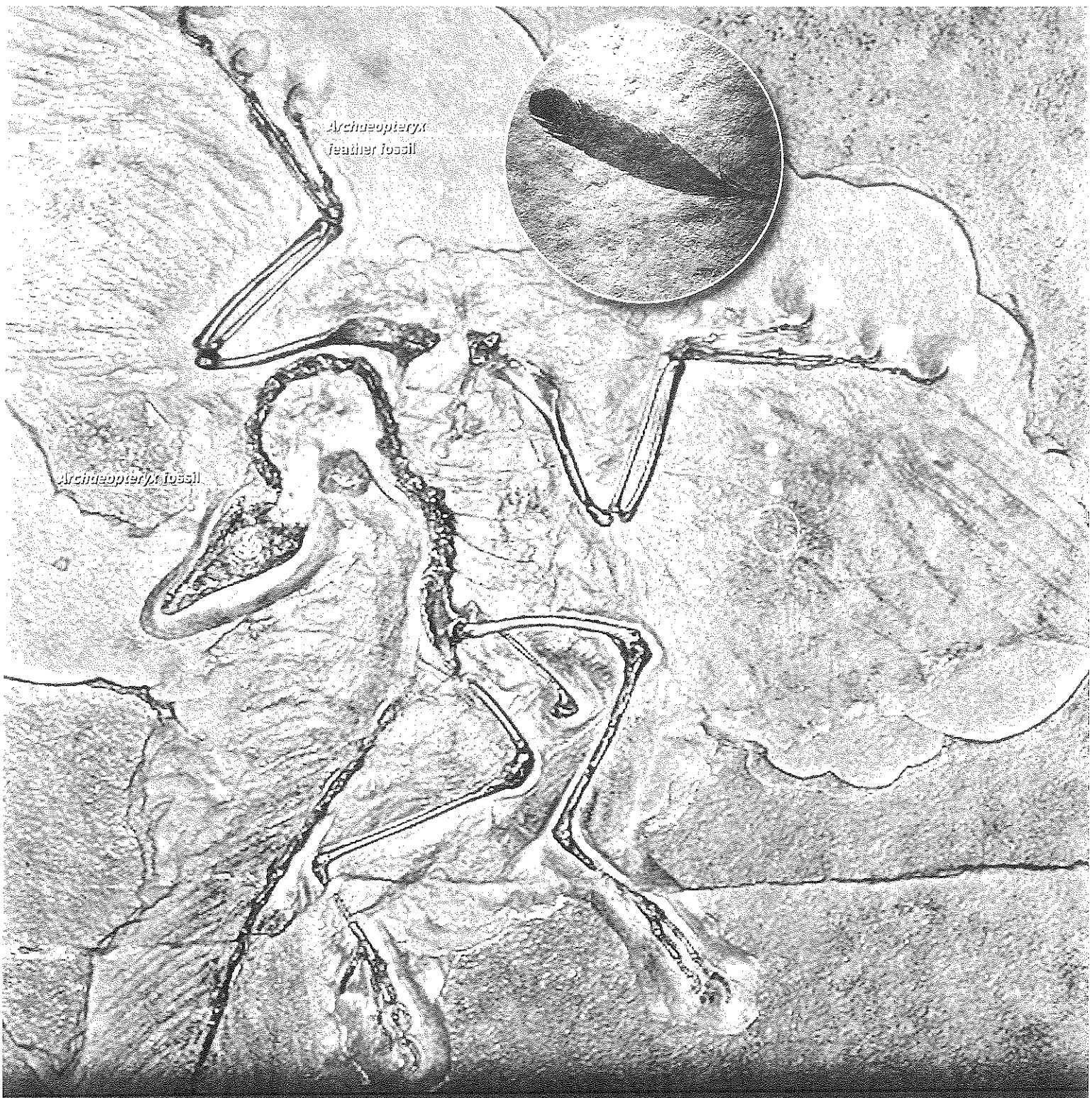



**THEME FOCUS** Stability and Change
**Fossils provide evidence how the diversity of organisms changed over time.**

**BIG Idea** Fossils provide key evidence for understanding the origin and the history of life on Earth.

Reading Preview

### Essential Questions

- What are the similarities and differences between Earth's early environment and Earth's current environment?
- What is a typical sequence of events in fossilization?
- How are the different techniques for dating fossils used?
- What are the major events on the geologic time scale?

### Review Vocabulary

**extinction:** the death of all individuals of a species

### New Vocabulary

fossil
paleontologist
relative dating
law of superposition
radiometric dating
half-life
geologic time scale
epoch
period
era
eon
Cambrian explosion
K-T boundary
plate tectonics

Multilingual eGlossary

# Fossil Evidence of Change

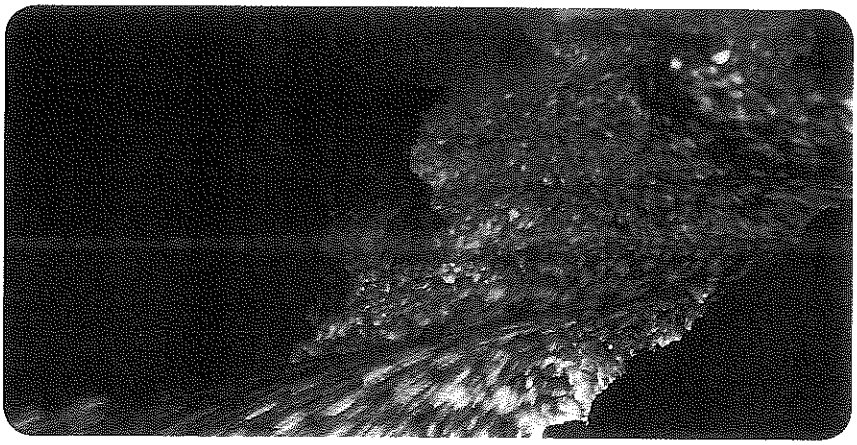
**Key Idea** **Fossils provide evidence of the change in organisms over time.**

**Real-World Reading Link** Did you know that when you look at the stars at night you are looking into the past? The stars are so far away that the light you see left the stars thousands and sometimes millions of years ago. You also are looking into the past when you look at rocks. The rocks formed thousands or even millions of years ago. Rocks can tell us what Earth was like in the distant past, and sometimes they can tell us what lived during that time.

## Earth's Early History

What were the conditions on Earth as it formed, and how did life arise on a lifeless planet? Because there were no people to witness Earth's earliest history, it might seem that this is an unsolvable mystery. Like any good mystery, however, it left clues behind. Each clue to Earth's history and life's origin is open to investigation by the scientists who study the history of the Earth.

**Land environments** By studying other planets in the solar system and rocks on Earth, scientists conclude that Earth was a molten body when it formed about 4.6 billion years ago. Gravity pulled the densest elements to the center of the planet. After about 500 million years, a solid crust formed on the surface, much like the crust that forms on the top of lava, shown in **Figure 1.** The surface was rich in lighter elements, such as silicon. From the oldest rocks remaining today, scientists infer that Earth's young surface included a number of volcanic features. In addition, the cooling interior radiated much more heat to the surface than it does today. Meteorites would have caused additional heating as they crashed into Earth's surface. If there had been any life on Earth, it most likely would have been consumed by the intense heat.



**Molten lava flow**



**Figure 1** Lava, molten rock ejected from volcanoes, forms a crust as it cools.
Infer *the importance of the crust to the origin of life on Earth.*

**Atmosphere** Because of its gravitational field, Earth is a planet that is able to maintain an atmosphere. However, no one can be certain about the exact composition of Earth's early atmosphere. The gases that likely made up the atmosphere are those that were expelled by volcanoes. Volcanic gases today include water vapor ($H_2O$), carbon dioxide ($CO_2$), sulfur dioxide ($SO_2$), carbon monoxide (CO), hydrogen sulfide ($H_2S$), hydrogen cyanide (HCN), nitrogen ($N_2$), and hydrogen ($H_2$). Scientists infer that the same gases would have been present in Earth's early atmosphere. The minerals in the oldest known rocks suggest that the early atmosphere, unlike today's atmosphere, had little or no free oxygen.

## Clues in Rocks

Earth eventually cooled to the point where liquid water formed on its surface, which became the first oceans. It was a short time after this—maybe as little as 500 million years—that life first appeared. The earliest clues about life on Earth date to about 3.5 billion years ago.

**The fossil record** A **fossil** is any preserved evidence of an organism. Six categories of fossils are shown in **Table 1.** Plants, animals, and even bacteria can form fossils. Although there is a rich diversity of fossils, the fossil record is like a book with many missing pages. Perhaps more than 99 percent of the species that ever have lived are now extinct, but only a tiny percentage of these organisms are preserved as fossils.

Most organisms decompose before they have a chance to become fossilized. Only those organisms that are buried rapidly in sediment are readily preserved. This occurs more frequently with organisms living in water because the sediment in aquatic environments is constantly settling, covering, and preserving the remains of organisms.

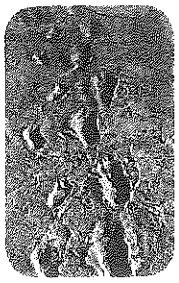
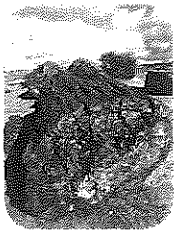
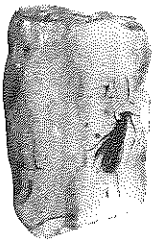
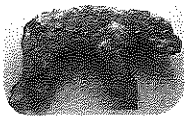
VOCABULARY

**Fossil**
from the Latin word *fossilis,* meaning *dug up*

What's BIOLOGY Got To Do With It?

**Table 1** Categories of Fossil Types

Interactive Table

| Category | Trace fossil | Molds and casts | Replacement | Petrified or permineralized | Amber | Original material |
|---|---|---|---|---|---|---|
| Example |  |  |  |  |  |  |
| Formation | A trace fossil is any indirect evidence left by an organism. Footprints, burrows, and fossilized feces are trace fossils. | A mold is an impression of an organism. A cast is a mold filled with sediment. | The original material of an organism is replaced with mineral crystals that can leave detailed replicas of hard or soft parts. | Empty pore spaces are filled in by minerals, such as in petrified wood. | Preserved tree sap traps an entire organism. The sap hardens into amber and preserves the trapped organism. | Mummification or freezing preserves original organisms. |

(l to r) John Reader/Photo Researchers; (2)Biophoto Associates/Photo Researchers; (3)©2/Tsuneo Yamashita/Ocean/Corbis; (4)Bernard Edmaier/Photo Researchers; (5)Francois Gohier/Photo Researchers; (6)VPC Travel Photo/Alamy

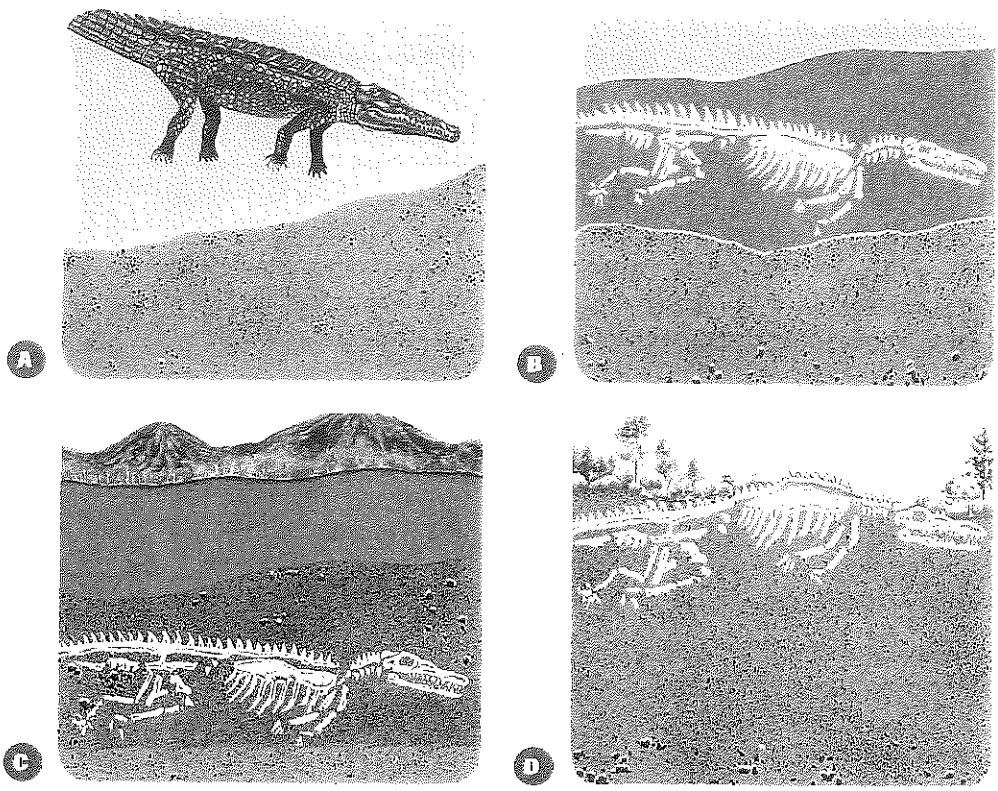


**Figure 2** (A) Organisms usually become fossilized after they die and are buried by sediment. (B) Sediments build up in layers, eventually encasing the remains in sedimentary rock. (C) Minerals replace, or fill in the pore space of, the bones and hard parts of the organism. (D) Erosion can expose the fossils.

*Study Tip*

**Background Knowledge Check** Based on what you know, predict the meaning of each new vocabulary term before reading the section. As you read, check the actual meaning compared to your prediction.

**Fossil formation** Fossils do not form in igneous (IHG nee us) or metamorphic (meh tuh MOR fihk) rocks. Igneous rocks form when magma from Earth's interior cools. Metamorphic rocks form when rocks are exposed to extreme heat and pressure. Fossils usually do not survive the heat or pressure involved in the formation of either of these kinds of rocks.

Nearly all fossils are formed in sedimentary rock through the process illustrated in **Figure 2.** The organism dies and is buried in sediments. The sediments build up until they cover the organism's remains. In some cases, minerals replace the organic matter or fill the empty pore spaces of the organism. In other cases, the organism decays, leaving behind an impression of its body. The sediments eventually harden into rock.

A **paleontologist** (pay lee ahn TAH luh jist) is a scientist who studies fossils. He or she attempts to read the record of life left in rocks. From fossil evidence, paleontologists infer the diet of an organism and the environment in which it lived. In fact, paleontologists often can create images of extinct communities.

**Connection to Earth Science** When geologists began to study rock layers, or strata, in different areas, they noticed that layers of the same age tended to have the same kinds of fossils no matter where the rocks were found. The geologists inferred that all strata of the same age contained similar collections of fossils. This led to the establishment of a relative age scale for rocks all over the world.

**Dating fossils** **Relative dating** is a method used to determine the age of rocks by comparing them with those in other layers. Relative dating is based on the **law of superposition,** illustrated in **Figure 3,** which states that younger layers of rock are deposited on top of older layers. The process is similar to stacking newspapers in a pile as you read them each day. Unless you disturb the newspapers, the oldest ones will be on the bottom.

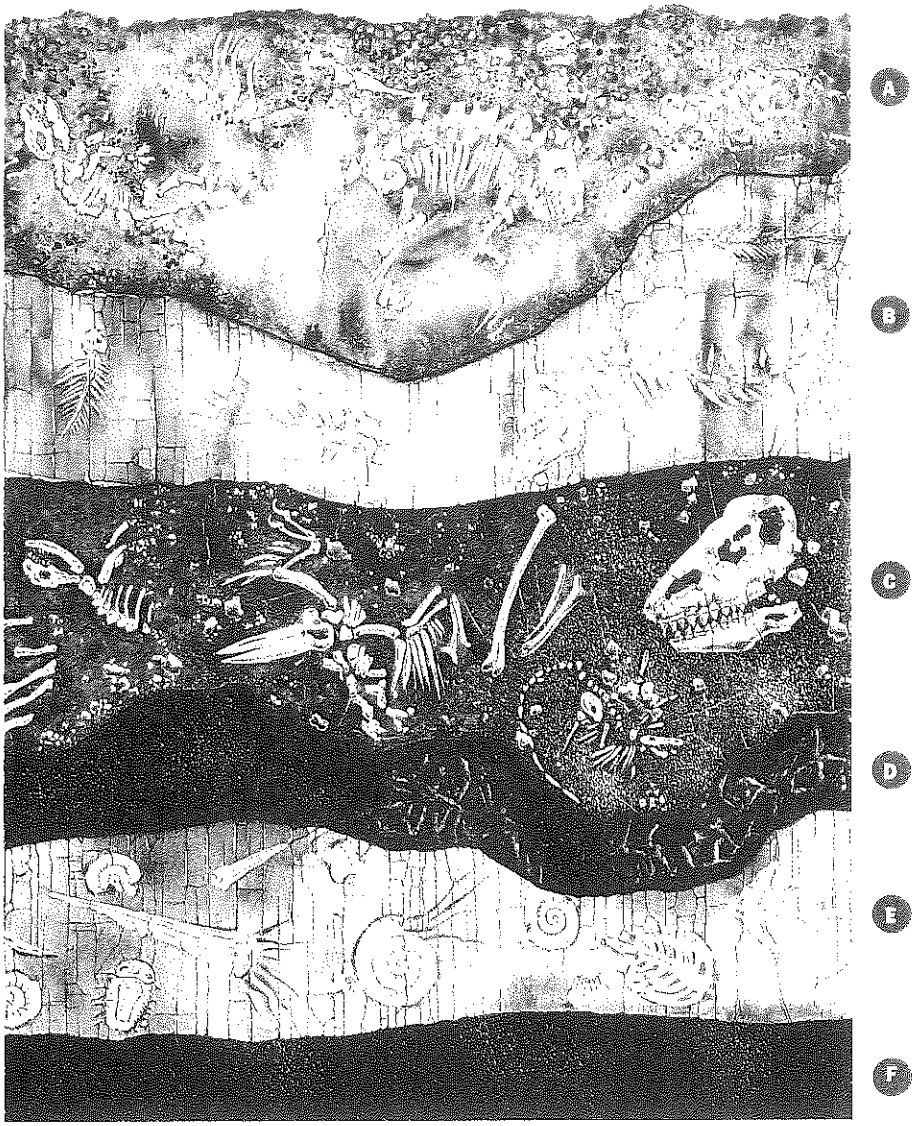



**Figure 3** According to the law of superposition, rock layers are deposited with the youngest undisturbed layers on top. Infer *which layer shows that an aquatic ecosystem replaced a land ecosystem.*

**Radiometric dating** uses the decay of radioactive isotopes to measure the age of a rock. Recall that an isotope is a form of an element that has the same atomic number but a different mass number. The method requires that the **half-life** of the isotope, which is the amount of time it takes for half of the original isotope to decay, is known. The relative amounts of the radioactive isotope and its decay product must also be known.

One radioactive isotope that is commonly used to determine the age of rocks is Uranium 238. Uranium 238 ($U^{238}$) decays to Lead 206 ($Pb^{206}$) with a half life of 4510 million years. When testing a rock sample, scientists calculate the ratio of the parent isotope to the daughter isotope to determine the age of the sample.

Radioactive isotopes that can be used for radiometric dating are found only in igneous or metamorphic rocks, not in sedimentary rocks, so isotopes cannot be used to date rocks that contain fossils. Igneous rocks that are found in layers closely associated with fossil-bearing sedimentary rocks often can be used for assigning relative dates to fossils.

Virtual Lab

BrainPOP

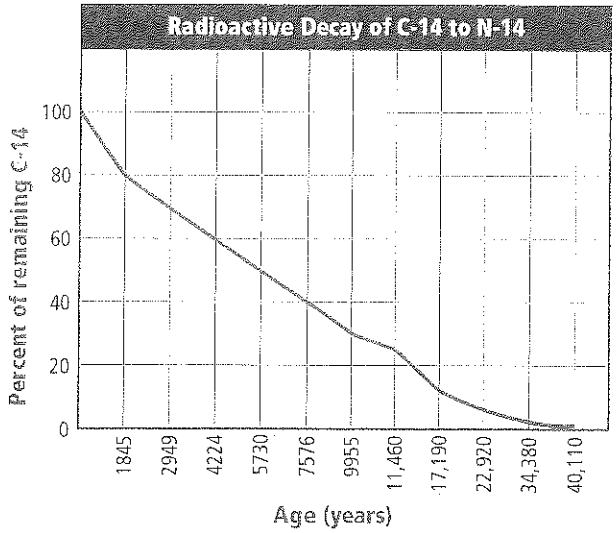



**Figure 4** The graph shows how the percent of carbon-14 remaining in a sample indicates age.

**Interpret the graph** ***What would the age of a bone be if it contained only 10 percent of C-14?***

Materials, such as mummies, bones, and tissues, can be dated directly using carbon-14 (C-14). Given the half-life of carbon-14, shown in **Figure 4**, only materials less than 60,000 years old can be dated accurately with this isotope.

## The Geologic Time Scale

Think of geologic time as a ribbon that is 4.6 m long. If each meter represents one billion years, each millimeter represents one million years. Earth was formed at one end of the ribbon, and humans appear at the tip of the opposite end.

The **geologic time scale** is a record of Earth's history. Major geological and biological events in Earth's history can be identified within the geologic time scale. Because geologic time spans more than 4 billion years, subdivisions of time are used to identify how many millions of years ago (mya) an event occurred. The geologic time scale is divided into two segments–Precambrian time and the Phanerozoic eon.

**Epochs,** which last several million years, are the smallest units of geologic time. **Periods,** which last tens of millions of years, are divisions of geologic time consisting of two or more epochs. An **era,** which lasts hundreds of millions of years, is a unit of geologic time consisting of two or more periods. An **eon** is the longest unit of time in the geologic time scale and can include billions of years. **Figure 5** shows a portion of the geologic time scale that includes the Phanerozoic eon.

**Reading Check** **Explain** why C-14 would not be useful for dating something from the Precambrian.

## MiniLab

### Correlate Rock Layers Using Fossils

MiniLab

**How can paleontologists establish relative age?** Scientists use fossils from many locations to piece together the sequence of Earth's rock layers. This is the process of correlation.

**Procedure**

1. Read and complete the lab safety form.
2. Your teacher will assign you to a group and will give your group a **container** with layers of material embedded with fossils.
3. Carefully remove each layer, noting any embedded materials.
4. Make a sketch of the cross section, and label each layer and any materials contained within it.
5. Collect copies of sketches from the other groups and use them to determine the sequence of all the layers the class has studied.

**Analysis**

1. **Describe** the materials in each cross section. What patterns did you observe?
2. **Explain** how your analysis would be different if different layers contained the same materials. What if some of the layers didn't overlap? Suggest a way to gather additional data that might resolve these issues.

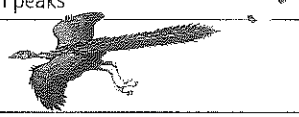
# Visualizing the Geologic Time Scale

**Figure 5**

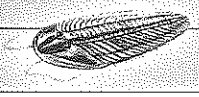
This figure illustrates the Phanerozoic eon of the geologic time scale. The major biologic events during the Phanerozoic eon are described in the figure. All of the times listed are approximate and as in all science fields, continuing research and discoveries might result in future revisions.

| Eon | Era | Period | Epoch | MYA | Biological events |
|---|---|---|---|---|---|
| Phanerozoic | Cenozoic | Quaternary | Holocene | | • Humans form civilizations |
| | | | Pleistocene | 0.01 | • Ice ages occur<br>• Modern humans appear |
| | | Neogene | Pliocene | 1.8 | • Hominins appear<br>• Flowering plants are dominant |
| | | | Miocene | 5.3 | • Apes appear<br>• Climate is cooler |
| | | Paleogene | Oligocene | 23.0 | • Monkeys appear<br>• Climate is mild |
| | | | Eocene | 33.9 | • Flowering plants scattered<br>• Most mammal orders exist |
| | | | Paleocene | 55.8 | • Mammals, birds, and insects scatter<br>• Climate is tropical |
| | Mass extinction K-T Boundary | | | | |
| | Mesozoic | Cretaceous | | 65.5 | • Flowering plants appear<br>• Dinosaur population peaks |
| | | Jurassic | | 145.5 | • First birds appear<br>• Dinosaurs scatter<br>• Forests are lush |
| | | Mass extinction | | | |
| | | Triassic | | 199.6 | • Gymnosperms are dominant<br>• Dinosaurs appear<br>• First mammals appear |
| | Mass extinction | | | | |
| | Paleozoic | Permian | | 251.0 | • Reptiles scatter<br>• Gymnosperms appear |
| | | Carboniferous | | 299.0 | • Ferns and evergreens make up forests<br>• Amphibians appear<br>• Insects scatter |
| | | Mass extinction | | | |
| | | Devonian | | 359.2 | • Sharks and bony fishes appear<br>• Tetrapods appear |
| | | Silurian | | 416.0 | • Coral and other invertebrates are dominant<br>• Land plants and insects appear |
| | | Mass extinction | | | |
| | | Ordovician | | 443.7 | • First vertebrates appear<br>• First plants appear |
| | | Cambrian | | 488.3 | • Cambrian explosion<br>• All body plans arise |







Animation

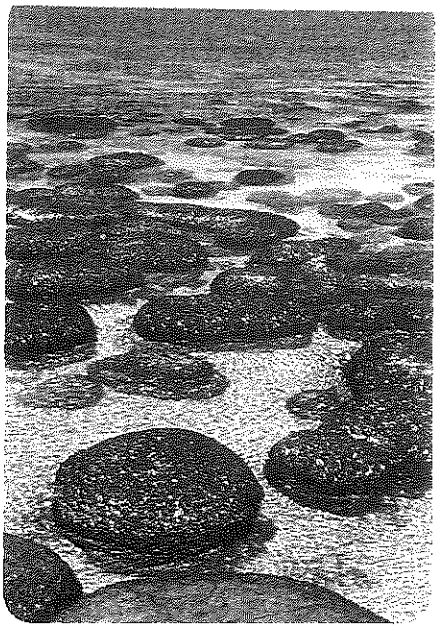


**Figure 6** Fossils much like these stromatolites are found in rocks almost 3.5 billion years old.
**Explain** *the importance of the organisms that left these stromatolites.*

**Precambrian** The first 4 billion years of Earth's history make up the Precambrian. This is nearly 90 percent of Earth's entire history, stretching from the formation of Earth to the beginning of the Paleozoic era about 542 million years ago. During the Precambrian, Earth formed and life first appeared. Eventually, autotrophic prokaryotes, much like the cyanobacteria that made the stromatolites in **Figure 6**, enriched the atmosphere with oxygen. Eukaryotic cells also emerged, and by the end of the Precambrian, life was flourishing and the first animals had appeared.

Extensive glaciation marked the second half of the Precambrian. This might have delayed the further evolution of life until the ice receded at the beginning of the Ediacaran (ee dee UH kur uhn) period. The Ediacaran period was added to the time scale in 2004. It was the first new period added to the time scale since 1891 and reflects new knowledge of Earth's history. The Ediacaran period lasted from about 635 million years ago to about 542 million years ago, representing about three quarters of a meter on the time ribbon at the end of the Precambrian. Simple organisms, such as the fossil in **Figure 7**, inhabited Ediacaran marine ecosystems. Food chains probably were short, and were dominated by animals that consumed tiny particles suspended in the water and by animals that ate debris on the bottom of the sea.

**Reading Check** **Infer** the process by which early autotrophic prokaryotes produced oxygen.

**The Paleozoic era** A drastic change in the history of animal life on Earth marked the start of the Paleozoic (pay lee uh ZOH ihk) era. In the space of just a few million years, the ancestors of most major animal groups diversified in what scientists call the **Cambrian explosion.** Not all major groups of organisms evolved rapidly at this time, and paleontologists still do not know when the rapid changes started or ended.

Major changes in ocean life occurred during the Paleozoic. More importantly, it seems the first life on land emerged during this era. Life in the oceans continued to evolve through the Cambrian period. Fish, land plants, and insects appeared during the Ordovician and Silurian periods. Organisms of many kinds, including huge insects, soon flourished in swampy forests that dominated the land, as shown in **Figure 8.** Tetrapods, the first land vertebrates (animals with backbones), emerged in the Devonian period. By the end of the Carboniferous period, the first reptiles were roaming the forests.

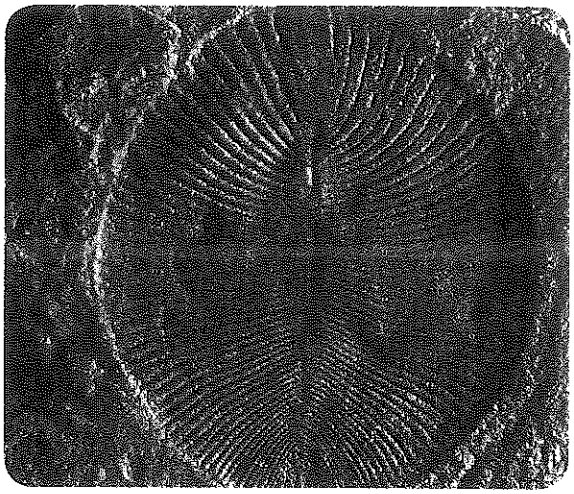


**Figure 7** Paleontologists disagree about scarce Ediacaran fossils such as this one. Some paleontologists suggest that they are relatives of today's living invertebrates such as segmented worms, while others think they represent an evolutionary dead end of giant protists or simple metazoans.

**Figure 8** During the Carboniferous period, swamp forests covered much of Earth's land surface. Insects dominated the air, and tetrapods flourished in freshwater pools. **Infer** *how the plants of the Paleozoic era were different from those of today.*

A mass extinction ended the Paleozoic era at the end of the Permian period. Recall that a mass extinction is an event in which many species become extinct in a short time. Mass extinctions have occurred every several million years with varying frequencies. Between 60 and 75 percent of the species alive went extinct in each of these events. During the Permian mass extinction, 90 percent of marine organisms disappeared. Geologists disagree about the cause of the Permian extinction, but most agree that geological forces, including increased volcanic activity, would have disrupted ecosystems or changed the climate.

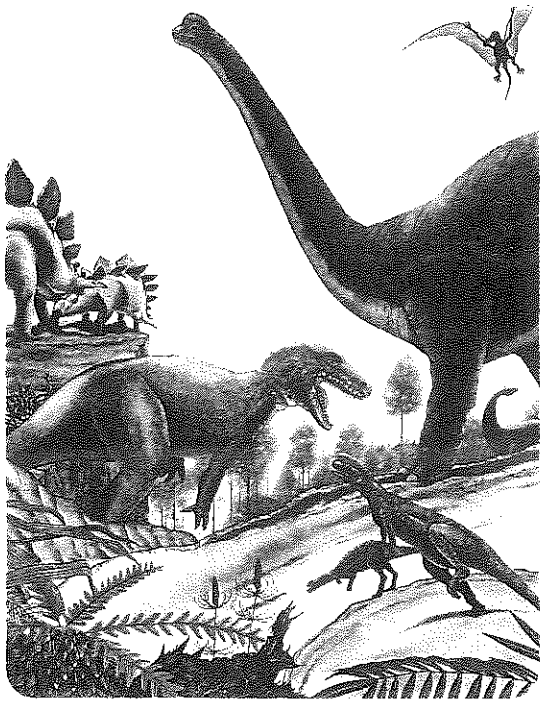
**The Mesozoic era** At the beginning of the Triassic period, the ancestors of early mammals were the dominant land animals. Mammals and dinosaurs first appeared late in the Triassic period, and flowering plants evolved from nonflowering plants. Birds evolved from a group of predatory dinosaurs in the middle Jurassic period. For the rest of the Mesozoic, reptiles, such as the dinosaurs illustrated in **Figure 9,** were the dominant organisms on the planet. Then, about 65 million years ago, a meteorite struck Earth.

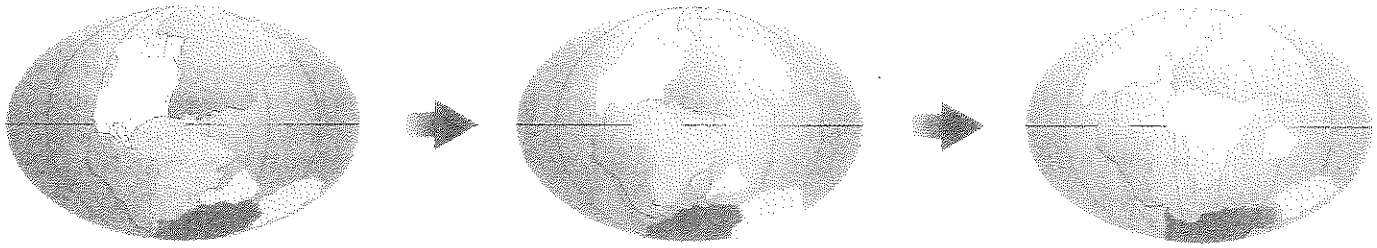
The primary evidence for this meteorite impact is found in a layer of material between the rocks of the Cretaceous (krih TAY shus) period and the rocks of the Paleogene period, the first period of the Cenozoic era. Paleontologists call this layer the **K-T boundary.** Within this layer, scientists find unusually high levels of an element called iridium. Iridium is rare on Earth, but relatively common in meteorites. Therefore, the presence of iridium on Earth indicates a meteorite impact.

Many scientists think that this impact is related to the mass extinction at the end of the Mesozoic era, which eliminated all dinosaurs, with the exception of their avian and reptilian descendents, many marine invertebrates, and numerous plant species. The meteorite did not wipe out all of these species, but the debris from the impact probably stayed in the atmosphere for months or even years, affecting global climate. Species that could not adjust to the changing climate disappeared.

**Reading Check** **Recall** the dominant land animals in the Triassic and Jurassic periods.

**Figure 9** The dominant organisms during the Mesozoic era were dinosaurs. A mass extinction occurred at the end of the Mesozoic era that eliminated approximately 60 percent of all species living during the Mesozoic era.





225 mya 135 mya 65 mya

**Figure 10** These illustrations show the movement of Earth's major tectonic plates from about 225 million years ago, when all of the continents were joined into one landmass called Pangaea, to 65 million years ago.

Animation

Scientists also think that the course of evolution in the Cenozoic era was shaped by the massive geological changes shown in **Figure 10** that characterized the Mesozoic era. While it might appear to us that continents are immobile, they have been moving since they formed. Alfred Wegener, a German scientist, presented the first evidence for continental drift in the 1920s. Continental drift has since become part of the theory of plate tectonics. **Plate tectonics** describes the movement of several large plates that make up the surface of Earth. These plates, some of which contain continents, move atop a partially molten layer of rock underneath them.

**The Cenozoic era** The most recent era is the one in which mammals became the dominant land animals. At the beginning of the Cenozoic (sen uh ZOH ihk) era, which means "recent life," most mammals were small and resembled shrews. After the mass extinction at the end of the Mesozoic era, mammals began to diversify into distinct groups, including primates–the group to which you belong. Humans appeared very recently, near the end of the geologic time scale, in the current Quaternary period. Humans survived the last ice age, but many species of mammals did not. To get an idea of how recently modern humans have appeared, you need to remove about two threads at the end of your geologic time ribbon. These threads represent the time that humans have existed on Earth.

# Section 1 Assessment

## Section Summary

- Fossils provide evidence of past life.
- Relative dating and radiometric dating are two methods used to determine the age of fossils.
- The geologic time scale is divided into eras, periods, and epochs.
- Major events in the geological time scale include both biological and geological changes.

## Understand Main Ideas

1. MAIN Idea **Discuss** how fossils provide evidence of change from the earliest life-forms to those alive today.
2. **Diagram** a typical sequence of events in fossilization.
3. **Discuss** two ways that radiometric dating can be used to establish the age of a fossil.
4. **Compare** Earth's early land environment with today's land environment.

## Think Critically

5. **Infer** what changes you might observe in the fossil record that would indicate the occurrence of a mass extinction.

MATH in Biology

6. Out of the total of Earth's history (approximately 4.6 billion years), modern humans have existed for only 200,000 years. To put this in perspective, calculate the percentage of Earth's history that modern humans have existed.



Online Quiz

Section 2

Reading Preview

### Essential Questions

- What are the differences between spontaneous generation and biogenesis?
- What might have been the sequence of events that led to cellular life?
- What is the endosymbiont theory?

### Review Vocabulary

**amino acid:** building blocks for proteins

### New Vocabulary

spontaneous generation
theory of biogenesis
endosymbiont theory

Multilingual eGlossary

# The Origin of Life

**Key Idea Evidence indicates that a sequence of chemical events preceded the origin of life on Earth and that life has evolved continuously since that time.**

Real-World Reading Link In a recipe, some steps can be out of order, but some steps have to occur earlier than others or the end result will be different from what was intended. In the same way, to arrive at the pattern of life that is seen today, events leading to the emergence of life had to occur in specific ways.

## Origins: Early Ideas

Perhaps one of the oldest ideas about the origin of life is spontaneous generation. **Spontaneous generation** is the idea that life arises from nonlife. For example, at one time people thought that mice could be created by placing damp hay and corn in a dark corner, or that mud could give rise to worms, insects, and fish. These ideas might seem humorous to us today, but before much was known about reproduction, it is easy to see how someone might form these conclusions.

One of the first recorded investigations of spontaneous generation came in 1668. Francesco Redi, an Italian scientist, tested the idea that flies arose spontaneously from rotting meat. He hypothesized that flies–not meat–produced other flies. In his experiment, illustrated using present-day equipment in **Figure 11,** Redi observed that maggots, the larvae of flies, appeared only in flasks that were open to flies. Closed flasks had no flies and no maggots. The results of his experiments failed to convince everyone, however. Although people were beginning to use the microscope during Redi's time and knew that organisms invisible to the naked eye could be found almost everywhere, some thought that these tiny organisms must arise spontaneously, even if flies did not.

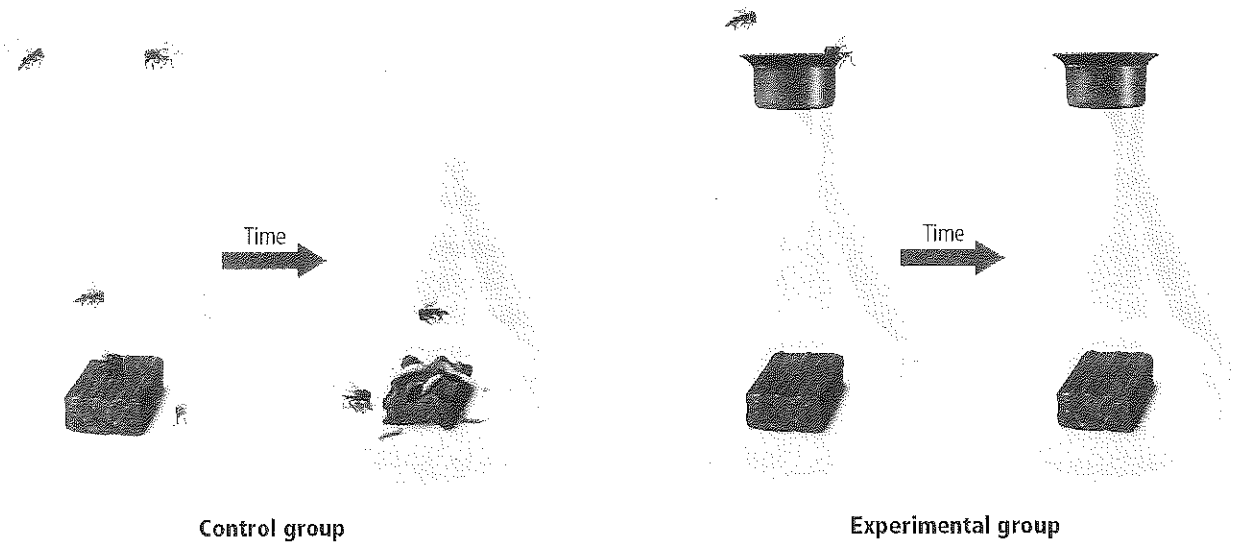



**Figure 11** Francesco Redi showed that flies and maggots did not arise spontaneously from rotting meat.
Infer *the purpose of the covered flask in Redi's experiment.*

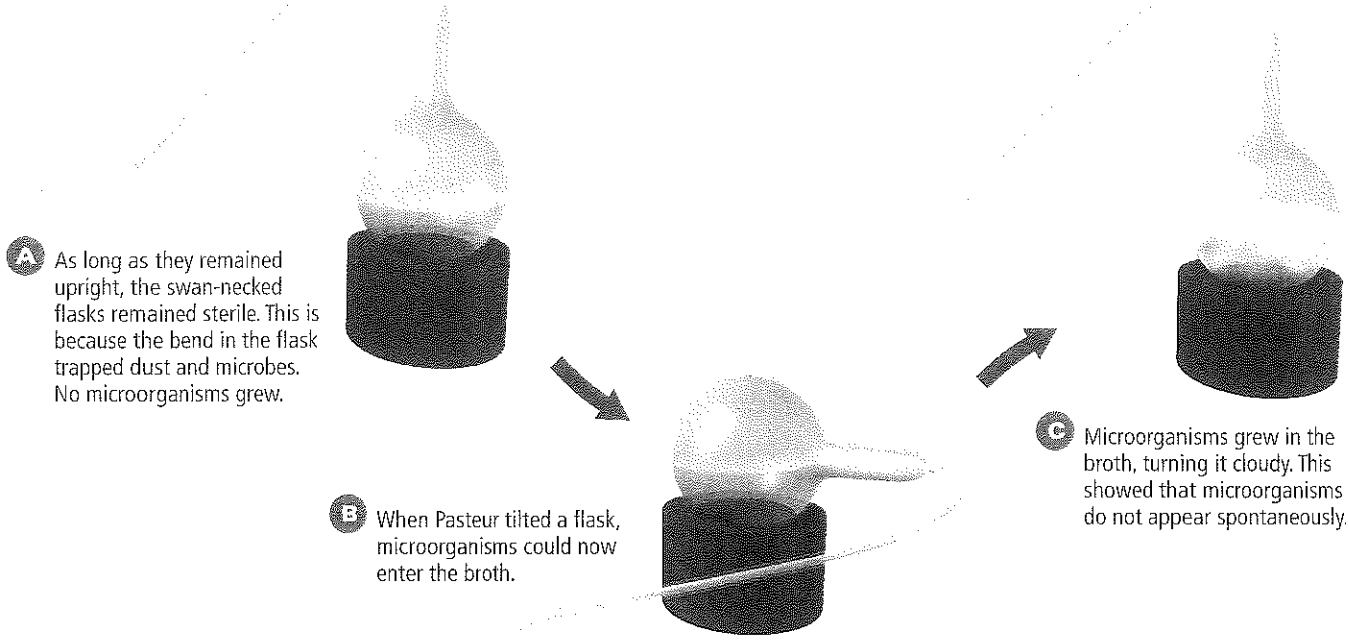



**Figure 12** Pasteur's experiment showed that sterile broth remained free of microorganisms until exposed to air.

FOLDABLES
Incorporate information from this section into your Foldable.

The idea of spontaneous generation was not completely rejected until the mid-1800s. It was replaced by the **theory of biogenesis** (bi oh JEN uh sus), which states that only living organisms can produce other living organisms. Louis Pasteur designed an experiment to show that biogenesis was true even for microorganisms. Pasteur's experiment is illustrated in **Figure 12.** In one flask, only air was allowed to contact a sterile nutrient broth. Nutrient broth supports the growth of microorganisms. In another flask, both air and microorganisms were allowed to contact the broth. No microorganisms grew in the first container. They did, however, grow in the second container.

## Origins: Modern Ideas

If life can arise only from preexisting life, then how did the first lifeform appear? Most biologists agree that life originated through a series of chemical events early in Earth's history. During these events, complex organic molecules were generated from simpler ones. Eventually, simple metabolic pathways developed. Such pathways allowed molecules to be synthesized or broken down more efficiently. These pathways might have led to the emergence of life as we know it. How this happened is a topic of ongoing research among scientists today.

**Simple organic molecule formation** The primordial soup hypothesis was an early hypothesis about the origin of life. Scientists Alexander Oparin and John Haldane suggested this hypothesis in the 1920s. They thought that if Earth's early atmosphere had a mix of certain gases, organic molecules could have been synthesized from simple reactions involving those gases in the early oceans. UV light from the Sun and electric discharge in lightning might have been the primary energy sources. They thought that these organic molecules would have eventually supplied the precursors to life.

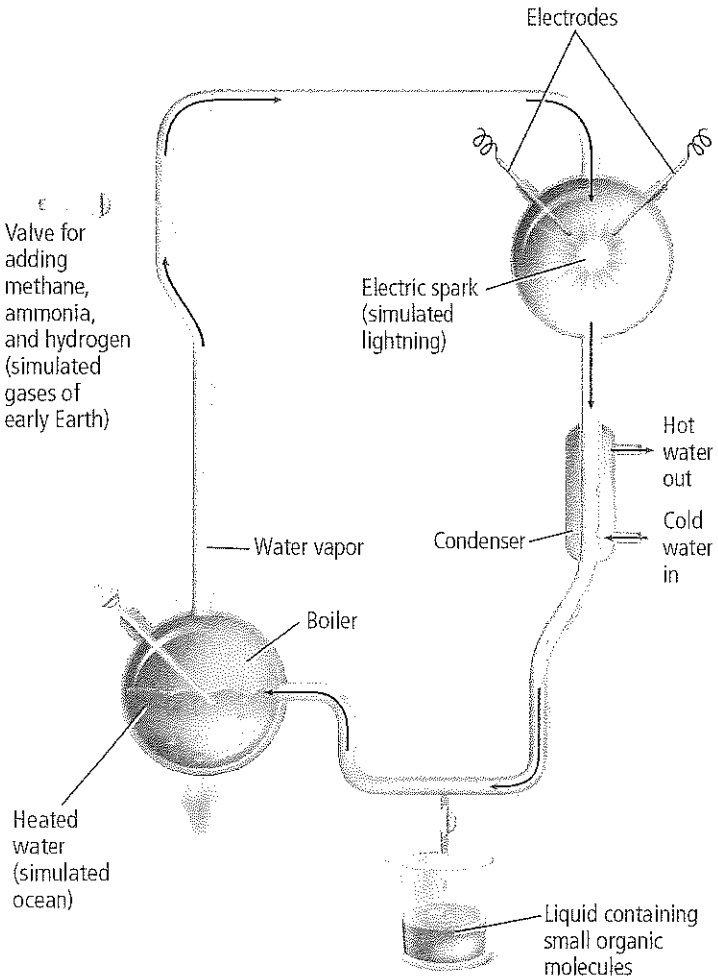
**Connection to Chemistry** In 1953, American scientists Stanley Miller and Harold Urey were the first to show that simple organic molecules could be made from inorganic compounds, as proposed by Oparin and Haldane. Miller and Urey built a glass apparatus, illustrated in **Figure 13**, to simulate the early Earth conditions hypothesized by Oparin. They filled the apparatus with water and the gases that they thought had made up the early atmosphere. The water was boiled and electric discharges were used to simulate lightning as an energy source. Upon examination, the resulting mixture contained a variety of organic compounds including amino acids. Because amino acids are the building blocks of proteins, this discovery supported the primordial soup hypothesis.

Later, other scientists found that hydrogen cyanide could be formed from even simpler molecules in simulated early Earth environments. Hydrogen cyanide can react with itself to eventually form adenine, one of the nucleotide bases in the genetic code. Many other experiments have since been carried out under conditions that probably reflect the atmosphere of early Earth more accurately. The final reaction products in these experiments were amino acids and sugars as well as nucleotides.

Some scientists suggest that the organic reactions that preceded life's emergence began in the hydrothermal volcanic vents of the deep sea, where sulfur forms the base of a unique food chain. Still others think that meteorites brought the first organic molecules to Earth.

**CAREERS IN BIOLOGY**

**Evolutionary Biochemist** Scientists who study chemistry and how it relates to life are biochemists. Evolutionary biochemists specifically study the structure and function of molecules from Earth's early history.




Animation

**Figure 13** The Miller-Urey experiment showed for the first time that organic molecules could be produced from gases proposed to have made up the atmosphere of early Earth.

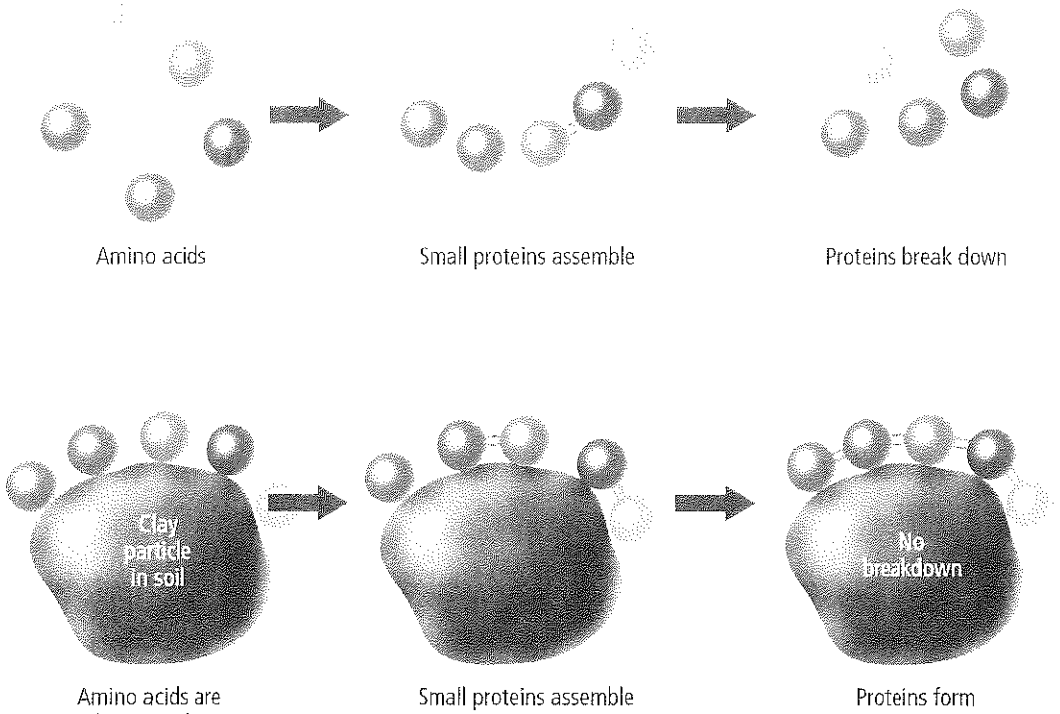



**Figure 14** Without clay, amino acids could have formed small, unstable proteins. In the presence of clay, amino acids might have come together in a more stable manner.

Personal Tutor

**Making proteins** Wherever the first organic molecules originated, it is clear that the next critical step was the formation of proteins. Amino acids alone are not sufficient for life. Life requires proteins, which are chains of amino acids. In the Miller-Urey experiment, amino acids could bond to one another, but they could separate just as quickly. One possible mechanism for the formation of proteins would be if amino acids were bound to a clay particle, as illustrated in **Figure 14.** Clay would have been a common sediment in early oceans, and it could have provided a framework for protein assembly.

**Genetic code** Another requirement for life is a coding system for protein production. All modern life has such a system, based on either RNA or DNA. Because all DNA-based life-forms also contain RNA, and because some RNA sequences appear to have changed very little through time, many biologists consider RNA to have been life's first coding system. Researchers have been able to demonstrate that RNA systems are capable of evolution by natural selection. Some RNAs also can behave like enzymes. These RNA molecules, called ribozymes, could have carried out some early life processes. Other researchers have proposed that clay crystals could have provided an initial template for RNA replication, and that eventually the resulting molecules developed their own replication mechanism.

**Molecules to cells** Another important step in the evolution of life was the formation of membranes. Researchers have tested ways of enclosing molecules in membranes, allowing early metabolic and replication pathways to develop. In these studies, as in other origin-of-life research, the connection between the various chemical events and the overall path from molecules to cells remains unresolved. However, scientists continue to search for the connection.

VOCABULARY

ACADEMIC VOCABULARY

**Mechanism**
an instrument or process by which something is done or comes into being
*The mechanism for protein synthesis was unknown for a long time.*

## Cellular Evolution

What were the earliest cells like? Scientists don't know because the first life left no fossils. The earliest fossils are 3.5 billion years old. Chemical markings in rocks as old as 3.8 billion years suggest that life was present at that time even though no fossils remain. Scientists recently announced the discovery of what appeared to be fossilized microbes in rock that is 3.5 billion years old. This suggests that cellular activity had become established very early in Earth's history.

**The first cells** Scientists hypothesize that the first cells were prokaryotes. Recall that prokaryotic cells are much smaller than eukaryotic cells, and they lack a defined nucleus and most other organelles. Many scientists think that modern prokaryotes called archaea (ar KEE uh) are the closest relatives of Earth's first cells. These organisms often live in extreme environments, such as the hot springs of Yellowstone Park or the volcanic vents in the deep sea, such as the one shown in **Figure 15.** These are environments similar to the environment that might have existed on early Earth.

**Photosynthesizing prokaryotes** Scientists think that oxygen was absent from Earth's earliest atmosphere until about 1.8 billion years ago. Any oxygen that appeared earlier than 1.8 billion years ago likely bonded with free ions of iron as oxygen does today. Evidence that iron oxide was formed by oxygen generated by early life is found in unique sedimentary rock formations, such as those shown in **Figure 16,** that are between about 1.8 billion and 2.5 billion years old. Scientists hypothesize that after 1.8 billion years ago, the early Earth's free iron was saturated with oxygen, and oxygen instead began accumulating in the atmosphere.

Many scientists think that photosynthesizing prokaryotes evolved not long after the archaea—very early in life's history. Fossil evidence of these primitive prokaryotes, called cyanobacteria, has been found in rocks as old as 3.5 billion years. Cyanobacteria eventually produced enough oxygen to support the formation of an ozone layer. Once an ozone shield was established, conditions would be right for the appearance of eukaryotic cells.

**Reading Check** **Create** a list of the steps that led to the formation of the ozone layer in Earth's atmosphere.

**Figure 15** Some archaea live near deep-sea hydrothermal vents. They use energy from inorganic molecules to form the base of the vent food web.

**Infer** *why some scientists think archaea most resemble the first cells.*

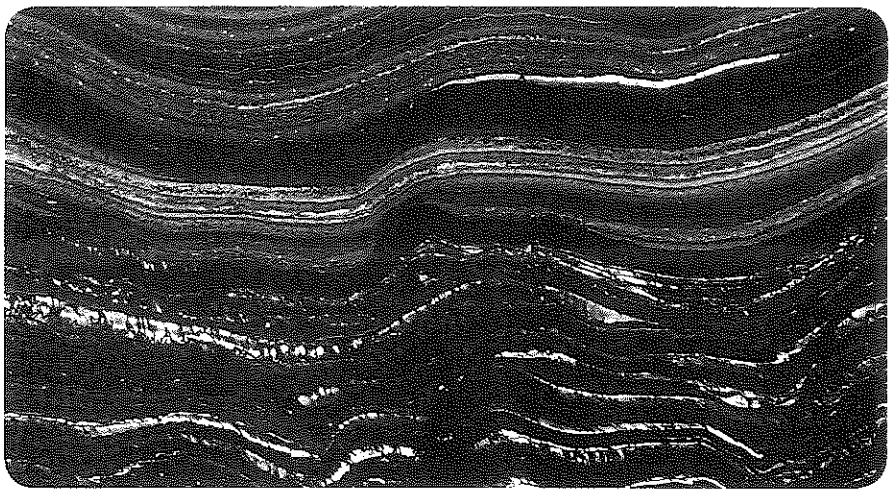


**Figure 16** These rock formations, called banded iron formations, or BIFs, are unique sedimentary deposits. These rocks formed as a result of free oxygen production by photosynthetic bacteria billions of years ago. Because this deposit is a result of an organism, BIFs are considered trace fossils.

(t)Dr. Ken MacDonald/Photo Researchers; (b)Francois Gohier/Photo Researchers

**The endosymbiont theory** Eukaryotic cells appeared in the fossil record about 1.8 billion years ago, around two billion years after life first formed. Eukaryotic cells have complex internal membranes, which enclose various organelles, including mitochondria and, in plant cells, chloroplasts. Mitochondria metabolize food through cellular respiration, and chloroplasts are the site of photosynthesis. Both mitochondria and chloroplasts are about the size of prokaryotic cells and contain similar prokaryote features. This led some scientists to speculate that prokaryotic cells were involved in the evolution of eukaryotic cells.

In 1966, biologist Lynn Margulis proposed the endosymbiont theory. According to the **endosymbiont theory,** the ancestors of eukaryotic cells lived in association with prokaryotic cells. In some cases, prokaryotes even might have lived inside eukaryotes. Prokaryotes could have entered a host cell as undigested prey, or they could have been internal parasites. Eventually, the relationship between the cells became mutually beneficial, and the prokaryotic symbionts became organelles in eukaryotic cells. This theory explains the origin of chloroplasts and mitochondria, as illustrated in **Figure 17.**

**Evidence for the endosymbiont theory** When Margulis first proposed the endosymbiont theory, many scientists were hesitant to accept it. There is evidence, however, that at least mitochondria and chloroplasts formed by endosymbiosis. For example, mitochondria and chloroplasts contain their own DNA. It is arranged in a circular pattern, just as it is in prokaryotic cells. Mitochondria and chloroplasts also have ribosomes that more closely resemble those in prokaryotic cells than those in eukaryotic cells. Finally, like prokaryotic cells, mitochondria and chloroplasts reproduce by fission, independent from the rest of the cell.

# DATA ANALYSIS LAB 1

**Based on Real Data***

## Analyze Scientific Illustrations

### How did plastids evolve?

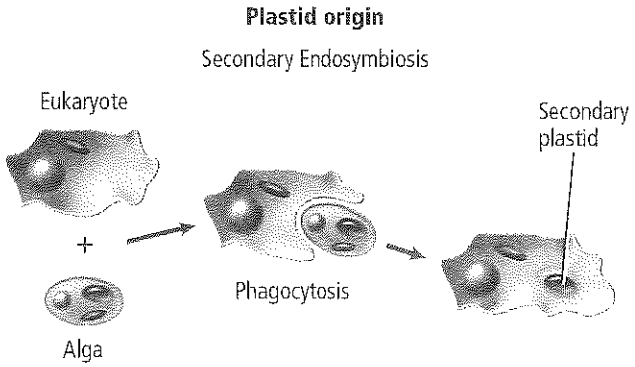
Chloroplasts belong to a group of organelles called plastids, which are found in plants and algae. Chloroplasts perform photosynthesis. Other plastids store starch and make substances needed as cellular building blocks or for plant function.

**Think Critically**

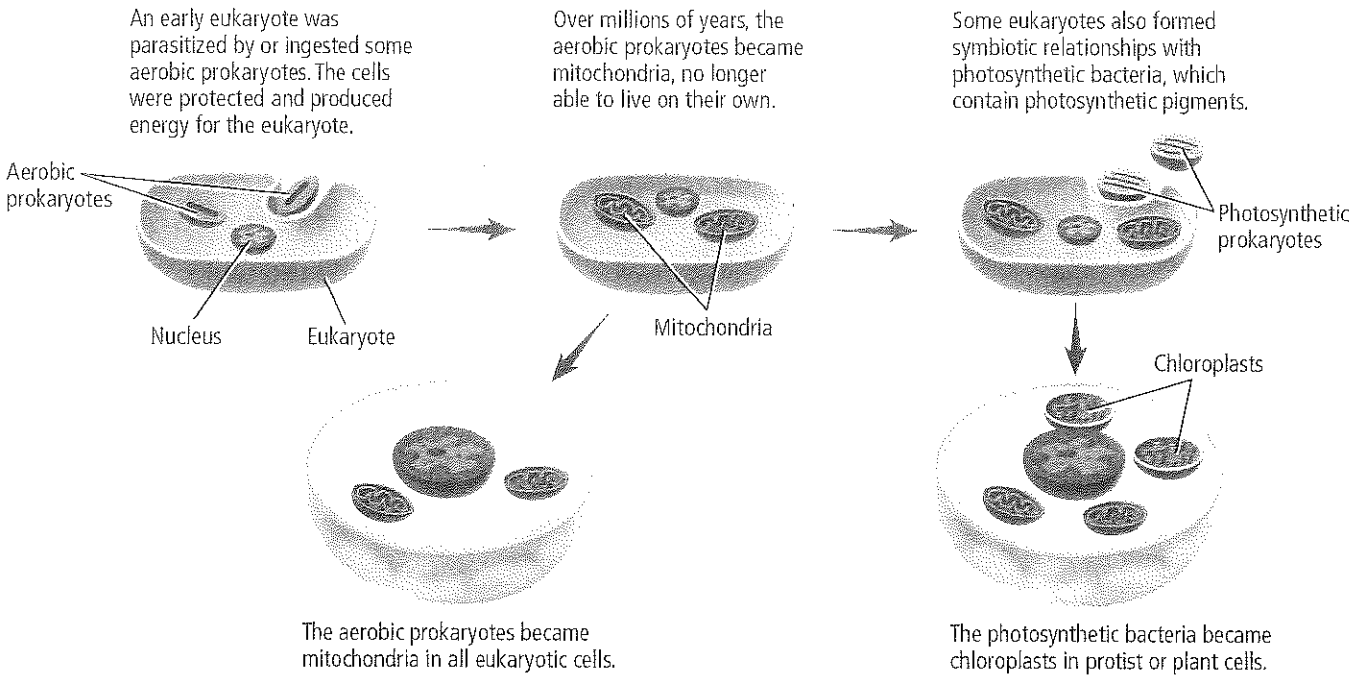
1. **Summarize** the process described in the diagram. Include the definition of phagocytosis in your description.
2. **Compare** secondary endosymbiosis to the endosymbiont theory described in **Figure 17.**

**Data and Observations**

The illustration shows a way these plastids might have evolved.




*Data obtained from: Dyall, S.D., et al. 2004. Ancient invasions: from endosymbionts to organelles. *Science* 304: 253–257.




Though the endosymbiont theory is widely endorsed, it is important to understand that scientists do not know the early steps that led to the emergence of life or to its early evolution. It is unlikely that any traces of the first life will ever be found. What scientists do know is that the conditions on Earth shortly after it took shape allowed the precursors of life to form.

The evolution of life is better understood than how the first life appeared. Fossil, geologic, and biochemical evidence supports many of the proposed steps in life's subsequent evolution. However, future discoveries might alter any or all of these steps. Scientists will continue to evaluate new evidence and test new theories in years to come.

**Figure 17** This illustration shows how Margulis hypothesized that eukaryotic cells and their organelles evolved.

Animation

# Section 2 Assessment

## Section Summary

- Spontaneous generation was disproved in favor of biogenesis.
- The origin of life is hypothesized to be a series of chemical events.
- Organic molecules, such as amino acids, might have been formed from simpler molecules on early Earth.
- The first cells probably were autotrophic and prokaryotic.
- The endosymbiont theory explains how eukaryotic cells might have evolved from prokaryotic cells.

## Understand Main Ideas

1. MAIN Idea **Infer** why scientists hypothesize that chemical events preceded the origin of life on Earth.
2. **Compare and contrast** spontaneous generation and biogenesis.
3. **Discuss** why prokaryotic cells probably appeared before eukaryotic cells.
4. **Hypothesize** whether prokaryotic cells might have been symbiotic before the evolution of eukaryotic cells.

## Think Critically

5. **Describe** the hypothesized sequence of chemical and biological events that preceded the origin of eukaryotic cells.

WRITING in Biology

6. Write a persuasive paragraph that explains why many scientists accept the endosymbiont theory.

Online Quiz

# In the Field

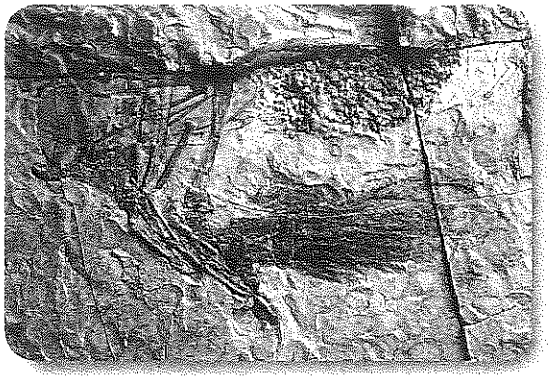
## Career: Paleontologist

### Paleontologists Debate the Evolution of Birds

Along lakeshores in northeastern China 130 million years ago, volcanic eruptions sealed the fate of millions of organisms. Ash rains buried dinosaurs, mammals, fish, insects, and amphibians. Entombed for tens of millions of years, their bodies fossilized, sometimes leaving impressions of feathers, fur, and even stomach contents! Today, in the fossil-rich area of the Laioning Province in China, paleontologists are making important discoveries about life in the early Cretaceous period.

**A feathered dinosaur** Organisms like the fossil specimen *Caudipteryx zoui* in the figure cause excitement in the paleontology community. In the fossil of *C. zoui,* there are clear traces of feathers from head to tail on the roughly one-meter long dinosaur. These feathers were not used for flight, but might have provided more stability for bipedal running.

**An early bird** A 130 million year old fossil of a new bird species, *Confuciusornis dui,* was discovered in the same general area as *C. zoui. C. dui* appears to have been a well-developed, tree-dwelling bird, not a feathered dinosaur that lived on the ground. *C. dui* and *C. zoui* lived during roughly the same time in history—between 120–150 mya. The coexistence of *C. dui* and *C. zoui* in this region provides an example of ancestral and derived species living together.



*Caudipteryx zoui* is an important fossil that shows that some dinosaurs had feathers.

**Link to the past** Paleontologists often interpret fossil evidence to make evolutionary connections between organisms. Paleontologists agree that an evolutionary link exists between birds and dinosaurs. They share many anatomical features, including hollow, thin-walled bones, flexible wrists, clawed hands, and a fused collarbone that forms a wishbone. Paleontologists think that birds came from dinosaurs, but they continue to debate about when the divergence took place. Fossil finds like those in China help to provide evidence and insight into the evolution of birds.

CAREERS IN BIOLOGY

**Interview a Paleontologist**

Work with a team to create a list of questions you would like to ask a paleontologist. Conduct an inter-view with a paleontologist at a local college or university. Use the information you gather to write an article which describes what you learned from the conversation.





WebQuest

# BIOLAB

## IS SPONTANEOUS GENERATION POSSIBLE?

**Background:** **In the mid-1800s, Louis Pasteur conducted an experiment that showed that living organisms come from other living organisms—not from nonliving material. Pasteur's classic experiment, which disproved the notion of spontaneous generation, laid an essential foundation for modern biology by supporting the concept of biogenesis. In this lab, you will carry out an experiment based on Pasteur's work.**

**Question:** *How can the idea of spontaneous generation be disproved?*

### Materials

| | |
|---|---|
| beef broth | string |
| graduated cylinder | rubber stopper (2) |
| Erlenmeyer flask (2) | Bunsen burner (2) |
| ring stand (2) | 5 cm of plastic tubing |
| wire gauze (2) | 30 cm of plastic tubing |

### Safety Precautions

### Procedure

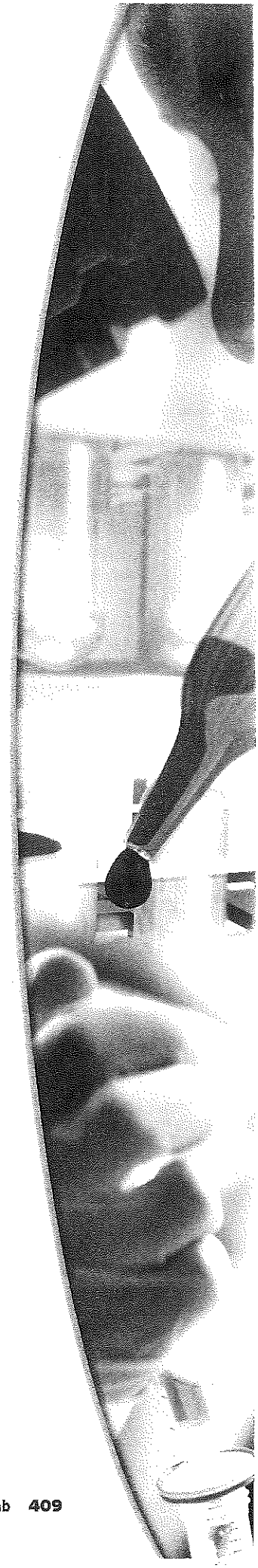
1. Read and complete the lab safety form.
2. Study the description of Louis Pasteur's classic experiment that disproved spontaneous generation.
3. Design and construct a data table to record changes in color, smell, and the presence of sediments.
4. Label the flasks "A" and "B." Flask A will be capped with a stopper holding a 5-cm piece of tubing. Flask B will be capped with a stopper holding a 30-cm piece of tubing.
5. Place 50 mL of beef broth in each flask. Cap each flask with the appropriate stopper.
6. Put each flask on a wire gauze on a ring stand over a Bunsen burner.
7. Bend the tubing on Flask B until it forms a U-shape. The bottom of the U should be near the base of the flask. Tie the end of the tubing to the ring stand to hold the U-shape.
8. Boil the broth in each flask for 30 min.
9. After the equipment and broth cool, move the apparatuses to an area of the lab where they will not be disturbed.
10. Observe the flasks over the next two weeks. Record your observations in your data table.
11. **Cleanup and Disposal** Dispose of beef broth according to your teacher's instructions. Clean and return all equipment to the appropriate location.

### Analyze and Conclude

1. **Describe** the experimental procedure you followed. How does it compare to the steps followed by Louis Pasteur?
2. **Compare** your findings to Pasteur's findings.
3. **Describe** why it is important for scientists to verify one another's data.
4. **Think Critically** Explain how Pasteur's findings disprove spontaneous generation.
5. **Error Analysis** If your results did not match Pasteur's results, explain a possible reason for the difference.

### WRITING in Biology

Pasteur's experiment resulted in wide acceptance of biogenesis by the scientific community. Write an essay explaining how Pasteur's work contributed to some of the central ideas of biology.



# Chapter 14 Study Guide

**THEME FOCUS Stability and Change** Fossils provide evidence how the diversity of organisms changed over time.

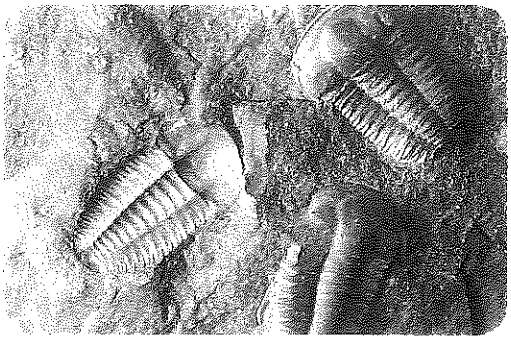
**BIG Idea** Fossils provide key evidence for understanding the origin and the history of life on Earth.

## Section 1 Fossil Evidence of Change

fossil (p. 393)
paleontologist (p. 394)
relative dating (p. 394)
law of superposition (p. 394)
radiometric dating (p. 395)
half-life (p. 395)
geologic time scale (p. 396)
epoch (p. 396)
period (p. 396)
era (p. 396)
eon (p. 396)
Cambrian explosion (p. 398)
K-T boundary (p. 399)
plate tectonics (p. 400)

**KEY Idea** Fossils provide evidence of the change in organisms over time.

- Fossils provide evidence of past life.
- Relative dating and radiometric dating are two methods used to determine the age of fossils.
- The geologic time scale is divided into eras, periods, and epochs.
- Major events in the geologic time scale include both biological and geological changes.

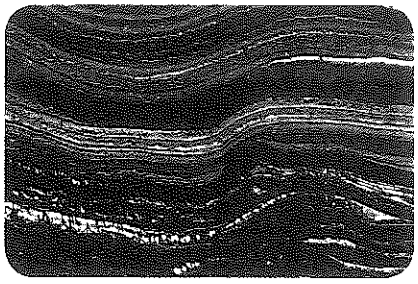


## Section 2 The Origin of Life

spontaneous generation (p. 401)
theory of biogenesis (p. 402)
endosymbiont theory (p. 406)

**KEY Idea** **Evidence indicates that a sequence of chemical events preceded the origin of life on Earth and that life has evolved continuously since that time.**

- Spontaneous generation was disproved in favor of biogenesis.
- The origin of life is hypothesized to be a series of chemical events.
- Organic molecules, such as amino acids, might have been formed from simpler molecules on early Earth.
- The first cells probably were autotrophic and prokaryotic.
- The endosymbiont theory explains how eukaryotic cells might have evolved from prokaryotic cells.







Vocabulary eGames

# Chapter 14 Assessment

## Section 1

### Vocabulary Review

*Choose the vocabulary term from the Study Guide page that best describes each of the following phrases.*

1. determining the age of a fossil by radioactive elements
2. the remains or evidence of an organism
3. scientist who studies fossils

### Understand Main Ideas

*Use the table below to answer questions 4 and 5.*

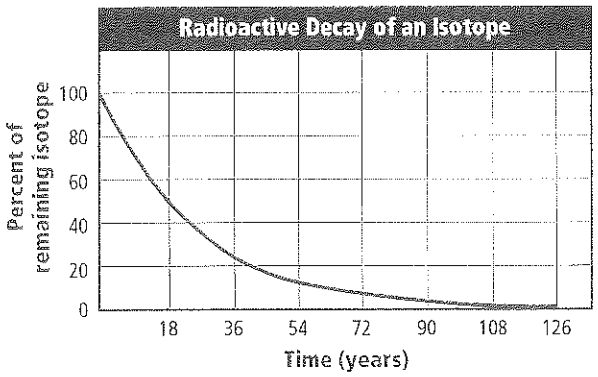
| Radioactive Isotope | Product of Decay | Half-Life (Years) |
|---|---|---|
| **Carbon-14** | Nitrogen-14 | 5730 |
| **Chlorine-36** | Argon-36 | 300,000 |
| **Beryllium-10** | Boron-10 | 1.52 million |
| **Uranium-235** | Lead-207 | 700 million |

4. According to the table above, if one-fourth of the original radioactive carbon is present in a fossil, what is the fossil's age?
   A. 2857.5 years old
   B. 5730 years old
   C. 11,460 years old
   D. 17,145 years old

5. Which isotope would be best for measuring the age of a rock layer estimated to be about one million years old?
   A. beryllium-10
   B. carbon-14
   C. chlorine-36
   D. uranium-235

6. Which fossil type provides the most anatomical information to paleontologists?
   A. trace
   B. molds
   C. replacement
   D. amber

*Use the graph below to answer questions 7 and 8.*




7. Which is the half-life of the radioactive isotope shown in the graph?
   A. 18 years
   B. 36 years
   C. 54 years
   D. 72 years

8. Assuming that you can only date material that has at least one percent of the radioisotope remaining, which age would be too old to date with this isotope?
   A. 35 years
   B. 50 years
   C. 75 years
   D. 125 years

9. What era followed the mass extinction at the end of the Permian period?
   A. Cambrian
   B. Mesozoic
   C. Paleozoic
   D. Neogene

10. Nearly all fossils occur in what kind of rocks?
    A. batholithic
    B. igneous
    C. metamorphic
    D. sedimentary

### Constructed Response

11. THEME FOCUS Stability and Change **Short Answer** How does the law of superposition help paleontologists?

12. **Open Ended** Explain the geologic time scale using an analogy other than a ribbon of time.

13. **Short Answer** Calculate the percentage of Earth's existence occupied by the Cenozoic era (65 million years). Show your work.

Online Test Practice

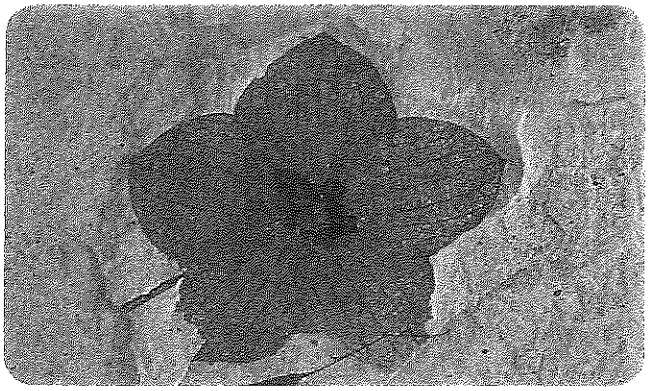
# Chapter 14 Assessment

### Think Critically

14. **Infer** Imagine that you found a piece of amber in a sedimentary rock layer. What environment likely was present at the time of the fossil's formation?

15. **Describe** a fossil type and how it helps paleontologists understand an organism's anatomy.

*Use the photo below to answer question 16.*



16. If you found the above fossil of a flowering plant in a layer of rock, what would you conclude about the age of the layer? Would you look in layers above or below the layer with the flower to learn about the Permian mass extinction?

## Section 2

### Vocabulary Review

*Replace the underlined words with the correct vocabulary term from the Study Guide page.*

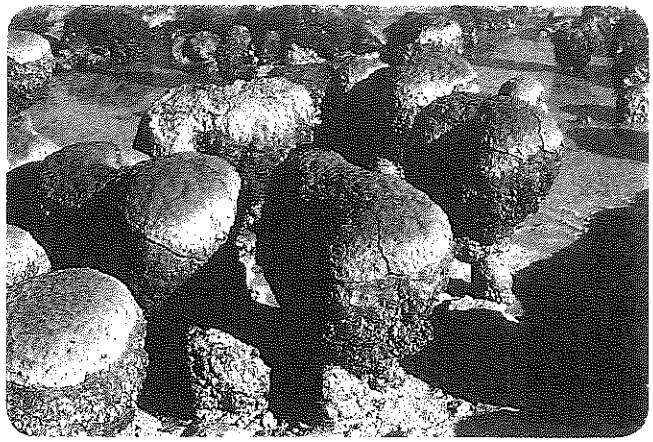
17. The belief that organisms originate from nonliving matter was disproven by Redi and Pasteur.

18. The explanation that bacteria might have lived inside prokaryotes and eventually became organelles was proposed by Lynn Margulis.

### Understand Main Ideas

19. Pasteur's experiments led to which theory?
   - A. biogenesis theory
   - B. endosymbiont theory
   - C. evolution theory
   - D. spontaneous generation theory

*Use the illustration below to answer questions 20 and 21.*



20. The organisms represented in the photo above had which effect on early Earth?
   - A. produced the first amino acids
   - B. increased oxygen in the atmosphere
   - C. became the first mitochondria
   - D. consumed the first heterotrophs

21. When did the fossils of organisms like those in the photo first appear in the fossil record?
   - A. 1.0 million years ago
   - B. 2.0 million years ago
   - C. 3.5 billion years ago
   - D. 4.5 billion years ago

22. Clay most likely was involved in which process?
   - A. producing the first oxygen in the atmosphere
   - B. forming the first plasma membranes
   - C. providing a framework for amino acid chains
   - D. capturing prokaryotes for chloroplast evolution

23. Scientists have fossil evidence for which idea for the origin of life?
   - A. first amino acids
   - B. first RNA
   - C. first cells
   - D. first autotrophs

24. Banded iron formations are important evidence for which idea in the early evolution of life?
   - A. photosynthetic autotrophs
   - B. endosymbiont organelles
   - C. heterotrophic prokaryotes
   - D. heterotrophic eukaryotes





Online Test Practice

### Constructed Response

25. **Open Ended** What would you expect the first step to be in the emergence of life from nonliving matter?

26. KEY Idea Explain the significance of the Miller-Urey experiment for understanding the origin of cells.

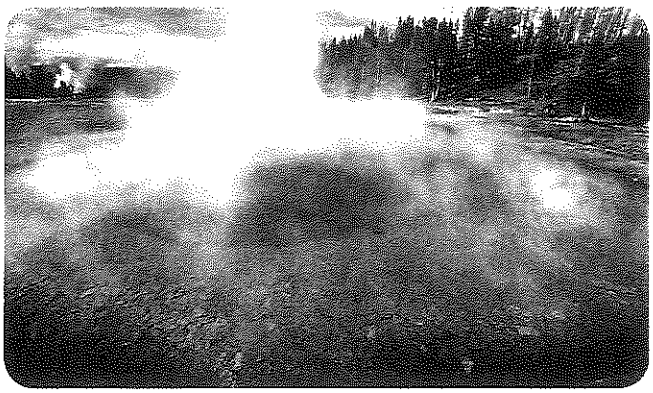
27. **Open Ended** Which evidence do you think is most important for the endosymbiont hypothesis? Why?

### Think Critically

28. **Sequence** the hypothesized events that led from a lifeless Earth to the presence of eukaryotic cells.

29. **Compare** the contributions of Redi and Pasteur in disproving spontaneous generation.

*Use the photo below to answer question 30.*



30. **Analyze** How is the hot spring shown above similar to conditions on early Earth? What kind of organisms can survive in this type of environment?

31. **Infer** How was evolution affected by the increase in oxygen caused by the first photosynthetic organisms?

32. CAREERS IN BIOLOGY How could a biochemist studying DNA sequences provide evidence for the endosymbiont theory?

33. **Analyze** and critique the endosymbiont theory. What are its strengths and weaknesses?

## Summative Assessment

34. BIG Idea There are six major fossil types discussed in **Table 1**. Create a hierarchy of the fossil types in **Table 1** based on the amount and type of information obtained from the fossil. Write a paragraph supporting your hierarchy.

35. WRITING in Biology Assume that you are a scientist searching for the cause of a mass extinction. Several causes have been hypothesized. Write a paragraph that explains how you could use dating methods to accept or reject them.

36. WRITING in Biology Explain the importance of a particular fossil being found in both South America and Africa.

37. Make a list of requirements for the existence of life. Put them in the order in which you think that they had to occur in order for life to begin successfully.

38. Explain why paleontologists find radiometric dating important.

39. Based on what you know about laws and theories, could the endosymbiont theory become a law? Explain your answer.

### DB Document-Based Questions

*"Probably all of the organic beings which have ever lived on this Earth have descended from some one primordial form."*
Charles Darwin in *The Origin of Species*, 1859.

40. If Darwin was alive today, do you think he would include proteins among "organic beings"? Why or why not?

41. Use the quote above to support why you think Darwin would or would not have supported the endosymbiont theory.

42. Discuss what Darwin might have meant by the phrase, "...descended from some one primordial form."

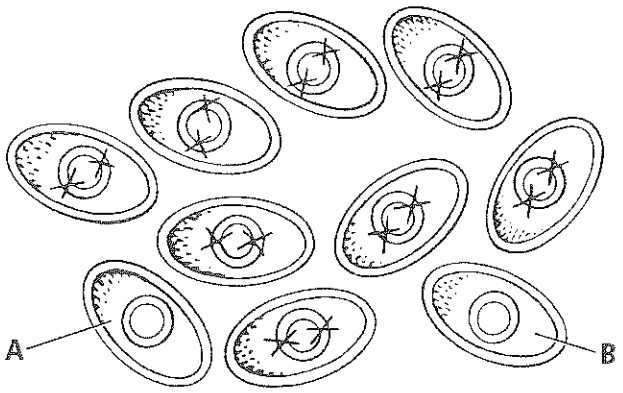
# Standardized Test Practice

**Cumulative**

## Multiple Choice

1. Which is associated with gene regulation in prokaryotic cells?
   A. DNA pairing
   B. repressor proteins
   C. RNA interference
   D. transcription factor

*Use the illustration below to answer questions 2 and 3.*

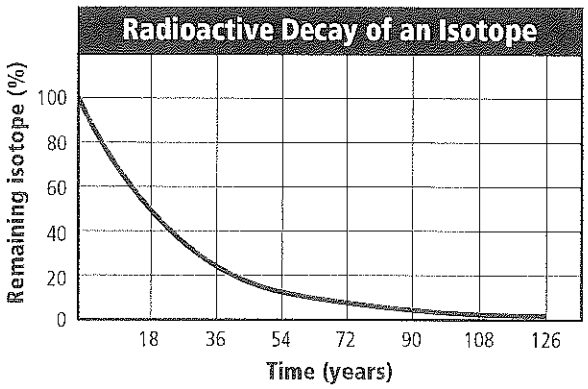



2. The bacterial cells in the figure above were transformed after they were mixed with recombinant DNA–represented by "XX" in the diagram. Which is one possible reason that Cells A and B do not have the new recombinant DNA plasmid?
   A. Cells A and B are resistant to antibiotics.
   B. Cells A and B do not have plasma membranes.
   C. Cells A and B did not take up the DNA fragment.
   D. Cells A and B initially had different plasmids.

3. In the figure, which step is likely to happen after the transformation of bacterial cells?
   A. Cells with the new plasmid will die after exposure to an antibiotic.
   B. Cells with the new plasmid will replicate quicker.
   C. Cells without the new plasmid will die after exposure to an antibiotic.
   D. Cells without the new plasmid will replicate more quickly.

4. A piece of DNA has the following sequence: CCCCGAATT. Suppose a mutation causes the following change: CCTCGAATT. Which term describes this mutation?
   A. chromosomal
   B. deletion
   C. duplication
   D. missense

*Use the graph below to answer question 5.*



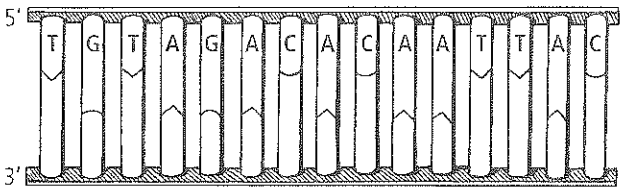

5. How much of the original isotope remains after 10 years?
   A. 50 percent
   B. 75 percent
   C. 10 percent
   D. 30 percent

6. Which causes DNA fragments to separate during gel electrophoresis?
   A. charge on the fragments
   B. DNA extraction of chemicals
   C. gel medium components
   D. source of the DNA

7. Where can Barr bodies be found?
   A. female body cells
   B. female sex cells
   C. male body cells
   D. male sex cells

## Short Answer

*Use the illustration below to answer questions 8 and 9.*




**8.** The diagram shows a molecule of DNA. What is the complementary DNA strand base code? Be sure to indicate the orientation of the strand.

**9.** Suppose the adjacent thymine bases in the figure formed a dimer after being exposed to ultraviolet radiation. How would the dimer affect the structure of the DNA molecule?

**10.** Describe the difference between petrified and replacement fossils.

**11.** Explain the three steps that take place in a polymerase chain reaction (PCR).

**12.** Describe why scientists infer that oxygen was absent from the early atmosphere on Earth.

**13.** Use a chart to show the role that different enzymes play in the replication of DNA. Be sure to put the steps in the correct order.

**14.** What are restriction enzymes? Assess why they are an important tool for genetic engineering.

**15.** How does a paleontologist use geologic principles for the relative dating of fossils?

## Extended Response

**16.** How is selective breeding related to genetic engineering?

**17.** Appraise how your body temperature is related to homeostasis.

## Essay Question

Some genes contain instructions for controlling when our cells grow, divide, and die. Certain genes that promote cell division are called oncogenes. Others that slow down cell division, or cause cells to die at the right time, are called tumor suppressor genes. It is known that cancers can be caused by DNA mutations (changes) that "turn on" oncogenes or "turn off" tumor suppressor genes.

The BRCA genes (BRCA1 and BRCA2) are tumor suppressor genes. When they are mutated, they no longer function to suppress abnormal growth and breast cancer is more likely to develop. Certain inherited DNA changes can result in a high risk for the development of breast cancer in people who carry these genes and are responsible for the cancers that run in some families.

*Using the information in the paragraph above, answer the following question in essay format.*

**18.** How could oncogenes and tumor suppressor genes play a part in the development of breast cancer? Use what you know about molecular genetics to write an essay explaining how these genes might contribute to the formation of tumors.

| NEED EXTRA HELP? | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| If You Missed Question . . . | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Review Section . . . | 12.4 | 13.2 | 13.2 | 12.4 | 14.1 | 13.2 | 11.2 | 12.2 | 12.4 | 14.1 | 13.2 | 14.2 | 12.3 | 13.2 | 14.1 | 13.2, 12.2 | 1.1 | 12.3, 12.4 |