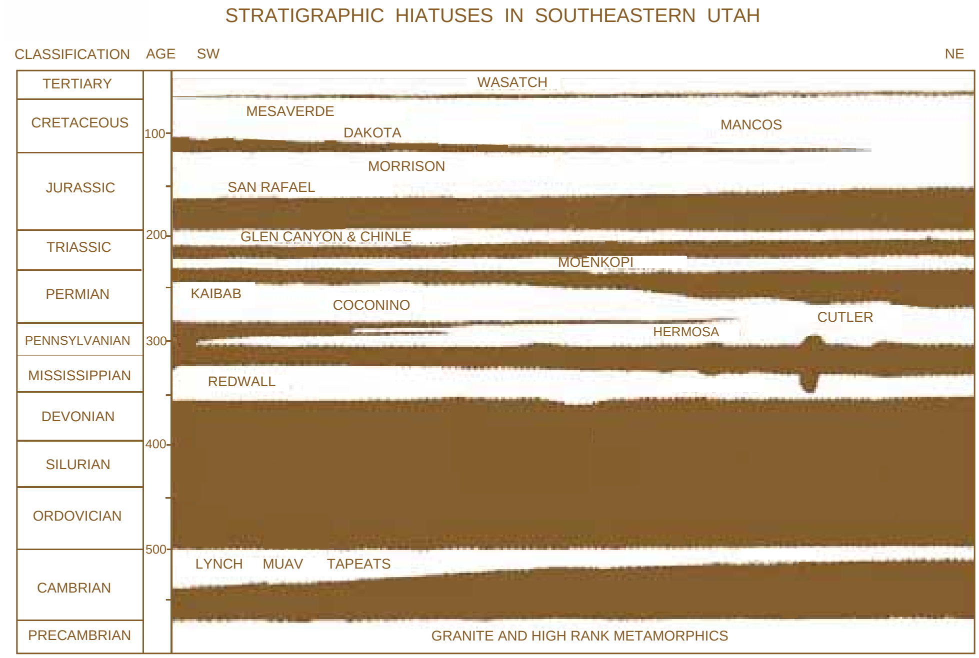


Figure 18.6. Sedimentary layers in southeastern Utah (clear) and time gaps (black) between the layers. Ages given are in millions of years, according to the geological time scale. Only the names of the major sedimentary formations are given. Vertical exaggeration is about sixteen times. The horizontal distance is about two hundred kilometers and the total thickness of the layers (clear areas) is about 3.5 kilometers (from Roth 1988). Courtesy of Ariel Roth.

believed to represent areas that have been uneroded for millions of years. These areas, however, do not serve as suitable analogues of the flat surfaces in the geological record. The very arid condition of these parts of Australia is not at all comparable to the apparent climate of the parts of the fossil record containing the time gaps, and also the Australian flatlands are not characteristic of the expected results of normal geological processes but rather oddities, which are "in some degree an embarrassment to all of the commonly accepted models of landscape development."[27]

We also do not know how these flat, uneroded surfaces were produced by short-age geological processes, but perhaps they would be more easily explained if the time span for these processes was much shorter. The above material does not imply that the geological record does not contain evidence for erosion. On the contrary, there is evidence for significant erosion of sediments as mountain ranges uplifted. Even when there was not a large scale uplift of the land, there are many cases of erosion of channels within the rock record. For example, in the Mississippian sediments of the Grand Canyon area are a number

Table 18.2. A few of the paraconformities—observed time gaps in the geological record (with little evidence of erosion, listing the location of the gap, time span of the gap, geological age of the gap, or the formations above and below the gap)

Texas	16 my	Late Triassic Tecovas/Permian Quartermaster
Grand Canyon	100 my +	Devonian Temple Butte/Cambrian Muav
Utah	10 my	Triassic Glen Canyon/Triassic Moenkopi
Utah	20 my	Triassic Moenkopi/Permian Kaibab; covers 250,000 km^2
Australia	5 my	Upper surface of Bulli coal; covers 90,000 km^2
Switzerland	35 my	Upper Cretaceous

From Roth 1988

of ancient channels averaging more than 200 feet deep, with a maximum of 401 feet[28] of erosion at several levels in the Grand Canyon sediments.[29] Indeed, it would be surprising if a major geological catastrophe had not eroded significant amounts of sediment at times. The point of the above argument is that, in some large areas, the amount of erosion is small in spite of the presumed passing of

How to explain geological time gaps (an interval of presumed time that is not represented by sediment)

DATA

Geological age (from radiometric dates or biostratigraphy) of rocks immediately below and above the contact between the two rock units. From these dates, determine how much time in years appears to be missing.

INTERPRETATION

Conventional science: Begin by assuming the geological time scale is correct. Examine the contact to see if there is evidence for erosion or other evidence of passing time. Propose a hypothesis for why the missing sediment is not present (this may be extremely difficult if the dates for a relatively undisturbed contact indicate significant "missing time").

Interventionism: Time in years is not assumed to be indicated by radiometric dates or biostratigraphy. Examine the contact to see if there is evidence for erosion or other evidence of passing time. Propose if and/or why there does or doesn't seem to be any missing sediment at this interval.

extremely long periods of time. Geological processes on our present earth do not seem to indicate that such a scenario is realistic.

Geographically Widespread Geologic Deposits

The large geographic extent of many sedimentary formations compared to the much more localized nature of modern analogues (fig. 16.3) is difficult to reconcile with conventional geological theory. In the western part of the United States, the Jurassic Morrison Formation covers an area from the Canadian border almost to Mexico (fig. 16.3). Many dinosaur specimens have been found in the Morrison Formation, and some of these can be seen in Dinosaur National Monument in Colorado and Utah. This formation is interpreted as a fluvial (river and flood plain) and lacustrine (lake) deposit with a fauna rich in dinosaurs. None of us have seen such deposits form, including short-age geologists, and we do not know just how it happened. However, a geological history that is more catastrophic, on a global scale, seems to offer more possibilities for explaining these widespread deposits. Nothing remotely resembling these widespread deposits is forming in the modern world in these environments.

The Triassic Shinarump Conglomerate is composed of sand and rounded pebbles in a sand matrix, like a braided stream deposit, but is much more uniform in composition, and it covers more than 150,000 square miles in Utah and adjacent states. In the eastern United States, another widespread deposit is the Chattanooga Shale and correlated shale formations, which cover a number of states. Another example is coal, which is believed to have formed in swamps as peat accumulated over long periods of time. Some coal layers extend for hundreds of miles. These very large swamps would have had to be very stable for millions of years to accumulate enough peat to form such coal deposits.

The geologist Derek Ager, in his book *The Nature of the Stratigraphical Record*, examines this phenomenon of widespread deposits in an even broader context. He points out to any who may wish to see this as evidence for Noah's flood that he finds no need for that hypothesis to explain the fossil record. But he adds, "Nevertheless, this is not to deny that there are some very curious features about the fossil record."[30] He prefers to interpret the evidence in terms of conventional geologic theory, though the evidence, we believe, is far easier to explain in a more catastrophic, short-age context, as is essentially acknowledged by his comment.

In his first chapter, Ager describes features of specific parts of the geologic column that are found over very large geographic areas or even worldwide. At the base of the Cambrian is a quartzite that is found in most locations worldwide typically followed by orthoquartzite, then glauconitic sandstones, and then marine shales and thin limestones. The quartzites (metamorphosed sandstone) and sandstone are course-grained deposits followed by fine-grained sediments. At the base of the Ordovician are prominent quartzites found in many parts of Europe and Africa and possibly more widespread than that. In the Devonian are continental red sandstones that extend from eastern Canada all the way to Iceland through northern Europe to Russia. The Mississippian Redwall Limestone is a prominent cliff-forming layer in the Grand Canyon. The same type of limestone formation, with similar fossils, is typical of the Mississippian throughout much of North America as far as Alaska and across Europe and into Asia. Pennsylvanian coal deposits are similar in fundamental ways, with similar fossil content, from eastern North America all the way into Russia. That is a distribution of coal facies that covers 130 degrees of longitude (adjusted for continental drift) or about two thousand miles.

The Triassic in western North America is characterized by a series of red formations. Series of these characteristic Triassic reddish sedimentary layers called red beds are also found in eastern North America, across Europe, in Mexico, and apparently in China and South America with very similar characteristics.

Ager gives more examples, and he only described deposits that he had seen personally. Thus some of these deposits may be much more widespread than what he described. In summary, in different parts of the geologic column are unique, characteristic deposits that cover extensive geographic areas and are often identifiably different from sediments in other parts of the column.

Other geologists also recognize this phenomenon. "Search for present day analogues of paraconformities in limestone sequences is complicated by the fact that most present configurations (topography, chemistry, circulation, climate) are strikingly unlike those that must have prevailed when the Paleozoic and Mesozoic limestone seas spread over immense and incredibly flat areas of the world."[31] More recently, Carlton Brett recognized that

> beds may persist over areas of many hundreds to thousands of square kilometers precisely because they are the record of truly oversized events. The accumulation of the permanent stratigraphic record in many cases involves processes that have not been, or cannot be observed in modern environments. . . . there are the extreme events . . . with magnitudes so large and devastating that they have not, and probably could not, be observed scientifically. I would also argue that many successions show far more lateral continuity and similarity at a far finer scale than would be anticipated by most geologists.[32]

These scientists are not interpreting the evidence as part of a global flood. They are simply recognizing the nature of the evidence, even though their worldview does not have the potential to explain that evidence as well as in a global flood. Such geographically extensive formations are a common feature of the Paleozoic and Mesozoic. In contrast, North American sedimentary formations in the Cenozoic are more localized, filling basins between the mountains that formed in the Cretaceous or Early Cenozoic or in river valleys (figs. 16.3B–16.3D; 18.7).

The tremendous geographic extent, and other features, of many Paleozoic and Mesozoic deposits are so

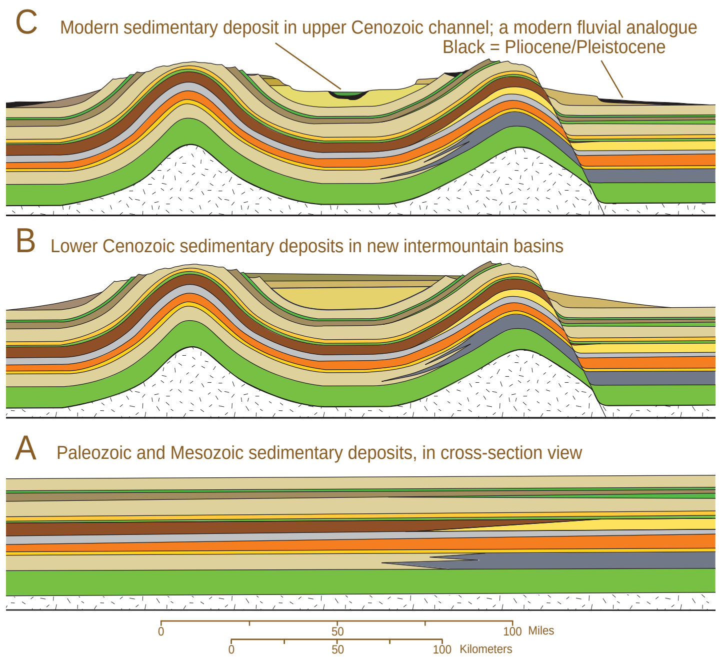


Figure 18.7. A diagrammatic representation of the geological history of the Rocky Mountain region in North America, in cross-section view. (A) Widespread, persistent sedimentary layers, as is typical of much of the Paleozoic and Mesozoic. (B) Uplift of the Rocky Mountain ranges and deposition of Lower Mesozoic sediments. Examples are the Green River and Bridger formations (see fig. 16.12). (C) Erosion of part of the Mesozoic sediments and local deposit of Pliocene to Pleistocene sediments. A channel in an intermountain basin represents the primary modern fluvial analogue. Compare this figure with figure 16.3, an aerial view of the same features shown here in cross-section. Figure by Leonard Brand.

out of character with the depositional environments that occur today that they beg for a very different explanation than can be supplied by modern analogues (fig. 18.7). A hypothesis that seems more consistent with these data is that they were formed by processes on a global scale, producing these unique and widespread types of deposits. The process began to wind down during the latter part of the geological column, producing the basin-fill deposits of the Cenozoic, and finally stabilizing to the even more localized processes that occur today. A profitable line of research would be a precise quantitative study of the geographic extent and physical character of ancient sedimentary formations compared with modern analogues to determine how general the above trends are.

Rapid Geological Processes and the Radiometric Time Scale

As we discussed above, the radiometric time scale is the most significant challenge to short-age geology. However, the scientific evidence does not all point in the same direction. In addition to the evidence discussed above, there is another line of evidence that is difficult to reconcile with the conventional geologic time scale. The Miocene/

Explanation for sedimentary units that are geographically widespread

DATA

Determine geographic distribution of a distinct and apparently continuous sedimentary unit, in square miles or kilometers. Evaluate what the most likely paleoenvironment the sediment was deposited in. Determine the geographic distribution and shape of comparable modern depositional environments.

INTERPRETATION

Both conventional science and interventionism: These attempt to interpret whether modern depositional analogues are adequate to explain the origin of the sedimentary unit.

Conventional science: Interpretation cannot question the accepted geological time scale or propose catastrophic conditions incompatible in scale or rate with basic modern geological processes.

Interventionism: This view lets the evidence suggest the time scale and whether the deposit requires a large-scale (even global) process and/or catastrophic rate.

Pliocene Pisco Formation in Peru is thought to span ten to twelve million years, based primarily on radiometric dates. However, the vertebrate fossils are generally articulated and very well preserved, indicating rapid burial.[33] Also, where good outcrops show details of the sediments, there typically are sedimentary structures that indicate storms and other fairly rapid sedimentary processes that may not require more than a few hundred years, at most, for the Pisco Formation. With so many indicators of rapid sedimentation, where in the sediments can we put those ten to twelve million years?

Another example is in the Eocene Bridger Formation in Southwest Wyoming. It consists of layers of limestone up to a few meters thick, separating much thicker fluvial (river-deposited) units. Radiometric dating requires about two-hundred-thousand-year cycles between limestones. The abundant fossil turtles, always in a clay layer right above a limestone, represent mass mortalities that included fairly rapidly burial. In the sediments that formed after a mass mortality, before another lake formed the next limestone, the turtles do not become more disarticulated and weathered as would be expected if long time periods had passed. Instead the turtles just disappear from the sediments until the next mass mortality.[34] The sediments above the mass mortality seem to indicate environmental conditions still suitable for turtles, but there are no turtles or turtle bones there. If these sediments between two limestones accumulated over several hundred thousand years, why are there no turtles in much of that interval (fig. 18.8)? The evidence is more consistent with a time period too short for the restoration of a turtle population. The turtles only reappeared after the next lake formed and lasted long enough for turtles to again become abundant. The Bridger and the Pisco Formations both contain evidence that seems to require some time—a few decades or a few hundred years during the transition from catastrophe to more modern processes—but they do not seem compatible with millions of years.

The Eocene Green River Formation (GRF) in southwestern Wyoming also contains evidence for rapid deposition. Radiometric dates indicate several million years for formation of the GRF, and a large part of the GRF consists of many thousands of very thin laminations, usually interpreted as annual layers (varves). Yet these "varved" deposits (which actually are not varves)[35] are full of exquisitely preserved fossils (fig. 17.7). There are beautifully preserved plants, including palm fronds several feet across. There are also many millions of articulated skeletons of vertebrate animals. These are mostly fish, but there are also occasional large turtles, crocodiles, a

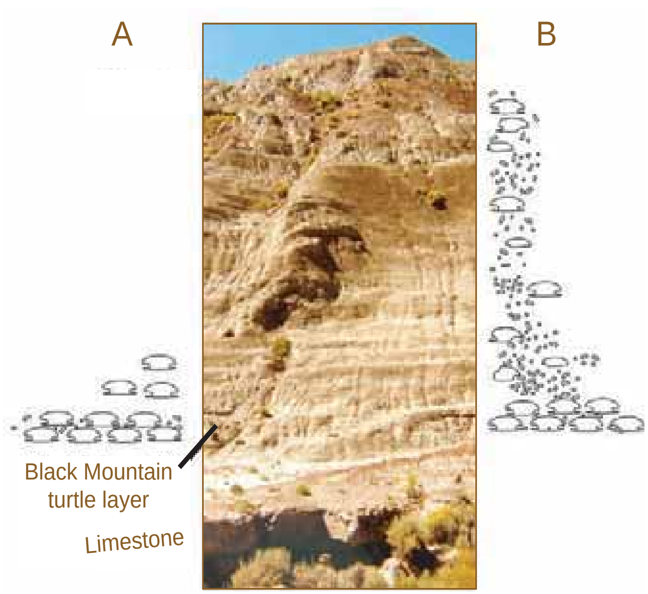


Figure 18.8. (A) Actual characteristics of the turtle assemblage in the Eocene Bridger Formation. (B) Expected characteristics of a fossil turtle assemblage if it accumulated over an extensive time period, showing complete turtle shells, partial shells, and disarticulated shell bones. Figure by Leonard Brand.

few bats, coprolites (fossilized dung), and a small, complete, very well-preserved, articulated Eocene horse skeleton. Although some fish are disarticulated, most of these fossils show exceptional preservation, and modern studies of decay processes in various environments indicate that such good preservation requires rapid burial. There is no reason to think that covering a fish or a ten-foot-long (3 m) crocodile with one millimeter of sediment per year would preserve them at all. It has been suggested that the organisms were preserved because the water was anoxic (no oxygen). There are two reasons that is not a satisfactory hypothesis. First, a lack of oxygen does not prevent decay nor necessarily even slow it down significantly. Also, study of a location in the GRF that was a shallow-water, nearshore environment had the same excellent preservation in the same laminated sediments, but that nearshore environment could not have lacked oxygen.[36]

It is hard to escape the need for rapid deposition of these fossiliferous sediments in the GRF. There must be an as-yet unknown process that can form these thin laminae rapidly. The deposit has evidence of an established ecology from nearshore environments to deep water, and stromatolites that grew along an advancing shoreline seem to indicate that it did not form in a few weeks. It took some years to be deposited, but where in the sediments could millions of years fit?

As indicated earlier, geologists are generally aware that much of the sediment in the geologic column shows evidence for rapid deposition. The explanation accepted by most of the geological community for this phenomenon is pictured in figure 18.4—repeated episodes of sediment deposition and erosion that did not leave a permanent record. This suggests that only the deposits from infrequent major storms or catastrophic events are preserved, while the rest of the sediments eroded away and left no record. But is it realistic to think that so much (up to 90 percent or more) of the sediment was really deposited and eroded away without leaving some evidence of those erosional events behind? A simpler explanation is that most of that time never existed, and the hypothesis shown in figure 18.4 (left) is not necessary. The time gaps (unconformities) that occurred generally left recognizable evidence in the rocks. Most of the other, hypothesized, time gaps never existed (fig. 18.4, right).

Erosion and Landscape Formation

After most of the sedimentary deposits accumulated, the land was eroded into the landscapes we see today. During this process, an unimaginable amount of sediment was eroded away to form valleys and canyons interspersed with cliffs, ridges, and mountains that remained. The western United States is one area where this can be seen very well because of low rainfall and limited vegetation cover.

Conventional geological theory interprets most of this erosion as resulting from the same processes we observe today as rainfall, streams, and rivers erode and carry away sediment over very long periods of time. However, there are landscape features that speak eloquently for a different process, much more catastrophic than modern erosion. This is a promising topic for future research, since short-age geologists also don't know just how this happened. One example is an extensive cliff in southern Utah called the Straight Cliffs. It is also called Fifty Mile Mountain because it is a fairly straight, almost continuous cliff, fifty miles long and up to one thousand feet high. There is no fault at this cliff, but the sediment in front of the cliff has simply been eroded away. Figure 18.9 is a photograph of the cliff and a diagram showing the structure of the area. Rain falling on the top of the cliff runs downhill away from the cliff face, and rainfall would not be expected to form such a uniform cliff with almost no side canyons cutting into it. It is hard to escape the idea that it took a massive water flow to carve such a feature.

Another example is the Grand Staircase (fig. 14.20). An area of more than twenty thousand square miles (55,600 km^2) in northern Arizona and southern Utah is carved into

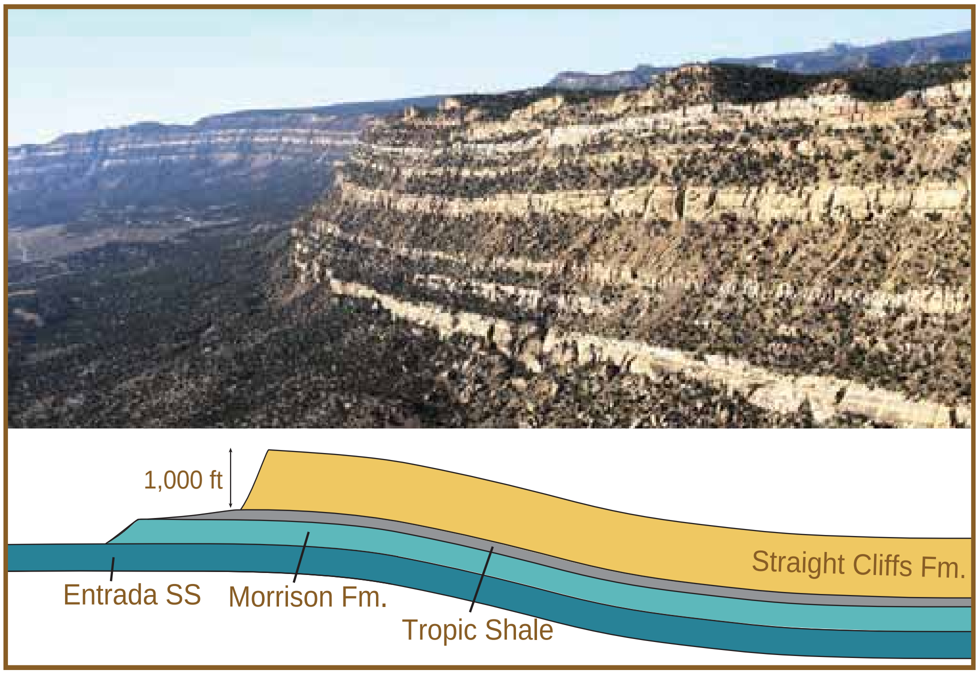


Figure 18.9. A photograph of the Straight Cliffs and a cross-section through the cliff. Figure by Leonard Brand.

a series of gigantic steps, dropping down to the south. When rivers erode the land they don't make a staircase; they form valleys with cliffs or ridges on both sides of the river valley. How could normal erosion carve the steps of the Grand Staircase? This also seems to call for eroding water flow on a grand scale. Was this from water runoff at the end of the global flood or a later erosion episode in connection with the Pleistocene glacial period? That is a question for more research. In any case, it does not appear to have been eroded by processes we observe today.

Trace Fossils and Bioturbation of Sediments

Any marks, or traces, left in the sediment by the activities of animals are called trace fossils. There are abundant fossil burrows and trails of invertebrates (fig. 18.10) and vertebrate animal tracks throughout the geological column. Since these were made by living animals, they indicate that living animals were active all during the formation of the fossil record. There are, for example, many trilobite trails, feeding marks, and resting marks where the animals dug into the sediment to rest while hidden in the mud.[37]

Interpreting the processes generating landscape features

DATA

Description of a landscape feature (cliff, canyon, etc.): sedimentary features, physical shape, geographical scope and arrangement, drainage patterns, and so on.

INTERPRETATION

Both conventional science and interventionism: Compare with modern analogues and interpret which modern process or hypothetical process is the most likely explanation.

Conventional science: Hypothesized processes are expected to be consistent with conditions and rates known from or feasible in the modern world. Catastrophic explanations are acceptable if they meet these restrictions.

Interventionism: This view allows the evidence to indicate what process is most likely, even if it requires very catastrophic and large-scale, even global processes.

Many of the tracks and burrows are similar to modern animal tracks and burrows.[38] Animals that live within sediment, including clams, worms, shrimp, or small echinoderms continually burrow through more and more sediment. This activity is called bioturbation. In the modern world, the activity of burrowing animals in underwater sediment generally results in the total bioturbation of the sediment so that little, if any, of the original layering or

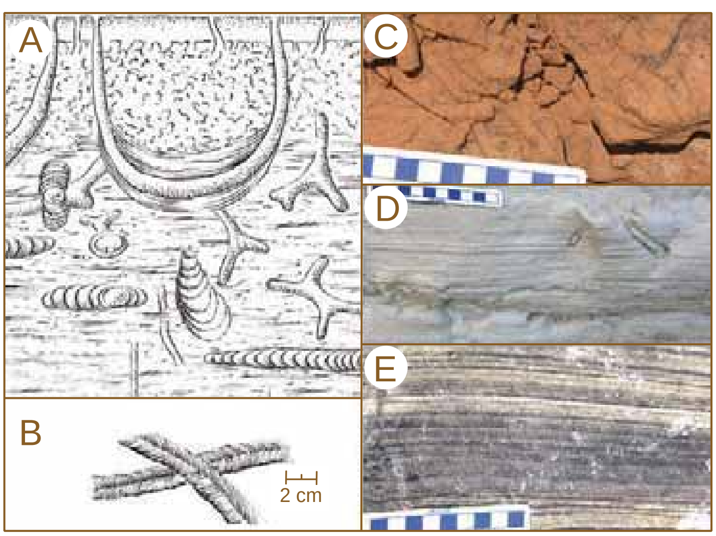


Figure 18.10. Representative trace fossils of invertebrate animals, including (A) burrows in the sediment, (B) crawling traces or trails of trilobites (after Bromley 1990; Frey 1975), (C) fully bioturbated (level 4 in fig. 18.13), and (D, E) little or no bioturbation (level 1 in fig. 18.13). Figure by Robert Knabenbauer and Leonard Brand.

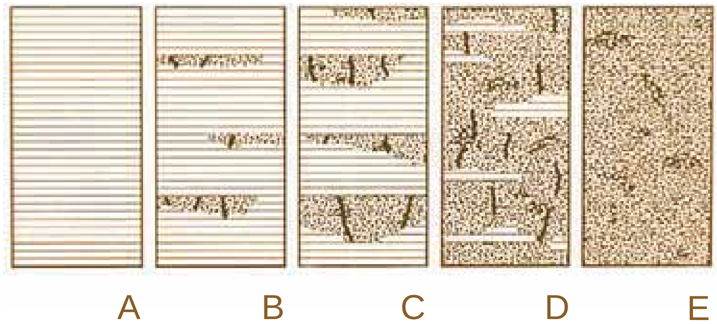


Figure 18.11. Relationship between bioturbation (animal traces) and sediments. In (A) the sediments were deposited rapidly and there was no time for bioturbation or else erosion removed the tops of sedimentary units, removing the traces. In (B) some time passed for bioturbation after some of the units were deposited, and (C) indicates more time after some units were deposited. Almost all of (D) and all of (E) have the original sedimentary structures removed by bioturbation, as would be expected if the deposits were produced slowly, under conditions favorable to animal life (after Bromley 1990). Figure by Carole Stanton.

other sedimentary structures remain (fig. 18.11D; 18.11E). If sediments preserved as rock have not been 100 percent bioturbated, that feature requires explanation.[39]

The nature and distribution of trace fossils in the rock record has important implications for short-age geology, and we will discuss, first of all, the relationship between bioturbation and preserved bedded rocks, then the implications of trace fossils for animal survival during the flood.

Bioturbation and Preserved Rock Bedding

Incomplete bioturbation or no bioturbation results if the sediments cannot support animal life or if they were deposited so rapidly that the animals had no time to do their work (fig. 18.11A; 18.11B). Rock layers with some bioturbation represent the passing of at least a few hours for the animals to move around and leave their footprints or burrow in the sediment before the next layer was deposited.

Many or most sedimentary deposits were laid down in water, often assumed to be ocean water. Once deposited, one of several things can happen to these deposits. The bed can be quickly covered by another bed. In this case, the fine internal structure should be preserved intact. Or the bed can be exposed to erosion, in which case some or all of the bed (and its internal structure) can be removed. The bed can sit exposed on the ocean floor for a period of time. During the passage of time the burrowing activity of bottom dwelling organisms will quickly damage or destroy the internal layering in the beds. If the beds are completely disrupted by repeated cycles of burrowing, the bed is considered to be homogenized. In such cases, all the evidence of sediment layers or other internal structure will be gone. Modern studies indicate that homogenization of sediments requires from one hour (experimental) to one year (field observations) to a depth of about ten centimeters. As Richard Bromley expressed, if the internal structure of sediments has not been completely bioturbated, that requires an explanation.[40]

Layers of sediment are also called beds, and this layered character of the rocks is called bedding. Typical rates of deposition for sedimentary layers based on radiometric dates give values of about one centimeter per thousand years. If the sediment really was deposited that slowly, we would expect all evidence of sedimentary bedding to be destroyed. Is that what we see in the geological record? The next section will answer this question.

Persistent Bedding in Rocks

The geological record contains an abundance of discrete layers of sedimentary rock with distinct bedding preserved (fig. 18.12; 18.7). These layers commonly do not blend gradually from one into the other but have distinct boundaries or contacts between layers of either the same or different types of sediment. If a sudden change in the

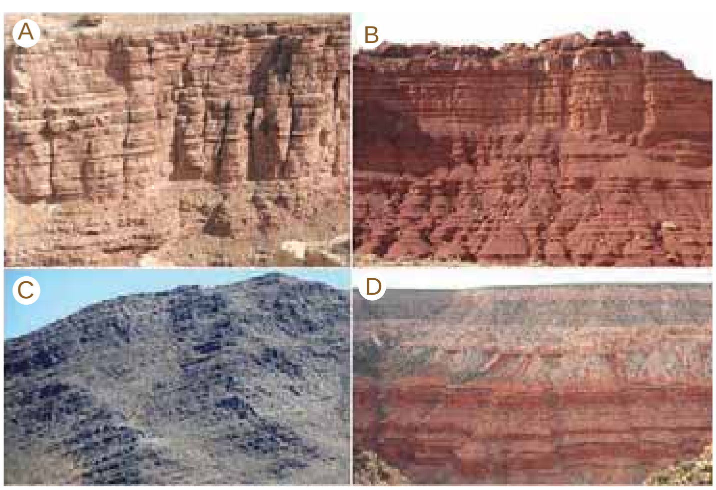


Figure 18.12. Examples of the distinct bedding, or layering, often evident in sedimentary rocks. (A) Permian limestone, northern Arizona; (B) Triassic sandstones and mudstones, northern Arizona; (C) Cambrian limestone, Utah; (D) Pennsylvanian and Permian limestones, sandstones, and shales, Grand Canyon, Arizona. Figure by Leonard Brand.

sedimentation process did occur, producing a sharp break between two sediment types, the normal activity of burrowing animals (bioturbation) would be expected to blur the contact, erasing any sharp sedimentary breaks or contacts.

But distinct bedding is so characteristic of the geological record that these sharp breaks require an explanation. In fact, sedimentologists, who rely on the internal structures in beds to understand the processes of sedimentation, would have a very hard time doing their research if the sediments were deposited as slowly as the radiometrically determined dates would indicate. In contrast, much of the sediment deposited during a global catastrophe would be deposited too quickly for complete bioturbation. Distinct bedding is much easier to explain if the record formed rapidly, as in a short-age theory.

Invertebrate Animal Activity during the Global Catastrophe

This evidence, in a short-age model, implies that even during the year of the flood, invertebrate animals were moving around. They were not all suddenly killed and buried. Many continued to live for a time and were able to

Interpreting relationships between bedding of rock units and bioturbation or other disturbances

DATA

Documented, specific bedding features in rock units. Observed, quantified bioturbation in each rock unit. Sedimentary features that may indicate the conditions under which the sediment was deposited.

INTERPRETATION

Conventional science: Interpretation cannot question the accepted geological time scale or propose catastrophic conditions incompatible with basic modern geological processes.

Interventionism: This view lets the evidence suggest the time scale and whether the deposit requires rapid, even catastrophic conditions to explain the amount of bioturbation or lack thereof.

burrow through the sediment. If there was a quiet period of time, even a few hours, the live animals would settle on the sediment and make burrows. If sediment accumulated over the burrow, some would try to burrow up through it, leaving escape burrows. Others would probably swim up in the water and come down on top of the next layer. It seems clear that abundant invertebrates were alive and being transported around during the catastrophe, but how abundant were they and their burrows? Is the amount of bioturbation consistent with such a rapid event, or does it imply the passage of a lot of time for the burrowing activity, as some claim?

A careful study of the distribution of bioturbated sediment through the geological record is important for answering this question. We have been surveying a number of rock formations in Utah and western Colorado, quantifying in detail the amount of bioturbation in rocks from Cambrian to Eocene. Although a simple diagram showing bioturbation in the geological column (fig. 18.13A) could be interpreted to indicate an abundance of bioturbation all through the column, detailed quantification reveals a different picture. There are some small vertical sections of sediment with abundant burrows (level 4) or a lesser amount (levels 2 or 3), but the vast majority of vertical intervals in all deposits surveyed had no bioturbation or a small amount (level 1), not enough to noticeably disturb the bedding. The bioturbation that is present is often only at the top of burrowed units. Figure 18.13B shows the amount of bioturbation through the Triassic Moenkopi Formation, which is about average for all deposits surveyed, and figure 18.13C shows a section through part of the Mancos Shale that is the maximum level of bioturbation found in our study. This shortage of bioturbation explains why so many geological deposits have distinct bedding preserved. It also says that although invertebrates were active at intervals all during the global catastrophe, the amount of activity is most consistent with short periods of time.

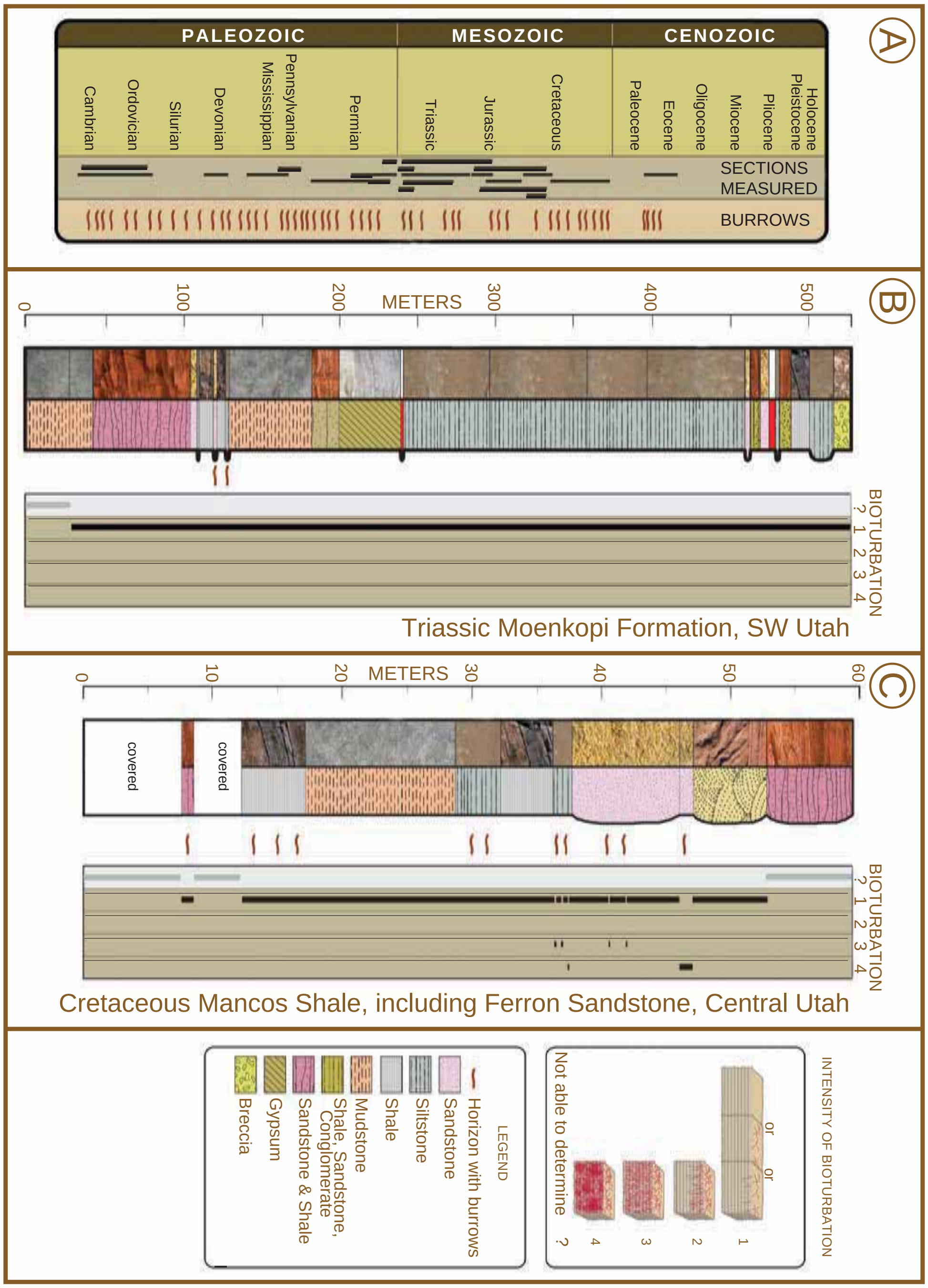


Figure 18.13. (A) The distribution of bioturbation through the geological column, showing the stratigraphic location of sections studied by Brand and Chadwick. (B) Quantitative distribution of bioturbation in the Triassic Moenkopi Formation, which is about average for the formations that we studied. (C) Bioturbation in part of the Cretaceous Mancos Shale, the highest level of bioturbation found in our study. Figure by Doug Oliver.

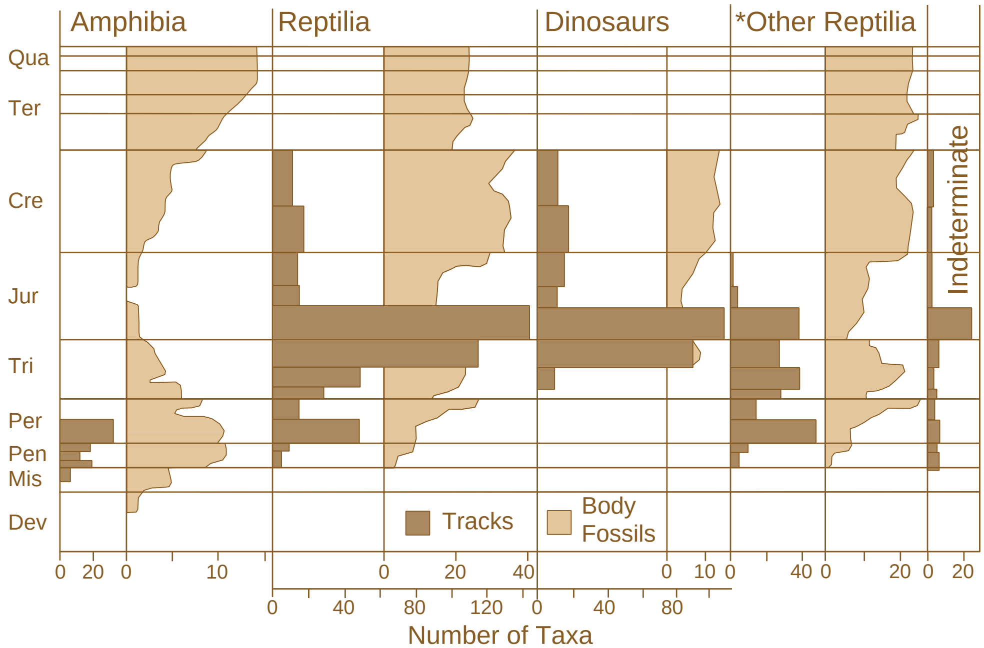


Figure 18.14. Stratigraphic distribution of fossil amphibian and reptile tracks and body fossils (from Brand and Florence 1982). *Other reptilia = nondinosaurs. Figure by Leonard Brand.

Vertebrate Animal Tracks on Ancient Sediments

Now we will leave the clams and worms to their burrowing and look at fossil tracks left by vertebrate animals. Leonard Brand and James Florence summarized the available data on stratigraphic distribution of vertebrate tracks.[41] More recent literature reports an abundance of new fossil track sites, and these new discoveries still seem to fit the stratigraphic pattern reported by Brand and Florence.

Many amphibians and reptiles were active, leaving footprints, and all except dinosaur tracks are almost entirely limited to the Upper Paleozoic, the Triassic, and the Lower Jurassic (fig. 18.14). These footprints are the right size and shape to have been made by the now extinct Paleozoic and Mesozoic amphibians and reptiles. By the end of the Early Jurassic, almost no more amphibian footprints are found, and very few have been fossilized since then. The greatest diversity of nondinosaurian reptile footprints occurs in the Triassic and Early Jurassic, but body fossils (bones) are most abundant higher up in the Cretaceous and Tertiary. Trackways indicate that smaller vertebrates were actively walking or running over the ground surface during much of the time before Late Jurassic.

Animal activity during the flood

DATA

Documented distribution and abundance of vertebrate and invertebrate trace fossils at different stratigraphic intervals in the geological record. Any other indicators of live animals (eggs, etc.) at each interval.

INTERPRETATION

Conventional science: Interpretation will assume standard geological time and ecological conditions equivalent to the same environment in the modern world.

Interventionism: Interpretation will assume a short time frame. Do not make other assumptions about processes during the flood. Allow the data to indicate amount and timing of live animal existence during the flood and after. Utilize evidence of animal activity in modeling the nature of flood processes.

It is strangely common for an animal's fossil tracks to appear in the rocks before its body fossils (bones). Dinosaur tracks are quite diverse in the Triassic and Early Jurassic, but the greatest diversity of dinosaur body fossils is in the Cretaceous. Fossil tracks of small dinosaurs and other reptiles almost came to an end by the mid-Jurassic, but in the Late Mesozoic, there were still abundant large dinosaur tracks.[42] Dinosaur tracks are very abundant and yield insight into the life of these animals.[43] The fossil trackways in flood deposits indicate that the surface was not continually covered by deep water. There had to be many brief time intervals of shallow water or exposed surfaces when the tracks were made.

Bird and mammal tracks were most abundant in the Late Cenozoic (fig. 16.15). The distribution and the necessary time to produce these Cenozoic tracks and burrows is readily explained in sediments that formed over several thousand years, after the main part of the flood.

Extinctions

At several points in the fossil record, often called crises in the history of life, an especially large number of groups of animals went extinct (fig. 18.15).[44] One prominent extinction came at the end of the Cretaceous.[45] Many of the large reptiles, including all the dinosaurs, went extinct. The pterosaurs and the swimming reptiles such as plesiosaurs, ichthyosaurs, and others also went extinct about the same time, along with many types of marine invertebrates.

Conventional theory proposes that at these times of crisis, something changed, such as climate, and the animals could not cope with it. Thus many types were wiped out. A prominent theory proposes that some of these crises were caused by catastrophic asteroid impacts on our earth[46] and/or massive volcanic activity.[47] Animals that survived recolonized the earth and evolved into new forms to fill the now empty niches.

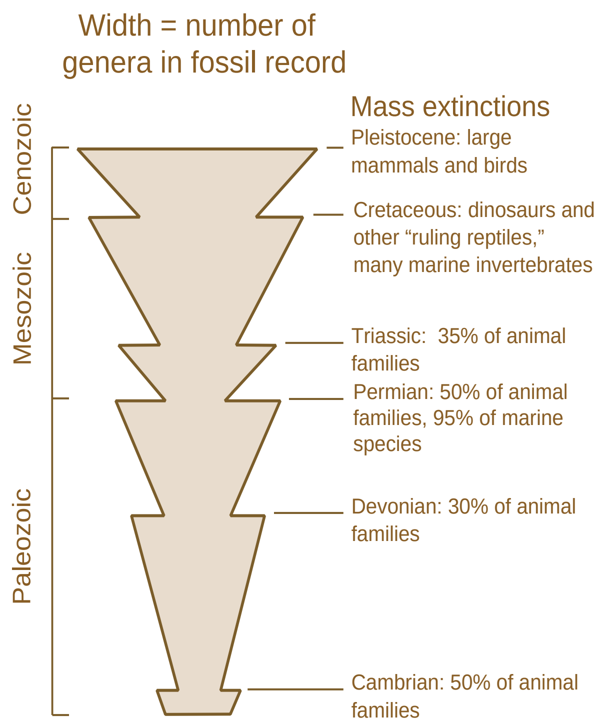


Figure 18.15. Extinctions in the fossil record. Width of the shaded figure indicates number of genera of animals in the fossil record at that level. Each place where the figure gets narrower is a mass extinction. Figure by Leonard Brand.

Short-age geology proposes, on the other hand, that these crises occurred when the geological catastrophe reached some critical point and the remaining members of certain groups of organisms were all killed and buried. A life zone may have been destroyed. For example, the lowland swamps that were inhabited by some Paleozoic creatures were destroyed and never reestablished. Thus the deposition of sediments and organisms from these lowland areas came to an end. Deposits forming afterwards no longer contained fossils from that life zone. In some cases, a group of organisms went almost extinct, and those individuals that survived the extinction avoided getting buried and fossilized. They are not found as fossils in later rocks, but they are still alive today. An example is the coelacanth fish that was thought to have been extinct for sixty-five million years but has been found living in the ocean near Madagascar and Indonesia.

Those who accept a short-age theory also do not know exactly what happened, but it is not too hard to imagine some critical stage in the geological catastrophe when the dinosaurs and some other animals were no longer able to survive. Perhaps an asteroid impact was at least part of the process that caused the extinction to occur at that time. The animals died out or were too decimated to reestablish themselves again. At least they did not live long enough to leave a fossil record.

Taphonomy

The field of taphonomy (the study of the processes from death to fossilization) has produced much fascinating data.[48] Research has shown how important rapid burial is for producing fossils, especially for well-preserved vertebrate fossils. It appears that these implications have not been fully explored. Many formations are interpreted as accumulating very slowly—perhaps only a few inches (or centimeters) of sediment accumulated in each thousand years—but they contain superbly preserved vertebrates in large numbers. Examples include the fish and other organisms in the Green River Formation, the turtles in the Bridger Formation,[49] and ancient diatomites with well-preserved whales and other vertebrates.[50]

The lack of decay is often explained by animals dying in anoxic water (no oxygen). However, experiments have not supported the hypothesis that anoxic water slows or eliminates decay. Published research shows that decay is not slower in anoxic conditions. It just involves anaerobic bacteria.[51] Recent research even indicates that the exquisite preservation of the Burgess Shale soft-bodied animals occurred in oxygenated water.[52] These well-preserved fossils seem to require very rapid sediment deposition.

The other side of taphonomic data also needs to be considered. If at least the Paleozoic and Mesozoic were deposited within a year, with systematic ecological processes killing and burying organisms, then most animals must have been buried very soon after death—within hours or days. The problem with such consistently rapid burial is that it should have preserved mostly intact, articulated specimens. However, the vertebrate fossil record includes many examples of disarticulated, scattered bones and teeth. Most of these disarticulated remains probably required several weeks or months of decay and disarticulation before burial. Is it possible to fit many episodes of several months of disarticulation into a one-year Cambrian to Cretaceous process?

The activities of predators and scavengers probably had a significant impact on the fossil record. Some Cenozoic vertebrate fossil deposits appear to be entirely composed of bone fragments from predator dung or owl pellets.[53] This could also happen during a catastrophic episode if large numbers of scavengers and predators were active. Perhaps the result would be fairly rapid processing of prey animals into bones ready for burial.

Ancient Biomolecules

Research on biomolecules such as proteins and DNA reveal that when they are exposed to the environment, they decay with half-lives of tens to thousands of years, depending on the molecule.[54] Consequently if deep time were real, there should not be any of these biomolecules preserved beyond hundreds of thousands of years. However, abundant research in recent years is finding increasingly convincing evidence that proteins and possibly even DNA exists in clearly identifiable form in fossils, even in the Paleozoic.[55] This is an emerging story, and there is much more yet to be learned. But even at this point, the presence of surviving biomolecules for tens or hundreds of millions of years is another indication that the widely accepted meaning of radiometric decay ages must be considered tentative at best.

Conclusion

The examples discussed here do not prove the radiometric time scale is wrong, but they make it unsatisfying. Some of us predict that we will discover more reasons why radiometric dating, at least in the Phanerozoic, does not give correct time in years. It is only a relative scale of isotope ratios produced by some factor other than time and associated with geological events occurring in a much shorter period of real time. This factor will be a significant process that affects all radiometric processes and will not involve separate "fixes" for each dating method.

Most scientists would object to considering supernatural causes for some events in geology. Yet the real question is not whether we like it but whether it happened. If it did happen, it is possible that some evidence of that unique occurrence would be left in the rocks, and we should be able to find that evidence. Of course, we are only likely to recognize that evidence if our minds are open to such a possibility. As we have indicated, we believe much of this evidence is already being found. It is often claimed that there is no evidence for a global flood, but perhaps the evidence is all around us but often not recognized because of incorrect assumptions (fig. 18.16). We are unlikely to see something if we don't believe it exists.

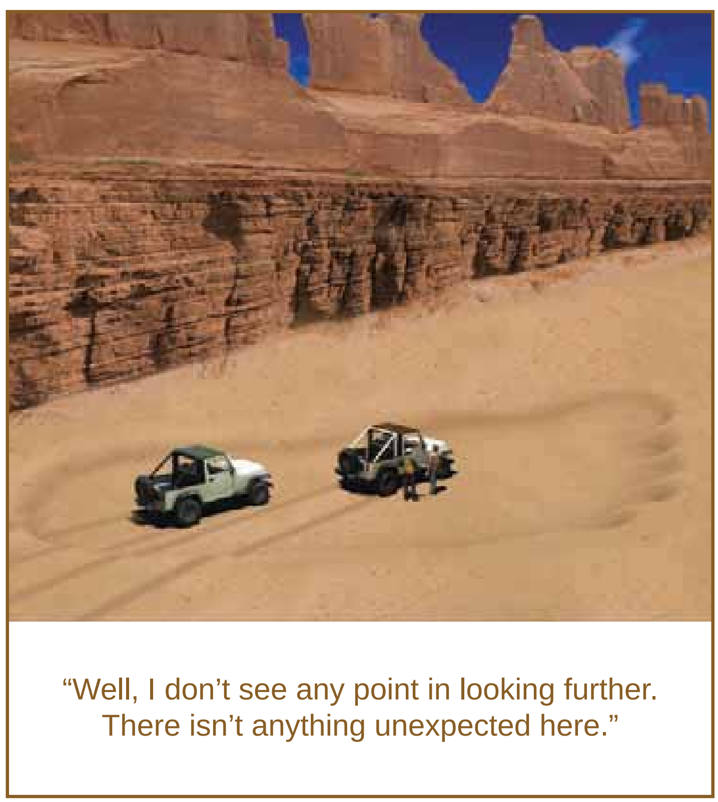


Figure 18.16. Observers reaching wrong conclusions because of some important, missing evidence. Figure by Doug Oliver.

In summary, radiometric dating is still the strongest evidence for the great age of the fossil-bearing formations, but it is not an air-tight methodology and much evidence is arguably contrary to its time scale. And even if we question the amount of time in earth history, radiometric dates do seem to be the result of a systematic process that occurred the same way everywhere. Even a short-age geologist can use these isotope ratios as a correlation tool to determine the relative age of rocks, irrespective of whether the ratios tell anything about real time.

The trend toward more catastrophic processes is a movement in the direction predicted by short-age theory. The field of geology will benefit if more earth scientists actively use the short-age theory in proposing and testing hypotheses about radiometric dating and geologic history, as long as they use careful scientific methodology and benefit from scientific peer review. The excitement of discovery awaits those who are willing to break new ground in research and look at familiar things from a new point of view. But this viewpoint will still need to account for the radiometric age data, not ignore that data.

When attempting to reconcile ancient history with Scripture, it is not wise to change one's position too readily. If a given theory of geology, for example, is based on and consistent with Scripture but we do not know how to fit it with the scientific data, that may just reflect inadequate knowledge of ancient processes and especially of how those processes may differ from our modern analogues. This is even more relevant if we consider that ancient processes (e.g., a global catastrophe) were very different from anything we have ever observed. Many ancient geological deposits are acknowledged not to have adequate modern analogues.[56]

There are those who have decided that we need to reinterpret Scripture to fit science as understood by the majority of scientists today. Though their reasons are understandable, there is also reason for trying a different approach—seeking a geological theory consistent with a more literal understanding of Scripture. God knows much more about earth history than we do and has shown a level of interest in communicating with us that is not consistent with an allegorizing of Genesis. However, the Bible indicates a literal one-week creation and a global flood but does not require that short-age geology theory explain all the geological column within the one-year flood. That is a matter for more extensive study.

Research and Predictions

Contrary to what many anticreationists say, interventionist and short-age theory makes numerous suggestions for research and predictions to be tested. Chapter 19 describes a number of completed and published research projects of this type and lists predictions that can lead to more successful research and new scientific insights.

The Weight of Evidence

We can now summarize a number of issues we have considered in the form of a list of evidence in the three categories in table 18.3. In some cases, it is a matter of opinion which list an item should be placed in. One cannot realistically decide the strength of a theory based on the length of such lists, since some lines of evidence are far weightier than others. In fact, to discourage the natural tendency to decide a question according to which list is longer, the table includes enough of the best lines of evidence to make the two outer lists the same length. These lists are merely a way to help organize the information.

Table 18.3. The balance of evidence for and against macroevolution and conventional geology

Evidence favoring intervention and/or short-age geology	Neutral evidence	Evidence favoring macroevolution and conventional geology
The problem of originating life	Microevolution	Radiometric dating, indicating long ages
Lack of fossil intermediates	Speciation	Biogeography (some)
The problem of originating new body plans	Embryology	Sequence of vertebrate fossils; fish, amphibians, reptiles, mammals
Epigenetics	Vestigial organs	Precise sorting of fossils in the fossil record
Cellular complexity	Hierarchical nature of life	Reptile/mammal fossil intermediates
Stasis—lack of evolutionary change in fossils	Diverse levels of biological complexity	Whales and their ancestors
Sedimentation rates	Homology	Time required for cooling of laccoliths
Megabreccias (the larger clasts)	"Suboptimal" adaptations	Glaciation (some of the evidence)
Small amount of sediments in the oceans	Biogeography (most)	Fossil reefs (some)
Rate of erosion of the continents	Archaeopteryx	Stromatolites requiring growth time
Gaps in the geological record with little or no erosion	Record of humans	Tidal cycles in sediments
Very widespread sedimentary formations	Fish/amphibian "transition"	Diabolical parasites
Extensive bedded sediments	Heterochrony and paedomorphosis	Evaporite deposits
Low levels of bioturbation	Regulatory gene evolution	Slow movement of continents
	Processes of formation of rocks and minerals	
	Carbon 14 dating	
	Ice cores	
	Evidence used for interpreting depositional environments	
	Evidence for water covering more of the continents in the past	
	Mountain building and general patterns of erosion and landscape development	
	Glaciation (most)	
	Fossilization processes	
	Channeled Scablands	
	Abundance of turbidites	
	"Nothing happens in the Grand Canyon except in a catastrophe"	
	Megabreccias (some)	
	Marine fossils on Mt. Everest	

The two outer lists are kept the same length to avoid the common tendency to evaluate issues according to which list is longer.

CHAPTER 19

Research and Predictions

Overview

Experience convinces some of us that interventionist interpretations can be effective stimuli for quality geology research, and when done with the standards of quality expected by any scientist, these researchers often find things not noticed by other geologists. This chapter describes several examples of research projects by interventionists, published in peer-reviewed scientific research journals.

Research under the Philosophy of Interventionism

Our experience indicates to us that interventionism, as described above, is an effective framework for doing science. The following are several specific examples of research done under this interventionist philosophy and published, in most cases, in peer-reviewed scientific journals. This work illustrates that belief in interventionism does not in any way inhibit productive research of a quality that can be published in the peer-reviewed scientific research literature. Statements have at times been made in print to the effect that creationists and those believing in "flood geology" have never attempted to contribute to the advance of science, and they do not publish scientific research papers. These statements are not true. We know many interventionist persons, educated in science, who are enthusiastic contributors to the scientific enterprise, following high standards of scientific practice.

Isaac Asimov once said, "The most exciting phrase to hear in science, the one that heralds new discoveries is not 'Eureka!' (I found it!) but 'that's funny.'"[1] The research described below often resulted from seeing something that "looked funny" because it didn't fit existing theory. Others didn't see these things or saw them but didn't investigate them further.

Yellowstone Fossil Forests

In and adjacent to Yellowstone National Park, volcanic deposits contain a series of fossil forests, one above another, with upright stumps that appear to be in their original position of growth. If these forests containing some very large trees grew in their current position, one forest after another, a very long time would be required. Interventionists began studying these forests to determine whether there was an equally valid alternative interpretation. Their research has led to the development of the hypothesis that the fossil trees did not grow where they now are but were transported to that location together with the sediments. Several lines of research, published in professional journals, lend support to this hypothesis.[2]

Grand Canyon Geology

Arthur Chadwick has been studying the Tapeats Sandstone near the bottom of the Grand Canyon. He and his collaborators found geological features that clearly change the interpretation of the Tapeats Sandstone.[3] Others have interpreted the Tapeats Sandstone as an accumulation of sand in shallow water along an ocean shore, with the water level and the top of the sand deposit rising along an existing cliff face over millions of years. The sand finally covered the cliff face and went over the top of the cliff. The findings by Chadwick and Elaine Kennedy require accumulation of the sand in deep water by very different processes from those that would occur in shallow water (it also could occur faster, but their research did not address that issue). They presented their data and conclusions to a professional meeting of geologists, and it was concluded that Chadwick and Kennedy were correct based on the new data. One geologist later asked Dr. Chadwick how he had seen these things that other geologists had missed. The answer is that our worldview prompts us to ask questions that others are not asking—to question conclusions that others take for granted—and it opens our eyes to see things that are more likely to be overlooked by a geologist working within a conventional naturalistic scientific theory.

A careful scientist who allows Bible history to inform his or her science will not use a different scientific method from the method used by other scientists. When we are at a rock outcrop, we all use the same scientific method. The types of data potentially available to us are the same, and we use the same scientific instruments and logical processes to analyze data. The differences are in (1) the questions that we tend to ask, (2) the types of hypotheses we are likely to consider (the range is shifted toward more rapid geologic processes, but is still fairly wide), and (3) which of the potential types of data are more likely to catch our attention.

Vertebrate Fossils in the Eocene Bridger Formation of Southwestern Wyoming

My own research (Brand) included a study of the fossils and sedimentary processes in the Bridger Formation, a classic vertebrate fossil-rich deposit. Many other vertebrate paleontologists have studied the Bridger Formation since the 1860s, but fossil turtles are still very abundant. My collaborators and I began study of the Bridger with some of us asking questions such as the following: "Is the assumed millions-of-years time scale for the Bridger supported by the evidence? What processes deposited the fossils and the sediment, and how long did it take?" Other scientists are more likely to think the answer is already dictated by the radiometric time scale, and thus some of our questions were different from questions that other scientists are asking.

The abundant turtles turned out to be an important line of evidence, in combination with study of the sediments that buried them. Several years of research pointed clearly to the conclusion that most of the fossil turtles resulted from mass mortalities of many thousands of turtles over several hundred square miles. The dead turtles were then buried by sediment within a few months, before normal decay processes could disarticulate their shells into individual bones.[4] These decay processes and their time frame were studied in the lab.[5] This evidence indicated that sediment associated with the turtles accumulated relatively rapidly.

Radiometric dating of some volcanic tuffs (volcanic ash layers) indicate a time span of several million years for the Bridger Formation. Our data indicate that at least some of the sediment was deposited rapidly, and similarities through much of the formation raise doubts about long durations of time in the Bridger.[6]

There are a number of limestone layers scattered through the Bridger Formation and formed in lakes. It has been stated in the geological literature that almost all of these limestones are local, and only one goes across the whole basin. It has also been assumed that the turtles died in local ponds or marshes that dried up. Because of my questions about how widespread and catastrophic the processes were, I began mapping the limestones to determine how extensive they really were. It became clear that most of the limestones cover the entire basin of several hundred square miles and that a turtle mass mortality that we studied in detail was a basin-wide process, not local concentrations of turtles. The questions that we were asking opened our eyes to notice things that others had not recognized.

This research accumulated data that raise questions about applying radiometric dates to the Bridger

Formation, but our findings also indicate that deposition of the Bridger Formation apparently could not have happened in a few weeks or months.

Experimental Taphonomy

If we understand the processes of decay and skeletal disarticulation of freshly killed animals today, as well as how long those processes take, our interpretations of those processes in fossil deposits are more likely to be correct. For that reason, we did a comparative study of decay and disarticulation in carcasses of small amphibians, reptiles, mammals, and birds in the laboratory.[7] In this research, the interventionist theory does not suggest unique hypotheses but simply recognizes the benefit of accurate research that can help us understand how fossil deposits formed.

Fossil Whales of the Miocene/ Pliocene Pisco Formation of Peru

The Pisco Formation in Peru contains numerous fossilized whales in diatom-rich sediment. Microscopic diatoms are organisms that float near the surface of lakes and oceans. Upon death, their silica skeletons sink, and in modern oceans, they usually form accumulations of diatomite a few centimeters thick in a thousand years. It is generally assumed that ancient (fossil) diatomite deposits formed at the same slow rate—a few centimeters per thousand years.

Geologists have published on the overall geology of the Pisco Formation, and paleontologists have studied the whales and where they fit into evolutionary scenarios, but apparently no one has previously asked how sediment that accumulated at the slow rate of a few centimeters per thousand years can contain complete, well-preserved whales, which would seem to require rapid burial for their preservation. This was another case in which our worldview opened our eyes to see things that others have not noticed or taken seriously—the incongruity of the well-preserved whales as opposed to the presumed slow rate of diatom accumulation. Our research by geologists and paleontologists points to rapid burial, probably within a few weeks or months for any given whale, and suggests some processes that can help explain how ancient diatomites may have formed much more rapidly than is usually assumed.[8]

As we publish our research findings, the best scientists in the field have the opportunity to evaluate our work and will be eager to point out our mistakes. That is a powerful incentive to keep us from being careless. Of course, in our publications, we will discuss scientific work only, not our personal philosophy, and if the data support our conclusions, our work will stand up to the criticisms of scientific reviewers. In our research, it is very important to be aware of the data and ideas of scientists who approach the subject from a different point of view and, in some cases, to even collaborate with them. Sometimes we may see things that others fail to notice, and they may see things that we would likely overlook, and this works as a mutual quality control.

This research does not prove that radiometric dates are wrong, but it shows how a faith-based research approach can yield new insights that were not found by others who were not asking the same questions.

Fossil Vertebrate Trackways in the Permian Coconino Sandstone, Northern Arizona

The Coconino Sandstone is generally interpreted as a deposit of wind-blown desert sand, and its only fossils, vertebrate trackways, have been considered supporting evidence of this interpretation. Because I wondered how this desert interpretation can fit into a biblical earth history model, I (Brand) have been doing research on these tracks for some years.[9] At present, it is not clear what the ultimate conclusion from this research will be. The trackways have features that seem virtually impossible to explain unless they were made with the animals completely underwater, while the sedimentary evidence, as interpreted by sedimentologists, seems to point to wind-blown sand. This seeming contradiction indicates there are some unknown pieces of the puzzle that remain to be discovered. When these pieces are found, they may provide new insights into processes of sand deposition or new insights into how trackways are made under unique conditions. Whatever the outcome will be, our understanding of the Coconino Sandstone and its fossil tracks will be on a stronger footing because of my questioning of the accepted interpretation of these tracks.

It is important not to go beyond our evidence in reaching conclusions. This research does not show whether the tracks were or were not made in the biblical flood. It simply points to the underwater origin of these trackways.

Injectites in the Base of the Coconino Sandstone

Along the length of the Grand Canyon, in the top of the Hermit Shale, there are vertical cracks filled with sand from the overlying Coconino Sandstone. For many years, these have been considered to be mudcracks, or desiccation cracks caused by drying of the Hermit Shale sediments, and then filled with Coconino sand. This interpretation had not been examined carefully until geologists who were open to new interpretations of the paleoenvironments of these sediments began a study of the cracks. They found several types of evidence, seemingly not noticed before, that are not compatible with desiccation cracks but point to forceful injection of wet Coconino sand into the underlying mud.[10] The researchers believe the sand-filled cracks were injected because of earthquake energy released during the movement of the Bright Angel Fault.

Speciation in White-Footed Mice

Study was done of possible speciation of white-footed mice (genus *Peromyscus*) on several islands in the Gulf of California. It began with two alternative hypotheses for the status of these mice: (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 automatically favor one over the other. The evidence supports the conclusion that the island mice have become a separate species, apparently in response to isolation on the islands.[11] This and a number of similar studies demonstrate that an interventionist philosophy can be an effective stimulus for research on evolution processes like microevolution and speciation without assuming that major groups of organisms arose by the process of evolution.

Beneficial Functions of Microbes in the Biosphere

The complexity of cells has become better understood, and the purpose of cells in multicellular living organisms is obvious as cells work together as part of intricate tissues and organs. However, the function of the most abundant creatures on earth, single celled microbes like bacteria, is less obvious. In addition, since microbes possess exquisitely designed mechanisms that participate in disease processes, they at first glance appear difficult to explain within a biblical framework. However, a great majority of microbes support the biosphere by cycling and recycling nutrients, in many cases on a global scale.

The fact that microbes participate in beneficial functions in the biosphere also leads to predictions about how they might operate in living organisms as beneficial agents. Research by Joseph Francis has shown that microbes that perform a beneficial function in one organism or location may be detrimental if displaced or relocated to another living organism. Use of this "displacement theory" may help us understand better the origin and function of pathogenic microbes.

All biological organisms, including lowly bacteria, have an exquisite and complex immune system. The presence of intricate immune systems in living organisms suggests that disease and death may have been part of the original creation. However, the receptors for pathogens in the mammalian immune system are activated by only a few molecules.[12] Francis is currently working on the idea that the mammalian immune system originally operated as a filtering system to promote and protect association of beneficial microbes with mammals and humans by filtering out microbes that were not part of the system. He is also working on the idea that the immune system is a sensory device used to detect beneficial microbes in the environment.[13]

Paleocurrents

An extensive review has been done of geological evidence for the direction of movement of currents (almost always water currents) that deposited the sedimentary layers in the geological column. The data came from geological publications and graduate student theses or dissertations. The total to date of more than a million data points come from the Precambrian through the Cenozoic from all continents. The published database of this information is useful for a variety of geological research projects, including seeking to understand geological processes during the global flood.[14]

Evaluation of Some Evidence Being Used in Favor of Creationism

Precambrian pollen in the Grand Canyon. Some creationist researchers 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 era). A claim as significant as this should be verified independently to be sure of its authenticity. Another interventionist repeated the research. 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.[15]

Human tracks in Cretaceous rocks. Some interventionists have claimed that Cretaceous limestone by the Paluxy River in Texas contains fossil human tracks in association with dinosaur tracks. As with the Precambrian-pollen story, such a significant claim should be followed up with extensive, careful study. The more significant the implications, the more rigorously the claim 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 interventionists that the tracks are not human.[16]

Other Fields

In the medical sciences and 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 philosophy does not in any way hinder them from effectively using the scientific process in their study of the workings of the natural world. The common assumption that belief in creation prevents a person from being an effective scientist is simply not true if the person is scientifically educated and values the quality of work expected of a scientist.

Predictions

Contrary to what many anticreationists say, interventionist and short-age theory makes numerous suggestions for research and predictions to be tested. The list in table 19.1 includes examples of general predictions or conclusions, and they could be subdivided into more specific, testable predictions. The list includes biological as well as geological predictions. Further study will no doubt generate additional types of predictions. Making predictions is never a foolproof venture, but these predictions generally follow directly from the tenets of biblical interventionism and short-age geology. We expect that testing these and other such predictions will generate scientific insights.

Research that tests whether conventional or short-age theory provides better explanations for the data should also be directed especially to the items in the two outer lists in table 18.3.

Table 19.1. Predictions following from short-age geology (within a time frame compatible with a literal biblical history)

1. Radiometric dates do not indicate real time for at least the Phanerozoic rocks. They seem to indicate relative age (which event preceded which other event) but not absolute age. Ratios of radiometric parent daughter isotopes have changed through the geological column for some reason other than the passage of large amounts of time. Deep time for at least the Phanerozoic is not real.
2. If Noah's ark is ever found and is dated with carbon 14, the date will not be a few thousand years but indicate nearly infinite age, or an age similar to Paleozoic coal deposits. This is because the ark was built from pre-flood wood, which was apparently living before living things contained significant amounts of carbon 14.
3. Some major portion of the Phanerozoic record was deposited by much more rapid and catastrophic processes than conventional theory expects. It will be found that some, and probably many, sedimentary deposits were formed by processes not seen, or at least not adequately seen, in modern analogues.
4. Features in the rocks interpreted as Milankovitch cycles (cyclic climatic processes controlled by solar variation, representing cycles of hundreds to tens of thousands of years each) did not result from such long cycles. They formed rapidly from some other process. Other cyclic processes in rocks also were rapid, not occupying eons of time.
5. Some finely laminated rock is generally interpreted as varves, which are laminations formed one per year, as occurs today in some lakes in glaciated areas. Our prediction is that these cycles of thousands of fine laminations in ancient deposits were not varves. There are other mechanisms to be discovered that will explain these finely laminated rocks with far more rapid processes.
6. Many examples found of fossil assemblages that resemble a modern analogue will be found to be the result of processes different from what we commonly see today. Dependence on deep time may not stimulate deeper, careful study if a modern analogue appears to offer an explanation—for example, the Yellowstone fossil forests.
7. Part of the rocks formed during the one-year catastrophe would not have true desiccation cracks (mudcracks) or other similar features of the type that require weeks or months to form at each level where they occur.

8. Stromatolites, reefs, and evaporates, in parts of the Cenozoic, will generally be explained by processes identical or similar to those used by conventional geological theory. They can be explained within the time frame of several thousand years without straining the theory. In lower parts of the geological column, similar-appearing phenomena will be found to be only superficially similar to true stromatolites or evaporates, formed by a different process, not requiring significant time.
9. Most structures called reefs were really some type of debris flow, or reefs grown before the flood.
10. Tidal cycles in the rocks, with about two lamination formed each day, will be more common in ancient rocks than now recognized.
11. A global flood theory will be far better at explaining many modern land forms than conventional geology theory. Some land forms (e.g., the Grand Staircase in Utah) will be best explained by massive water flow.
12. The majority of Lower Phanerozoic rock formations were deposited at very rapid, catastrophic rates perhaps equivalent to the magnitude of a modern flash flood on a global scale. There could be breaks in deposition of up to a few months.
13. Drift of continents in much of the past occurred orders of magnitude faster than at present.
14. The theory that the sequence of appearance of fossil groups in most of the fossil record was the result of large-scale evolution will eventually be refuted by new evidence.
15. As research proceeds in biochemistry and molecular biology, it will be increasingly evident that the likelihood of life ever arising without an intelligent designer is roughly inversely proportional to the growing body of data.
16. In the study of biological evolution, there will be increasing evidence that microevolution and speciation are not primarily the result of random mutations (and selection) but facilitated by the genetic potential already present in organisms from the beginning, and the changes do not go beyond that potential.
17. Sequences of species or genera of organisms resulting from evolution during the deposition of the sediments may be found only in the upper parts of the fossil record. The time frame for this deposition could have been long enough for rapid microevolution and speciation to occur.
18. The lower part of the fossil record does not contain numerous successive episodes of animal death, with each episode followed by several months of in situ decay and disarticulation. There would not be time for these successive episodes.
19. Recent evidence indicates that microevolution can occur much faster than previously thought, even in a few years (e.g., changes in Galapagos finch beaks). We predict this trend will continue.

20. The part of the fossil record formed during one year does not record any microevolution or macroevolution occurring during the time when these rocks were deposited because there was not nearly enough time for that. Any stratigraphic changes in species or higher taxa of organisms were the result of some type of sorting process, not evolution. A possible exception could be marine microorganisms, with life cycles of hours to days (Wise 1989).

CONCLUSION

Faith, Reason, and Earth History

Individually we face the important decision of what to do with the alternative paradigms of earth history. On the one hand is the scenario developed by naturalistic science of life arising and evolving by itself over several billion years. Many thousands of scientists use this concept as the basis for interpreting all their evidence. It has worked well in some ways and gives the appearance of a stable, reliable explanation for earth history and the history of life.

On the other hand, some believe that although some portions of that standard scientific paradigm are on the right track, other significant aspects are not. Those of us who are of that persuasion are convinced that, if we allow our Christian worldview to open our minds to new ideas and testable hypotheses suggested by the biblical story of origins, this approach ultimately will lead to an even more successful explanation for the history of life and of the earth. This implies that some segments of scientific theory that now appear to be solid are going to break down in the future in the face of a continuing accumulation of evidence.

The latter interventionist paradigm promotes vigorous research in all areas of science. Progress is made by opening our minds to new possibilities generally excluded from consideration by the rules of naturalistic science rather than by ridiculing or downgrading the ability of science and scientists. This work must be done with the highest standards of scientific quality. Elton Trueblood set an important objective before us when he stated that "the religious scientist has more reason to be careful of his evidence than has the nonreligious scientist, because he is handling what is intrinsically sacred. Shoddiness, for him, is something to spurn because it is a form of blasphemy."[1]

Science based on an arbitrary, philosophical limitation such as methodological naturalism is uninteresting to many of us. We think sentiments like the following statement do not give an appealing view of science: "Dembski thinks that intelligence has a magical power that permits it to do something that would be impossible through natural causes alone."[2] True science must be an open-minded search for truth, including a willingness to admit that our science may not be able to answer some questions from within our human limitations. Perhaps in some cases, science can only say "we don't know" unless we have outside information.

Based on the foregoing, the following summary of current scientific theory is suggested (the lists below are representative and are not intended to be complete):

1. Fields of science that, at least ideally, do not need to be affected by the assumptions of interventionism or naturalism and should be able to progress with equal effectiveness under either paradigm—fields that do not focus on the study of history—are as follows:
   - Anatomy
   - Physiology
   - Biochemistry
   - Molecular biology (most)
   - Medical science
   - Physical chemistry
   - Organic chemistry
   - Physics
   - Animal behavior (most)
   - Ecology
2. Areas of scientific theory that attempt to explain history and are accepted by interventionists as

generally worthy of our confidence—with the normal changes expected as science advances—are as follows:

- Genetics of microevolution and speciation, and macroevolution at lower taxonomic levels (at least genera)
- Analysis of phylogenetic pathways of biological change at the level of subspecies to approximately genera (not involving the evolution of new structures or physiological systems)
- Genetic analysis of behavioral changes outlined in sociobiology theory (not including any interpretations that depend on naturalistic assumptions)
- Geological and paleontological processes that can be studied in the modern world, and recognition of these processes in the geological record (as long as we understand that modern analogues do not represent the entire range of processes occurring in the past)
- The geological and paleontological sequence of events that can be determined by evidence in the rocks

3. Areas of scientific theory that attempt to explain history and are predicted by interventionists to be unreliable—ultimately to be refuted by new evidence—are as follows:
   - The time scale for events in the Phanerozoic portion of the geological record
   - The origin of life by natural processes, without informed intervention
   - Macroevolution—the evolution of new life forms, new body plans, and significant new structures by natural processes
   - Explanation of landform origin by reference to modern analogs

These lists demonstrate that interventionism is in harmony with most of science. The areas of disagreement are the time scale for the history of life on earth and the concept that life can originate without intelligent input and can evolve into new life forms or body plans by mutation and natural selection or any similar process. The reality of microevolution and speciation is based on a strong body of evidence. In contrast, the biological evidence for macroevolution is slim and will remain very weak unless it can be convincingly demonstrated that new, coordinated, adapted complexes of genes can arise by a process that begins with random mutations and then proceeds only by the natural selection processes available in nature. Until that can be empirically demonstrated (and we predict that it cannot), the possibility of the amazing complexity of life arising by itself remains an intellectually unsatisfying idea to many.

It is often stated that the existence of several levels of complexity in eyes of various animals demonstrate how more complex eyes have evolved. But it is simply assumed that the evolution from one type of eye to another will work. There is no evidence for the vast series of biochemical transformations needed to accomplish the task. This type of reasoning is common in evolutionary publications.

Without the sequence of appearance of life forms in the rocks, the concept of macroevolution would have little firm evidence to suggest it. But the evidence of that sequence of fossils demands an explanation. Is the Phanerozoic geological record the result of catastrophic activity in a short time frame or of 541 million years of evolution? Recognition of more catastrophic geological processes is an important trend in science. It is consistent with short-age interventionist expectations, but many challenges remain.

Try to imagine yourself back in the time of Noah. The people living then probably were very intelligent. Maybe they studied science in great depth, since many of them had more than nine hundred years in which to study. Picture Noah working on his ark with the usual crowd of hecklers gathered around. Not only were the curious bystanders laughing at him, but the scientists were presenting him with the data showing that his predicted flood was impossible. Noah listens thoughtfully and says, “Yes, I have examined those data myself and have tried to understand how the flood could happen. I don’t have an explanation to give you, but I believe that God is smarter than we are.” Noah then proceeds to drive the next nail into his ark.

God is still smarter than we are—smart enough to communicate truth to us in spite of the humanity of the Bible writers. We like to have answers for everything, but we do not have answers for all the questions about earth history. We will be much better off to recognize that the limitations in the available evidence and in the amount of time we have for research on these issues makes it unrealistic to expect scientific answers for all of our questions in the near future.

In addition to the evidence we have considered in this volume, we can’t help thinking of other nagging doubts about the evolution of life. Look around and think about the beauty of a rose or butterfly wings, or a symphony played by a great orchestra, or the unfathomable mental skills of some individuals. Consider the physical finesse exhibited by a violinist or pianist or the mental and physical skill of a left fielder following the fast movements of a little ball through the air and positioning his baseball glove at the precise place to catch it. These and much more seem far beyond what is needed for survival and reproduction, the only goals visible to natural selection.

Although we respect scientists who see these issues very differently from us, it does seem to us that the intellectual content of a naturalistic view of origins can be compared to Isaiah 44:14–17. “He plants a pine, and the rain nourishes it . . . He burns half of it in the fire . . . And the rest of it he makes into a god, his carved image. He falls down before it and worships it” (NKJV).

When we allow the Scriptures to aid us in developing hypotheses about earth history, opening our eyes to see what is really there in the rocks, we can successfully use these hypotheses to guide us in productive scientific research. Karl Popper stated, "Only . . . in our subjective faith can we be 'absolutely certain.'"[3] To expect science to provide that type of certainty is looking in the wrong place. Scientific findings do not indicate that we should abandon trust in God. We can have confidence in our relationship with Him and in His communication to us. If we do trust Him, that belief will help us be good scientists.

In summary, the acceptance of a literal biblical creation is not a denial of science. Instead, science practiced under this biblical interventionist worldview explains much and leads to the discovery of many things missed by others. I believe this view will eventually answer our biggest questions once new evidence is discovered that will force a reinterpretation of things that now seem to contradict it (evidence related especially to geological time and macroevolution).

Whether a person thinks the interventionist theory of a short-age geologic record is worth pursuing depends largely on whether he or she has more trust in God's communication to us through the Bible or more confidence in contemporary human scientific theories of earth history. The explanation of the fossil record is significant to the Christian because of its implications for the nature and future of humankind. If life is the result of evolution (either naturalistic evolution or theistic evolution), then humans have been evolving and improving. Humanity did not fall from a perfect state, and a Savior was not needed to redeem us. But if life, including humans, was created perfect and humans fell from that perfect state, then the Bible account of a Savior who died to save us means everything.

Glossary

ABIOGENESIS: The naturalistic origin of life by combining inorganic molecules into increasingly complex organic molecules until a living organism results. This would involve random action of natural processes without any intelligent direction.

ADAPTIVE RADIATION: The evolution from a single ancestral species of a variety of forms that occupy somewhat different habitats.

ALLELE: Any of several different gene forms that could exist at a given position on a chromosome (e.g., different alleles for different eye colors).

ALTRUISTIC BEHAVIOR: Behavior that benefits another individual at some cost or potential cost to the individual performing the behavior.

AMINO ACIDS: The building blocks of proteins. Twenty different amino acids are in the proteins of living organisms. These amino acids combine in chains of a specific sequence to make a protein.

ANALOGOUS: A characteristic present in two or more groups of organisms but not present in their presumed ancestor, implying that the character evolved independently in each group.

ANOXIC: Devoid of any oxygen.

BARAMIN: A word coined by Frank Marsh (1941, 1976) to designate a created group of animals or plants. The limits of created baramin are unknown but can be explored through further research.

BENTHON: Organisms that live on the bottom of a body of water.

BIOCHEMICAL EVOLUTION: A term for the theorized process of life arising by natural law alone; by random chemical processes (abiogenesis).

BIOGEOGRAPHY: The study of the distribution of organisms over the surface of the earth and the processes that produced that distribution.

BIOTA: The combined total of living organisms in a given area.

BIOTURBATION: The mixing and stirring of the sediment by organisms as they burrow through it or walk on it.

BODY PLAN: The overall structural organization of a group of organisms. The arthropod body plan includes a jointed external skeleton, jointed appendages, and internal organs inside of its several body segments.

CATASTROPHISM: The concept that at least some geological processes can happen and have happened very rapidly.

CLADISTICS: An approach to the study of systematics (classifying and naming of organisms) based on evolution theory. Evolutionary principles are used to identify ancestor-descendant relationships, which in turn are the basis of the classification. Also called phylogenetic systematics.

CLASS: A biological systematic unit that includes one or more orders of organisms (e.g., the class Mammalia includes the mammals, which are placed in about twenty orders).

COCCOLITH: Microscopic calcium carbonate skeletal elements of minute floating marine organisms. Accumulations of coccoliths form chalk and deep-sea oozes.

CONSOLIDATED: Sediments that have been cemented or compacted into solid rock.

CONTROL: See *experimental control*.

CONVERGENCE: The process by which a characteristic evolves independently in different groups of organisms (i.e., their structure converges toward being more similar than their ancestors were).

CRATON: The portion of a continent that has been stable through much of geologic time. The North American craton includes most of the continent, except the far west and the east coast.

CREATIONISM: The belief that life was created by an intelligent God.

DARWINISM (DARWINIAN THEORY): The evolution theory proposed by Charles Darwin. This term is not always used consistently. Darwin's original theory was different in some ways from the modern Neo-Darwinian Synthesis. The term Darwinism is used by some authors as a synonym for the modern theory, but that is not entirely correct.

DEDUCTION: A logical process that uses a generalization as a basis for interpreting the data in a particular case.

DNA: The organic molecule (deoxyribonucleic acid) consisting of a long chain of building blocks called nucleotides that form the genetic information in the chromosomes of almost all living cells. There are four types of nucleotides, and each set of three nucleotides (a codon) along the DNA form a code that specifies a particular amino acid in a specific protein.

EDIACARAN FAUNA: A group of fossils in the uppermost Precambrian rocks. They are the only complex organisms below the Cambrian, and it is not clear what kind of organisms they are.

ENDOCRINE: A system of ductless glands that produce hormones, which control growth and development and regulate body functions such as metabolism.

ENZYME: An organic molecule (a protein) that serves as a catalyst to speed up the rate of a specific biochemical reaction inside a living cell.

EPIGENETICS: Processes of inheritance above or outside of the DNA. Includes the processes of attaching chemical tags to specific genes, which modify the action of those genes; these changes are inherited by daughter cells, but these processes do not change the DNA sequence.

ETHYL GROUP: One of the small molecular tags that is attached to DNA in epigenetic processes, turning the gene on or off or reducing its effect.

EUKARYOTE: A living organism made of cells that have a nucleus containing its DNA. Most living things are eukaryotes (see *prokaryote*).

EVOLUTION: The process of change in organisms through time; descent with modification.

EXPERIMENTAL CONTROL: A standard in an experiment against which the experimental group can be compared. For example, the effects of an experimental diet fed to one group of rats (the experimental group) can be evaluated by comparison with the effects of a known and tested diet fed to another group of rats (the control group).

FACIES: A distinctive rock type formed in a particular environment or by a specific geologic process (e.g., marine facies formed in the ocean, freshwater facies, deep water facies, shore facies, etc.). A continuous rock formation may grade laterally from one facies to another, depending on the environment in which it was deposited.

FAMILY: A biological systematic unit consisting of one or more genera of organisms (e.g., the family Canidae includes several genera of dogs and their relatives). Several families form an order.

FITNESS: The ability of an organism to pass its genes on to the next generation through successful reproductive efforts.

FLUVIAL DEPOSIT: A deposit of sediment laid down by flowing water, as in rivers or streams.

FOUNDER EFFECT: When a small group of individuals becomes isolated from others of its species and founds a new species, the characteristics of the new species will reflect the characteristics of the founder group. If the founders are larger than average, the new species will be larger than the ancestral species.

GENE FLOW: The movement of genes through a population by movement of individual animals or plant seeds or pollen in each generation.

GENETIC DRIFT: Random genetic changes in a species or, more specifically, random changes in gene frequencies in a population.

GENETIC VARIABILITY: The variability of traits within a population (e.g., variation in size of individuals within the same species).

GENOME: The total complement of genetic material of a given organism.

GENUS (PL. GENERA): A biological systematic unit consisting of one or more species of living organisms (e.g., the genus *Canis* includes dogs and wolves). Several genera form a family.

GEOLOGIC COLUMN: The sequence of rock formations, one above the other, from the oldest rocks (at the bottom) to the youngest that form part of the outer crust of the earth.

GLACIATION: The formation and movements of ice in mountain glaciers or continental ice sheets.

GONDWANA: The southern continents gathered together in one large continent in an early stage of plate tectonics.

GRADUALISM: The concept that biological and/or geological change occurs only slowly and gradually.

HETEROCHRONY: Changes in the timing of embryological developmental processes, resulting in the acceleration or slowing of the development of a particular developmental or structural feature. Three types of heterochrony are neoteny, paedomorphosis, and progenesis.

HOMOLOGY (HOMOLOGOUS): A similarity between two organisms due to (1) similarity in embryological development, (2) inheritance of the feature from a common ancestor, or (3) similarity due to a common plan used by the Designer of life. Items 2 and 3 are interpretive definitions.

HOMOPLASY: Two concepts are included under this term: (1) a similar characteristic that is shared by two groups of organisms but does not meet the criteria of a homology and (2) an analogy or feature believed to have evolved independently in each group (convergence).

IGNEOUS ROCK: Rock that forms by cooling of molten or partially molten material (e.g., granite or volcanic lava).

INCLUSIVE FITNESS: The ability of an organism to pass its genes directly to the next generation through its own offspring and indirectly through the offspring of relatives who share many of the same genes that it has.

INDUCTION: A reasoning process that begins with individual observations and uses these to develop generalizations.

INFORMED INTERVENTION (INTERVENTIONISM): The worldview or philosophy that accepts the reality of divine intervention in history as described in the Bible, especially in the origin of life forms and in the flood catastrophe.

IN SITU: This term refers to features that grew or formed where we find them as fossils—for example, forests or animals that lived where their fossils are rather than being transported from somewhere else before being buried. A synonym for in situ is autochthonous.

INTELLIGENT DESIGN (ID): The concept that living things show evidence of being designed, rather than arising by natural processes alone. The Intelligent Design movement does not concern itself with geological history or the identity of the designer, but only with evidence for intelligent involvement in life origins. The evolutionary literature often calls it Intelligent Design Creationism (IDC), which it uses as a derogatory term.

IRREDUCIBLE COMPLEXITY: A structure or system composed of several well-matched, interacting parts that are necessary for the functioning of the system. They must all be there at once for the system to work.

JUMPING GENES: See *transposable elements*.

KIN SELECTION: Natural selection through animal behaviors that will improve the reproductive success primarily of close relatives (e.g., alarm calls given by squirrels living close to many relatives, thus improving the chances that these relatives will escape danger).

LACUSTRINE DEPOSIT: A deposit of sediment laid down in the quiet water of a lake.

LATERAL GENE TRANSFER: See *transposable elements*.

MACROEVOLUTION: In this book, we use the term to refer to major evolutionary changes sufficient to produce new families, classes, or phyla of organisms. (Note: some scientists define it as any evolutionary change above the species level.)

MATERIALISM: The philosophy that holds that matter is the fundamental substance in the universe. All phenomena are only the result of interactions of physical matter under the laws of physics and chemistry.

METABOLISM: The sum of the chemical reactions within a cell or organism that release heat and energy. The rate of metabolism varies according to temperature and/or internal control by the organism.

METAMORPHIC ROCK: Rock formed by alteration of other rocks by temperature or pressure, usually resulting from burial under a thick overburden of additional rock.

METHODOLOGICAL NATURALISM (MN): The version of naturalism that does not say whether there is a miracle-working god or not but is simply a method of scientific thinking that does not ever use the supernatural as an explanation. In practice, however, MN has the same effect as philosophical naturalism in denying there ever were any supernatural actions by a Creator.

METHYL: A small molecular tag that is attached to DNA in epigenetic processes, turning the gene on or off or reducing its effect.

METHYLATION: The epigenetic process of attaching methyl molecules to specific genes in DNA.

MICROEVOLUTION: Small-scale evolutionary changes that produce variation within a species of organism.

MODERN SYNTHESIS: Another name for the Neo-Darwinian Synthesis of evolution.

MOVABLE ELEMENTS: See *transposable elements*.

NATURAL SELECTION: The individuals in a population that are best able to survive and reproduce in their environment pass on more of their genes to succeeding generations than other individuals.

NATURALISM: The scientific worldview or philosophy that only considers hypotheses or theories that do not require any divine intervention in the functioning of the universe at any time in history.

NEOCATASTROPHISM: The modern geological paradigm that recognizes the evidence for catastrophic processes but places these events in a time frame of hundreds of millions of years in evolutionary time.

NEO-DARWINIAN SYNTHESIS: The version of evolution theory developed in the 1930s and 1940s, combining new understandings of genetics, population biology, and paleontology. In this theory, all new biological information originates by random, nondirected mutations and natural selection. Also called the modern synthesis.

NEOTENY: The retention of formerly juvenile features into the adult life of an organism. For example, in some species of salamander, the gills (normally a juvenile feature) remain functional in adults.

NICHE: The role of an organism in its environment. For an animal, this includes where it lives; what it eats; when, where, and how it gets its food; and its relationships to other types of organisms.

NUCLEIC ACIDS: The building blocks that link together in long chains to form DNA and RNA.

ONTOGENY: The embryological development of an organism; the sequence of developmental events during that process.

ORDER: A biological systematic unit consisting of one or more families of organisms (e.g., the order Rodentia, which is one order in the class Mammalia, includes all the rodents).

OVERTHRUST: Large-scale lateral movement of rock along a fault, pushing the rock over other, younger rocks for distances generally measured in kilometers.

PAEDOMORPHOSIS: The retention of ancestral juvenile characters into later stages of embryological development.

PANGEA: A hypothesized supercontinent early in Phanerozoic history that was composed of all the present continents joined into one.

PARACONFORMITY: A level in the geological record that shows no evidence of erosion and/or uplift of sediments before the next layers were deposited, although a portion of geological time is missing at this contact.

PARADIGM: A broad, explanatory scientific theory; a framework for interpreting evidence, such as the heliocentric theory or the theory of naturalistic evolution.

PHANEROZOIC: That part of the geologic column containing abundant life—from the Cambrian to the present.

PHYLOGENY: The evolutionary history of a group of organisms.

PHYLUM (PL. PHYLA): A biological systematic unit consisting of one or more classes of organisms (e.g., the phylum Chordata consists of several classes of animals with backbones).

PLATE TECTONICS: A global theory of the structure and changes of the earth's crust in which the outer crust is divided into a number of plates that move in relation to one another (continental drift). The movements of these plates are involved in the generation of earthquakes, volcanoes, and mountain ranges.

PRIMEVAL SOUP: Ocean water in which organic molecules were accumulating and where abiogenesis is presumed to have occurred.

PROGENESIS: Alteration of embryological timing so that sexual maturation is reached by an organism that is morphologically juvenile.

PROKARYOTE: A cell without a distinct nucleus. Bacteria and some other simple organisms are prokaryotes (see *eukaryote*).

PROPOSITIONAL TRUTH: In theology, specific, true, and objective information or concepts, such as the Ten Commandments or the history of life's origins, that can be communicated by God to His prophets.

REEF: A mound-like structure built by calcareous organisms, especially corals, and consisting largely of their remains. The term reef is applied to a variety of geological structures whose origin is thought to have involved biological processes. Lower Paleozoic "reefs" are typically mud mounds.

REPTILE/REPTILIA: In evolutionary phylogenetic systematics, the term "reptile," as generally used, is not appropriate because it is a paraphyletic group (does not include all descendants of reptiles). However, the term is used here as it will be understood by readers not familiar with the details of phylogenetic systematics.

RIBOSOME: Small organelles present in cells that are the sites of protein synthesis.

RNA: A form of nucleic acid (ribonucleic acid) that is involved in protein synthesis and in carrying genetic information from the DNA to sites of protein synthesis.

RNA WORLD: The theory that RNA played a critical role in the early steps of the origin of life. DNA later took over the role initially served by RNA.

SCIENTIFIC REVOLUTIONS: The process by which a new paradigm or theory replaces another one after a crisis reveals problems in the old theory and a successful competitor wins the allegiance of the scientific community.

SEDIMENTARY ROCK: Rock formed by erosion of other rock; this eroded sediment is transported into a basin and deposited as layers.

SHIELD: An area of exposed basement rocks (generally Precambrian) not covered by sediments (e.g., the Canadian Shield in eastern Canada).

SHORT-AGE GEOLOGY: Geology theory based on the time since the base of the Cambrian being thousands of years, not millions of years. It also includes a global flood catastrophe.

SOCIOBIOLOGY: The application of evolution theory to the explanation of animal behavior, with the assumption that all behavior is the result of evolution.

SPECIATION: The evolution process that produces a new species.

SPECIES: Organisms of a population that normally in nature do not reproduce with other populations of similar organisms.

STASIS: No change is occurring. According to paleontology, if a fossil species does not change through time, it is an example of stasis.

STRATA: Layers of rock deposited one above the other, forming the geological column.

STROMATOLITE: A structure—usually mound-shaped—composed of a series of layers of sediment stacked one layer upon another and created by organisms, mostly cyanobacteria (blue-green algae) that grow on their surface.

TAPHONOMY: Study of the processes that produce a fossil, including the death of the organism, that determine whether it will be buried and in what condition; changes that cause fossilization; and alterations to the organism that occur after it is fossilized.

TAXON (PL. TAXA): A general term referring to any group of animals or plants. Species, genera, families, and phyla are examples of taxa.

TRANSPOSABLE ELEMENTS: A portion of a chromosome that can move to other parts of the chromosome or even be copied to another species (lateral gene transfer), with viruses acting as the agent to make this transfer. Many mutations are caused by transposable elements.

TURBIDITE: A distinctive deposit of sediment produced by a turbidity current, which is a rapid flow of water and sediment usually down a very gentle slope under water.

UNCONSOLIDATED: Sediments that have not been cemented or compacted into hard rock.

UNIFORMITARIANISM: The concept that geological processes occur by the action of natural laws that are always the same and by processes that can be observed today. Charles Lyell also included the now rejected concept that these processes are always slow and gradual (gradualism).

VICARIANCE BIOGEOGRAPHY: The theory that the distribution of many groups of organisms was the result of movements of continents. For example, the evolution of different families of monkeys in Africa and South America was the result of those continents moving apart in the ancient past before the monkeys evolved into separate families.

WORLDVIEW: A philosophy that answers the big questions in life, such as where did we come from, why are we here, where are we going, and is there a God who has been involved in earth history.

YOUNG EARTH CREATIONISM: The belief that all of life, the earth, and the entire universe were created in the biblical creation week a few thousand years ago. Creationists who believe the universe is very old but life has only been on the earth for thousands of years are sometimes incorrectly called young earth creationists.

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