Chapters 28 through 32 showed that geology is, to a significant degree, the application of physics and chemistry to the study of the earth (and, by extension, to the other solid bodies in the solar system, whose surfaces and interiors we are just beginning to understand). The plants and animals that inhabit the earth and its atmosphere are sometimes called the biosphere (as is also the region inhabited by them) and are the proper province of the biological sciences. There is, however, a bridge connecting geology and the biological sciences. Usually when organisms die, they are attacked by bacteria and the elements, or are eaten by animals, and thus their remains are destroyed. Occasionally, however, a plant or animal is buried in sediment soon after it dies, protecting it from such destructive effects. In this case it may eventually become lithified (“made into stone”) along with the sediment that surrounds it, and become a fossil—that is, remains (or other evidence) of a formerly living organism, preserved by natural processes within the crust of the earth. Here is where geology and biology meet. Most geologists acquire a working knowledge of fossils sufficient to aid them in their work, but they do not specialize in studying them. The specialists who make the investigation of fossils the focus of their work are paleontologists, and the field of study is known as paleontology. We have used fossils as necessary in our discussions in previous chapters, but now we pause to look deeper into the subject of paleontology.

Obviously, fossilization is the exception rather than the rule, and so the observed fossils must represent a very small fraction of all plants and animals that have ever lived. Fossils are not rare—in fact, they are much more common than you may think—but neither are they uniformly distributed. With relatively few exceptions, they are found in sedimentary rocks, but not in all sedimentary rocks. Often rock layers that contain fossils in some locations are barren in others. Some kinds of sedimentary rocks, such as the chalk of the famous “white cliffs of Dover,” are made up entirely of fossils, but it is not obvious because they are very tiny fossils. In other rocks fossils are not just obvious, but spectacular (see Fig. 33.1). Fossils range in size from the very large dinosaur skeletons that grace the halls of famous museums to remains of tiny organisms visible only under a microscope. The latter are generally called microfossils. Certainly fossils have been known from the most ancient historical times, but the recognition that fossils are remnants of things that once lived is a fairly recent achievement.

Figure 33.1. Although they constitute a minority of fossil occurrences, examples like this fossil bone bed are spectacular evidence that fossils are the remains of living things.

The Significance of Fossils—A Gradual Awakening

By today’s standards, we would not consider the opinions of the ancients about fossils to be very enlightened. (It is remarkable how intelligent hindsight makes us appear!) Most thought fossils were inorganically produced, perhaps as accidents or even as jokes of nature. A few, among whom was Aristotle (Greek philosopher, 384-322 B.C.), recognized at least some fossils as the remains of living organisms but seem to have concluded that they had met their demise during relatively recent times and had been incorporated in the rocks by mysterious means. Others, recognizing the organic origin of fossils, thought they might have begun as seeds of some sort and grown in the rocks. Spontaneous generation was a popular explanation on the grounds that if maggots appeared from nowhere in decaying food, then fossils might do so in rocks.
The word “fossil” did not assume its current meaning until comparatively recently. In the 16th century, Konrad von Gesner (German naturalist, 1516-1565) published a work often referred to as *On Fossil Objects*. A full translation of the title, however, reads *A Book on Fossil Objects, Chiefly Stones and Gems, Their Shapes and Appearances*. Evidently, Gesner’s concept of fossils was considerably broader than ours, but it was consistent with long-standing usage at the time. A fossil was, in those days, any strange object that came from the earth or was found on the ground, including inorganic crystals or rocks of curious appearance. The word itself comes from the Latin *fodere* (to dig) and means “an object dug up.” The change in meaning over several centuries reflects much more than merely linguistic evolution. First, it documents the intellectual struggle in determining that some of what were called fossils were of organic origin and, second, in differentiating between those that were and those that were not.

The recognition that fossils, as we use the word now, were once alive came gradually. It is clear that medieval Europeans knew of the existence of fossils that looked very much like living plants or animals, but these were explained in various ways. Some, prompted by the revival of classical influence, echoed the thinking of Greek philosophers in attributing them to mysterious “molding forces” within the earth, unrelated to living things, or else to spontaneous generation, or to seeds that fell into the rocks (perhaps from the stars!). Others, like Leonardo da Vinci (1452-1519), recognized fossil shells as the remains of formerly living animals that had inhabited seas that must once have covered the locations in which they were found. Even when fossils were recognized as remains of living things, the medieval preoccupation with giants led to the attribution of bones too large to have belonged to familiar animals, like cows or horses, to these mythological beings.

Following the invention of printing, there was a gradual diffusion of knowledge in the western world, and naturalists became more and more aware of one another’s observations of fossils. Slowly the idea took root that these objects represented ordinary plants and animals that had lived and died on this planet. Likewise, it became apparent that certain fossils were consistently associated with certain sedimentary rock layers in a given geographical region and must, therefore, have been deposited with the sediment in a decipherable sequence. In Chapter 29 the name of William Smith (1769-1839), the British civil engineer and geologist, was mentioned in connection with this concept. He was not alone in his discovery, however, and two other geologists—Giovanni Batista Brocchi (1772-1826) working in Italy, and Alexandre Brongniart (1770-1847) in France—deserve equal credit for similar work. There emerged from their studies the Principle of Faunal Succession, which not only affected the way in which relative geologic time is measured (see Chapter 29) but also constituted a great stride toward the correct perception of the fossil record.

Another scientist working about the same time was the French paleontologist Georges Cuvier (1769-1832), an expert in comparative anatomy. (Actually, his name was Georges Léopold Chrétien Frédéric Dagobert, Baron Cuvier—which is the reason for using the shortened version!) Careful examination of fossils in the Paris Basin convinced Cuvier not only that there was a succession of fossils in the rocks—that is, that life had undergone change—but also that some fossils were very different from anything he knew of that still lived on the earth. He had thus recognized extinctions in the fossil record. This called for an explanation, and for Cuvier that explanation was successive divine creations, each followed by a catastrophic extinction, the final catastrophe being the flood of Noah. His scientific brilliance, bolstered by his social and official position in society, made his views particularly influential.

The catastrophic perspective was a popular one for a time, but increasingly it came into conflict with the uniformitarianism of James Hutton (see Chapter 29). Catastrophism was favored, of course, by those who interpreted the Book of Genesis as a literal mechanical description of creation and who thus felt obliged to force agreement between the accepted theological orthodoxy of the day and the observed physical evidence. Others, who preferred a more symbolic interpretation of Genesis or who had little religious inclination anyway, were compelled by the record of the rocks to the view that is now generally held—that fossils represent past life, that life-forms have changed throughout geologic time, that many have become extinct, and that all of this has happened slowly over a vast period of time and in ways that can be explained adequately by appeal to solely natural processes. (We note that, while individual scientists may hold personal views, this interpretation of fossils does not conflict with the existence of the Creator, nor does it abridge His powers. If correct, however, it provides some insight into how He works.)

**Preservation of Fossils**

Given that most organisms die and disappear in one way or another without ever becoming fossilized, somewhat atypical conditions must be required to preserve a plant or animal as a fossil. The primary requirement is to isolate the organism from the atmosphere and from destructive bacteria, and this implies rather rapid burial in sediment. Decomposition is slowed under very low temperature or humidity, or by encapsulation in tar or resin, or by burial in sea water. The probability of eventual fossilization is greatly enhanced by the presence in the organism of hard parts—bones, teeth, shells, and so forth. Once organisms are buried in sediment or other-
wise protected, there are several methods by which fossilization may occur.

**Complete Preservation**

This sort of preservation is quite rare, but also yields very spectacular fossils. In 1976, the complete and unaltered frozen body of a baby mammoth was discovered in a remote mountainous region of Siberia, entombed in muddy ice since the Great Ice Age. Carbon-14 dating showed it to be 17,000 years old. It is not the first frozen Ice Age mammal to be found, but it is the most perfectly preserved so far. When animals that live in cold climates are frozen quickly, both soft and hard parts are preserved—hair, skin, bones, internal organs, and even stomach contents.

Perfectly preserved human bodies thousands of years old have been unearthed from peat bogs in north-central Europe. The water of the bogs is anaerobic, prohibiting bacterial growth and the decay of the bodies. Many geologists, incidentally, would disqualify these and other organisms preserved in historical times as fossils. The distinction is arbitrary, but it serves to divide what rightly belongs in the fields of anthropology, archaeology, and biology from paleontology.

**Unaltered Hard Parts**

Usually, just the hard parts are preserved unaltered from their original compositions. Bones, teeth, and other hard parts are generally made of calcium carbonate (CaCO₃), silicon dioxide (SiO₂), or complex organic compounds, all of which are quite resistant to alteration under near-surface conditions on the earth. Hence, they may remain unchanged for geologically long periods of time—even hundreds of millions of years. Because they are unaltered, the most intricate structures of such fossils are still clearly visible—growth lines on shells, layers in teeth, original mother-of-pearl in oyster shells. Figure 33.2 shows a fossil shell that consists of the original, unaltered hard components. An interesting and paleontologically valuable variation on unaltered hard parts consists of insects and spiders trapped in globules of resin from plants (Fig. 33.3). The resin protects them from bacterial attack, and when it hardens it keeps the delicate organisms from being crushed under the weight of sediment in which they are buried. Because resin is transparent, the fossils can be studied from all angles without the need to remove them from it.

**Replacement**

Commonly little or none of the original matter is...
left, but it has been replaced by some new material that may or may not have a composition similar to the original. Groundwater (water that percolates slowly through permeable rocks) contains many elements in solution, and it can precipitate them as minerals. The voids of porous materials, such as bone or wood, may be filled with minerals precipitated in this way, sometimes resulting in replacement on a microscopic level and preserving even the most delicate organic structures in stony replica. One of the more common types of fossils of this sort is petrified wood (Fig. 33.4).

Sometimes a shell or other hard part is gradually completely dissolved and simultaneously replaced by some more stable mineral that precipitates from percolating groundwater. Unlike the cell-by-cell replacement, this wholesale replacement often obliterates all traces of the microstructures of the organism, retaining only the outer shape. This process accounts for large numbers of fossils.

Molds and Casts

The sediment that packs closely around a fossil and is lithified (that is, turned into rock) with it may be of quite a different chemical composition than the fossil itself. Sometimes, if the rocks are porous and permit the free circulation of water, shells or bones may be removed by solution, leaving cavities in the rock. These are called molds. They are commonly filled with sediment of some sort, and this constitutes a cast. (To help recall which is which, remember that a fancy gelatin dessert is made in a Jell-O mold, and think of the gelatin as the cast.) A mold may reveal the shape of the outer surface of hard parts (an external mold), or it may show impressions made by the inner surfaces (an internal mold). A mold is shown in Figure 33.5.

Carbonized Residues

Living things are made mostly of carbon, oxygen, nitrogen, and hydrogen. The last three are gases in their natural states near the surface of the earth, and so when dead organisms are subjected to relatively high pressures and temperatures by deep burial in sediment, these elements tend to volatilize. Sometimes delicate organisms, which would ordinarily not be preserved by any of the modes of fossilization already discussed, are preserved as thin residues of carbon that remain after the other elements have been driven off into the surrounding sediment. These are called carbonized residues, and the process is known as carbonization.

By this method some creatures with no hard parts have been preserved in remarkable detail. Animals as delicate as butterflies and insects have been found in rocks as carbonized residues (although sometimes even the carbon is gone and only an impression remains). Plants are commonly preserved in this way (Fig. 33.6).

Trace Fossils

There are some objects that nonspecialists might not classify as fossils at all, but paleontologists consider them as such. Neither the tracks left by birds in the wet mud of a tidal flat, nor the filled-in burrow of a worm in a former seabed, nor the petrified excrement of an animal on the floor of an ancient forest were ever alive themselves, yet they are unquestionably indications of life. When found in rocks, fossils that reveal the existence but not the form of the body are called trace fossils. The dinosaur footprints shown in Figure 33.7 are trace fossils.

As you have read the various descriptions of how plants and animals can be preserved as fossils, you have recognized that sediment has been mentioned in all of
them. Virtually all fossils are found in sedimentary rock, but there are exceptions. In Yellowstone National Park in Wyoming there stands an ancient forest of per-mineralized (replaced) tree trunks. Actually, it is several forests—each of which grew, was killed by showers of ash from the nearby volcanoes, and was eventually succeeded by a new forest. However, this is an exceptional instance, because most igneous processes would result in the destruction, rather than the preservation, of organic matter. Likewise, the temperatures and pressures typical of metamorphism result in obliteration—or at least severe deformation—of fossils.

The environment of deposition also has a great influence on whether fossilization will occur. Because the chances of preservation are enhanced by rapid burial, marine organisms are more likely to be fossilized than are terrestrial ones. The sea supports large populations of animals and plants in the relatively shallow waters near shore where terrestrially derived sediments are most abundant. When a clam or fish dies in such an environment, it stands a fair chance of being covered quickly by sediment. On the other hand, a bird that dies on land will likely simply lie on the ground and decay. This is not to say that fossils are absent from nonmarine sedimentary rocks, but they are much less common there than in marine rocks.

Uses of Fossils

There is no question that some of the most popular uses for fossils have little to do with science. They are sold in curio shops worldwide and end up on fireplace mantelpieces, in bookcases, and as jewelry, and serve other decorative purposes limited only by the imaginations of their owners. For the geologist, fossils are far more than objects of curiosity. Their more important scientific uses are as markers of the passage of time, as indicators of ancient environments, and as documentation of the history of life on earth.

Markers of the Passage of Time

In Chapter 29 we considered the measurement of relative geologic time and learned that the Geologic Column owes its structure essentially to fossils; the appearance or disappearance of key fossils defines the boundaries between periods. That which makes fossils useful for determining the passage of time (even if the amount of time is not known) is the Principle of Faunal Succession, wherein changes in assemblages (groups) of fossils are found to proceed in only one direction with time, so that assemblages are never repeated in younger rocks once they have disappeared from older ones. That allows sequences of fossil assemblages to be used as “relative clocks.” The advent of radiometric dating (Chapter 29) has provided geologists with the additional ability to assign numerical ages to rocks of some types. It is clear that if an absolute age can be assigned to a sedimentary rock, then that age applies also to the fossils in the rock. Hence, fossils can often now be used by themselves to assess approximate absolute ages.

Some fossils are better suited than others for assessing absolute age. Organisms that lived in restricted localities or that did not change over substantial periods of time are not very useful for determining geologic age. Those that are widespread and that changed rapidly are termed index fossils. Among the best index fossils are the remains of animals called ammonoids, cephalopods with coiled, chambered shells similar to those of the pearly nautiluses. Existing from the Devonian Period to the Cretaceous Period, they lived in the ocean and were geographically widespread. Existing from the Devonian through Cretaceous is a very long time, rather rapid changes in the structures of their shells make them good time markers.

Figure 33.8a shows a typical ammonoid shell, with the sutures that mark the walls between chambers labeled. As the animal grew, it would enlarge its shell.

Figure 33.7. Dinosaurs once walked this ground, as revealed by the footprints now found in the rock.
at the aperture by deposition of calcium carbonate (CaCO$_3$) and periodically close off the excess space in the living chamber by depositing a calcium carbonate wall, or partition, behind it. The line where that wall joins the inner shell is called the “suture,” and it is visible on the shell itself when the outer shell layer has not been preserved or is peeled away. The shape of the suture changed fairly rapidly (from a geologic perspective) from one species to another with time, and ammonoid suture patterns are thus very useful in geologic dating. Figure 33.8b shows a drawing of an ammonoid as viewed from the front, revealing that the suture patterns are symmetrical about a vertical plane that divides the shell in half and demonstrating the way in which the suture pattern for an individual shell is typically drawn. The arrow represents the symmetry plane.

Figure 33.8. (a) A typical Paleozoic (Mississippian Period) ammonoid, showing the living chamber and sutures that mark the junction of the rear walls of the successive living chambers with the inner shell. The sutures are contorted because those walls were not simply curved, but folded. (b) Suture patterns are usually represented as flat drawings with an arrow to show the symmetry plane. Often only the pattern on one side of the arrow is drawn, because the other side is a mirror image of it.

Figure 33.9 traces some of the changes in suture patterns that occurred from species to species over time. One who is an expert in the study of ammonoids could identify the species to which a given specimen belongs from the suture pattern alone (though the shapes of the shells also vary), and could therefore use that to determine the ages of rocks in which ammonoid fossils were found. Note that the few suture patterns shown in Figure 33.9 are simply representative, intended to illustrate the principle. During the nearly 350 million years that ammonoids inhabited the seas, a great many species made their entrances and exits in the fossil record.

Indicators of Ancient Environments

If you were asked to find living corals today, you would no doubt think of traveling to the Caribbean or some other area of the world where you could find warm, shallow seas. It would not occur to you to look in a desert or in the Antarctic, because you know that those environments are not inhabited by corals. Uniformitarianism (see Chapter 29) requires us to accept, in the absence of any evidence to the contrary, that the environment in which corals thrive now is similar to any in which they would have thrived anciently. Thus, when we find fossil corals in the Paleozoic limestones of a mountain range at an elevation of 4000 meters above sea level, we must conclude that the sediments that became the limestone were deposited on the floor of a shallow sea, despite their present location. That, incidentally, also places some constraints on the time of formation of the mountains, which must be more recent than the age of the limestone.

Although the search for a new and better understanding of our universe is sufficient justification for studying any facet of science, the ability to interpret sedimentary environments is of more than academic interest. The formation and accumulation of many types of natural resources depends in large measure on environmental factors, and in a world that is voraciously consuming natural resources, the ability to interpret favorable environments of formation is significant. Coal, for example, is the fossilized remains of great vol-
umes of plant life that grew in ancient swamps. These deposits do not extend laterally indefinitely, of course, but gradually merge with deposits typical of the environments surrounding the ancient swamp. The ability to recognize that paleoenvironment for what it is enhances the probability of locating important coal beds. Oil is often trapped in ancient reefs, porous moundlike structures consisting of the fossilized remains of marine organisms like corals and sponges. Recognition of the shallow marine paleoenvironment of reef formation aids in the search for petroleum. These are just two examples of the impact of paleoenvironmental studies on the discovery of natural resources, and paleontology plays a central role in such studies.

History of Life on Earth

Fossils provide the best evidence that life on the earth has undergone change—substantial change—over the great expanse of geologic time. Evidence of some of that change has already been cited above, because it is that very change that makes fossils useful as gauges of geologic time. Figure 29.9 and the accompanying discussion in that chapter have alluded to the succession of life-forms documented in the record of the rocks.

The earliest evidence of life on earth comes from rocks about 3.5 billion years in age, and it consists of fossil bacteria and algae—very simple life-forms indeed. The development of more complex forms proceeded exceedingly slowly, but by the end of the Precambrian there is rare but clear fossil evidence of the existence of numerous soft-bodied animals (worms, jellyfish, and so forth) in the seas. The beginning of the Paleozoic Era is marked by the nearly explosive appearance of very abundant hard-shelled marine invertebrates (animals without backbones). Anatomically, they were still rather simple creatures, but a tremendous advance over the early bacteria and algae.

The fossil record shows that over the succeeding millions of years, animals and plants of increasingly greater complexity made their appearances. Fish, for example, got a slow start in the Cambrian Period, but were flourishing so successfully by the Devonian Period that it is often called the “age of fishes.” Plants, like animals, got their start in the sea but had appeared on land by the Silurian Period. However, it took them tens of millions of years to establish the first forests, in the Devonian. Plants with flowers entered the scene much later, in the Cretaceous Period. The fossils of the first reptiles are found in Pennsylvanian rocks, and by the Mesozoic Era reptiles—the dinosaurs—had become temporary rulers of the earth. Their reign lasted about 150 million years, and their extinction opened the world to the dominant form of the Cenozoic Era, mammals. Obviously, we could go on listing various sorts of fossils that made their appearances and then vanished, but the point is made: Life developed from the simple to the complex; the appearance of the simpler forms always preceded that of the more complex forms.

One may well ask why populations of organisms would change at all, much less flourish, only to later become extinct. It is well-known now that deoxyribonucleic acid (DNA) plays the key role in passing on inherited characteristics to offspring. If the DNA molecule involved in reproduction has been modified, characteristics that differ significantly in some respect from those of the parent may appear in the offspring. Natural radiation from terrestrial sources and cosmic rays from space constantly bombard all living things, mostly doing no harm but occasionally resulting in a mutation in the progeny. Most such mutations would result in either a distinct disadvantage or at least no particular advantage for the organism. Rarely a favorable mutation would occur; and because it was “programmed” into the DNA, it would be passed on to the next generation, and a more successful strain of the organism would result. One would expect that the more successful modification would eventually become dominant in the population. Such a mechanism would be especially useful in producing modified organisms that could deal successfully with changing environmental conditions.

As you think back on what we have learned of plate tectonics, you recognize that the operation of that system would naturally and continually bring about environmental changes. As moving plates bring continents together in continental collisions, entire ecosystems must be obliterated along converging coastlines. While this might not cause the worldwide extinction of widely distributed species, it would cause local extinction (as well as total extinction of localized species). As plates carry their cargo of organisms north or south, climates must slowly change, requiring that life-forms do likewise or face extinction.

Even changes in plate speeds have a profound effect on life. If plates speed up in response to changes in asthenospheric convection currents, then the rates of spreading along ocean ridges increase, causing more rapid injection of hot material into the oceanic lithosphere and thereby elevating the ridges. These then displace additional ocean water, and sea level rises. A rather modest rise in sea level can result in a marked relocation of the shoreline for coastal lowlands, with attendant changes in environmental conditions. Former shallows become deeper as new shallows are developed where terrestrial lowlands used to be. Organisms that produce sufficient numbers of offspring to insure a variety of genetic variations are more likely to be successful at adapting to such changing environments.
Summary

Fossils are the remains of living organisms (or traces of them, such as footprints or burrows) that have been preserved through special conditions. Those conditions have evidently occurred often enough to ensure an abundant body of fossilized evidence of past life, even though the vast majority of all life that has existed on the earth has disappeared without a trace. It is likely that many entire species have lived and died on the planet without leaving any hint of their existence.

Fossils provide us with the most efficient and economical way to determine geologic age—including estimates of absolute ages of sedimentary rocks, given that radiometric dating of igneous rocks has provided a framework of reference dates for the Geologic Column. Fossils are also the best indicators of ancient sedimentary environments, and this has important implications in the search for fossil fuels and some mineral resources. Finally, fossils provide evidence that life on earth has changed in a systematic way, with simpler life-forms appearing before more complex life-forms.

STUDY GUIDE
Chapter 33: Fossils: The Record of Life

A. FUNDAMENTAL PRINCIPLES: No new fundamental principles.

B. MODELS, IDEAS, QUESTIONS, AND APPLICATIONS
1. What are “fossils”?
2. How are fossils preserved?
3. To what uses are fossils put?
4. How are fossils used as “markers of time”?
5. What do fossils tell us about the history of life on earth?

C. GLOSSARY
1. Biosphere: That spherical shell surrounding the earth that is inhabited by living things.
2. Carbonization: Process of fossilization where the oxygen, nitrogen, and hydrogen have been driven off (volatilized) by relatively high pressures and temperatures when deep burial in sediment occurs. The carbon in the organism remains as a thin film. The result of the process is called a carbonized residue.
3. Cast: Method of fossilization where a mold is filled with sediment of some sort to preserve the form of the organism.
4. Fossil: Remains or other evidence of a formerly living organism, preserved by natural processes within the crust of the earth.
5. Index Fossil: A generic term for a kind of fossil that is particularly useful as a marker of time. To be useful, index fossils must be relatively common and they must have some easily recognizable feature that changed in some systematic way over time. Ammonoids are extinct, shelled creatures that serve well as index fossils.
6. Microfossil: Remains of tiny organisms individually visible only with the aid of a microscope.
7. Mold: Method of fossilization in which the sediment that packs closely around a fossil turns into rock and allows water to remove (by solution) the fossil. A cavity, called a mold, is left in the rock to preserve the form of the organism. A mold may reveal the shape of the outer surface of hard parts (an external mold), or it may show impressions made by the inner surfaces (an internal mold).
8. Paleoenvironment: The ancient environment of a particular place on earth and the conditions which existed in the environment at that time. The paleoenvironment may be quite different than the present environment.
11. Replacement: Method of fossilization where little or none of the original matter is left but it has been replaced by some new material that may or may not have a composition similar to the original.
12. Trace Fossil: A fossil that reveals the existence but not the form of the body, such as tracks, filled-in burrows, or petrified excrement.
13. Unaltered Hard Parts: Method of fossilization where the hard parts of an organism such as bones and teeth are preserved unaltered from their original compositions.

D. FOCUS QUESTIONS
1. Consider fossils.
   a. What is a fossil?
   b. What conditions are generally required for the preservation of a fossil?
   c. List and describe six ways fossils are preserved.
   d. Explain how fossils are used to give evidence of ancient environments.

E. EXERCISES
33.1. Compare, in a qualitative way, the abundance of fossils found today in rocks with the abundance of life on earth throughout geologic time.

33.2. Of the following, which is least likely to be fossilized?
   (a) clam
   (b) bird
   (c) fish
   (d) worm
33.3. Of the following, which is second least likely to be fossilized?
   (a) fish
   (b) bird
   (c) worm
   (d) clam

33.4. Why are nearly all fossils found in sedimentary rock?

33.5. Of the following, which type of fossil would most likely be associated with coal beds?
   (a) alligator
   (b) whale
   (c) penguin
   (d) camel

33.6. Which of the following is not a correct statement?
   (a) The rates of spreading that the tectonic plates have experienced in the past can affect the fossil record.
   (b) The direction of plate motion in the past can affect the fossil record.
   (c) The ancient organisms that reproduced most slowly had the greatest impact on the fossil record.
   (d) Chance modification of the DNA of an individual organism can affect the nature of the fossil record.