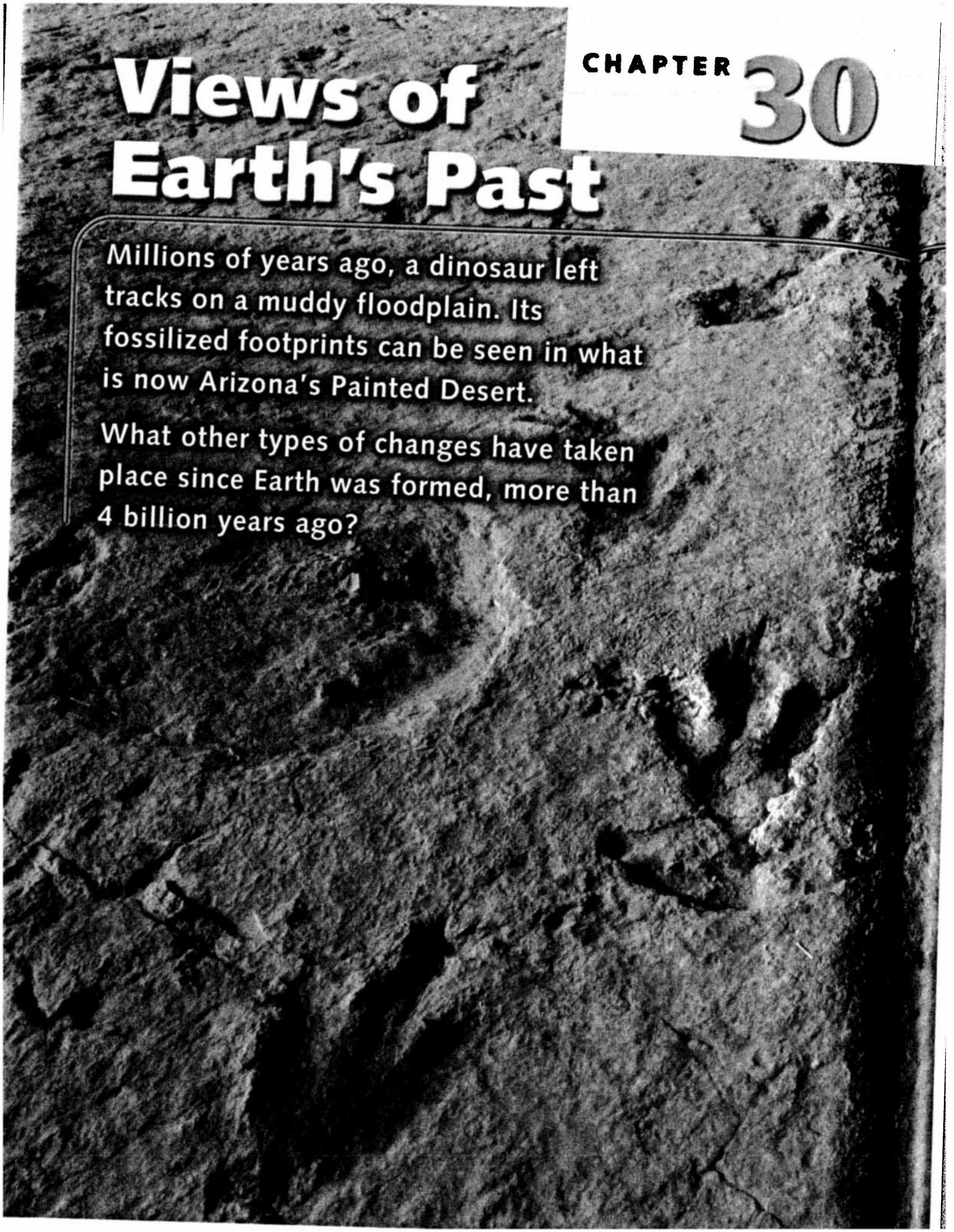


CHAPTER 30

Views of Earth's Past

Millions of years ago, a dinosaur left tracks on a muddy floodplain. Its fossilized footprints can be seen in what is now Arizona's Painted Desert.

What other types of changes have taken place since Earth was formed, more than 4 billion years ago?

CHAPTER 30

PREVIEW

FOCUS QUESTIONS

In this chapter you will study Earth's past and learn more about the key questions below.

Section 1 How do scientists organize the major events of Earth's past?

Section 2 How do Precambrian time and the Paleozoic Era differ?

Section 3 What are the major events of the Mesozoic Era?

Section 4 What significant events characterize the Cenozoic Era?

REVIEW TOPICS

As you investigate Earth's past, you will need to use information from earlier chapters.

- fossils **(pp. 130, 648–649)**
- fossil fuel formation **(pp. 148–150)**
- plate tectonics and continental growth **(pp. 182–183, 185)**
- ice ages **(pp. 330–331)**
- the composition of Earth's atmosphere **(pp. 366–367)**
- global warming **(pp. 381–382)**
- climate change **(pp. 474–475)**

READING STRATEGY

QUESTION

Before you begin Chapter 30, read the chapter opener, scan the chapter contents, and read the key ideas for each section. In your science notebook, write questions about the material for which you want to find answers in the chapter.

INTERNET RESOURCES

CLASSZONE.COM

At our Web site, you will find the following Internet support for this chapter.

DATA CENTER

EARTH NEWS

VISUALIZATIONS

- Breakup of Pangaea
- K-T Boundary Asteroid Impact

LOCAL RESOURCES

CAREERS

INVESTIGATIONS

- How Has Life Changed over Geologic Time?
- Where and When Did Dinosaurs Live?

30.1

KEY IDEAS

The geologic time scale, based on the rock record, summarizes major events in Earth's history.

The geologic time scale is divided into eons, eras, periods, and epochs.

KEY VOCABULARY

- geologic time scale
- eon
- era
- period
- epoch
- evolution
- natural selection

The Geologic Time Scale

Historians sometimes name time periods after unique characteristics or remarkable events—the Ming Dynasty, for example. Similarly, geologists divide Earth's past into time periods based on distinguishing traits. Scientists have reconstructed Earth's extensive past by using geological evidence, sophisticated dating techniques, and deductive reasoning. Like the periodic table of elements, the time scale is a useful organizational tool.

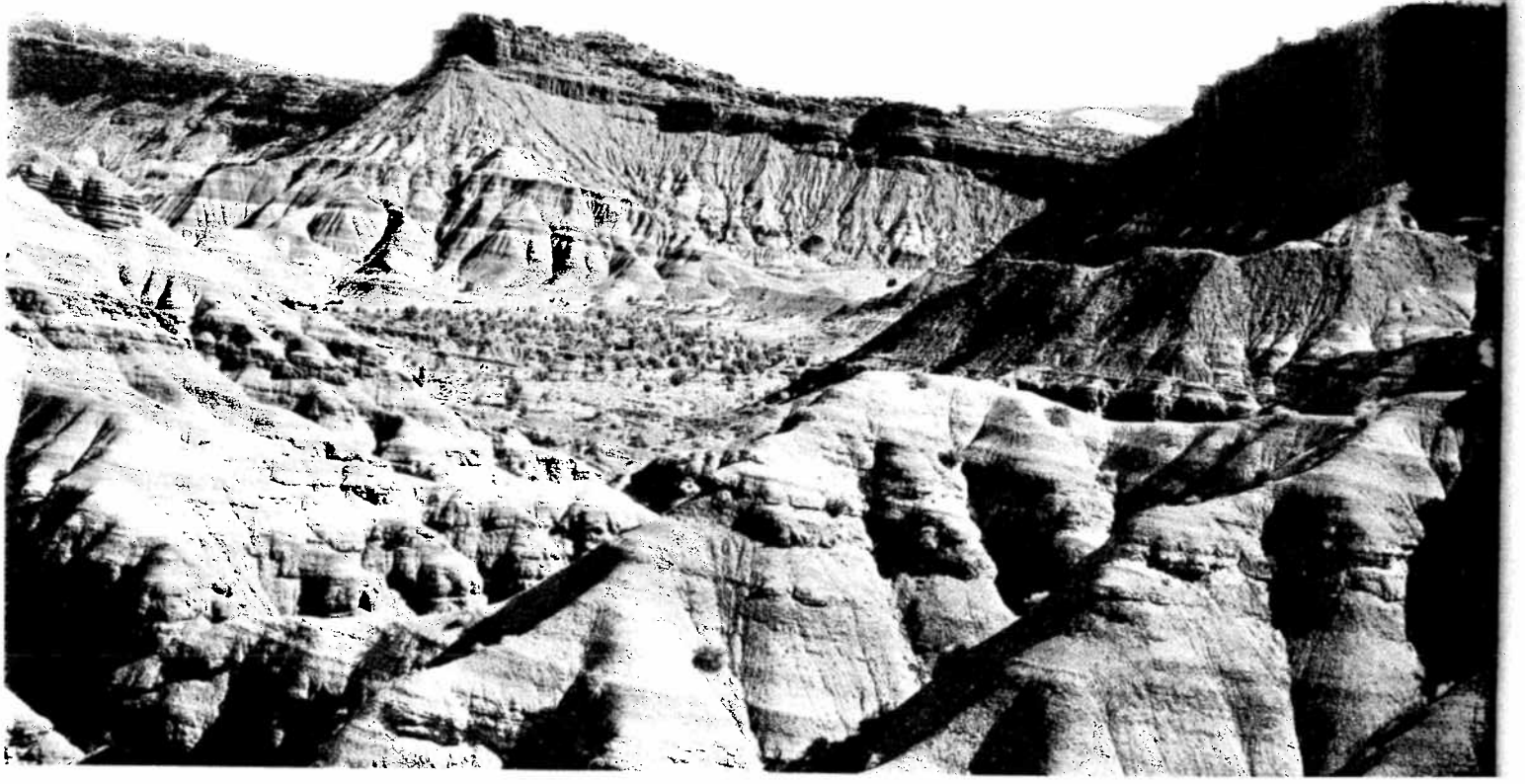
Division of Geologic Time

A geologist studying the rocks in an area can use rules, such as the principle of superposition, to determine the relative ages of the rocks. By correlating rocks over large areas, geologists have determined the relative ages of most of the rocks on Earth's surface. Over many years, geologists have used rock formations to develop a time scale that divides geologic time into units.

The **geologic time scale** (pages 668–669) is a summary of major events in Earth's past that are preserved in the rock record. Although several slightly different versions of the time scale exist, all are based on evidence. Fossils are an important part of the history. In fact, many rock layers have been identified and matched based on the fossils they contain.

Geologic time is divided into eons, eras, periods, and epochs. As the first division, the **eon** represents the longest segment of geologic time. The Archean Eon (ahr-KEE-uhn) is the oldest, beginning with the formation of Earth's crust almost 4 billion years ago. The earliest known rocks formed during this eon. The Proterozoic Eon (PROHT-uhr-uh-ZOH-ihk) began about 2.5 billion years ago. Rocks from this time contain the earliest fossils, simple organisms that lived in the oceans. No fossil evidence of life on land has been found from this eon.

The most recent eon, the Phanerozoic (FAN-uhr-uh-ZOH-ihk), is characterized by signs of visible life. It is subdivided into three **eras.**



THE ROCK RECORD Rock layers such as these at Vermillion Cliffs, Utah, provide information about Earth's lengthy past.

- The Paleozoic (PAY-lee-uh-ZOH-ihk) Era began about 543 million years ago. Rocks formed during the Paleozoic contain fossils of both land and ocean plants and animals.
- The Mesozoic (MEHZ-uh-ZOH-ihk) Era began about 248 million years ago. Dinosaurs thrived during most of this era.
- The Cenozoic (SEE-nuh-ZOH-ihk) Era, the most recent era, began about 65 million years ago and continues today. Events of the era include the last Ice Age and the appearance of humans in the fossil record.

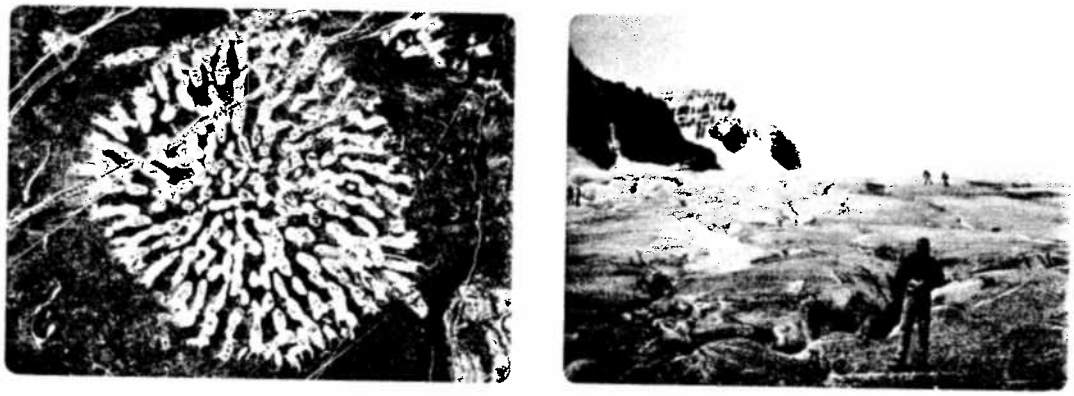
Eras are divided into **periods.** Like eras, periods differ from one another in characteristic plant and animal life; these differences, however, are less dramatic than differences between eras. Some geologic periods are further divided into **epochs** (EHP-uhks). These divisions are briefer, and the distinguishing changes in life are not as great as those between periods.

VOCABULARY STRATEGY

The suffix *-zoic* comes from the Greek word *zōikos,* meaning "pertaining to living beings." *Protero-* comes from the word *proteros,* meaning "earlier," and *paleo-* comes from the word *palaios,* meaning "ancient." *Meso-* and *ceno-* come from the words *mesos* and *kainos,* respectively. *Mesos* means "middle," and *kainos* means "new."

Changes Through Geologic Time

Since its formation, Earth has undergone many physical and biological changes. These changes have made today's Earth very different from early Earth. The changes were not all dramatic; very small alterations can become significant over millions or billions of years. For example, small, gradual changes in Earth's movements have resulted in a modern year that is days shorter than an early Paleozoic year. Geological events have resulted in the formation or disappearance of landmasses, mountains, and seas. Where corals once grew in warm oceans, you might now find cool mountains. Climatic changes have included the rise and fall of global temperatures.



CHANGE OVER GEOLOGIC TIME
The fossilized reef organism (left) was found in the Canadian Rocky Mountains in Golden, Canada (right). Geological events over time changed what was once an ocean environment where coral thrived to a mountain environment.

The atmosphere has also changed significantly over time. Scientists theorize that Earth's first atmosphere was composed mostly of gases released from volcanic eruptions, including carbon dioxide, sulfur dioxide, water vapor, and nitrogen. Although the molecules of some of these gases contained oxygen atoms, the form of oxygen on which human life depends (O_2) was not originally part of the atmosphere. Oxygen (O_2) entered the air with the appearance of photosynthetic organisms, such as algae. The level of oxygen in the atmosphere increased gradually. As the atmosphere changed, so did the numbers and types of organisms. The fossil record shows the appearance, evolution, and disappearance of a great variety of organisms over time.

Geologic Time Scale

Eon	Era	Period		MYA* (*Millions of years ago)	Epoch
Phanerozoic	Cenozoic "Age of Mammals"	Quaternary		0.01 (10,000 yrs)	Holocene or Recent
				2	Pleistocene
		Tertiary — Neogene		5	Pliocene
				24	Miocene
		Tertiary — Paleogene		34	Oligocene
				55	Eocene
				65	Paleocene
	Mesozoic "Age of Reptiles"	Cretaceous		144	
		Jurassic		206	
		Triassic		248	
	Paleozoic "Age of Invertebrates"	Permian		290	
		Carboniferous	Pennsylvanian	323	
			Mississippian	354	
		Devonian		417	
		Silurian		443	
		Ordovician		490	
		Cambrian		543	
Archean Proterozoic				2,500	
				3,800?	

MYA	Life	North American Rock Record
0.01 (10,000 yrs)	Humans dominant. Domestic animal species develop.	West Coast uplift continues in U.S.; Great Lakes form.
2	Hominids develop. Elephants flourish in North America, then die out.	Ice Age. Raising of mountains and plateaus in western U.S.
5	Hominids appear. Modern horse, camel, elephant develop. Sequoias decline; tropical trees driven south.	North America joined to South America. Sierras and Appalachians re-elevated by isostatic rebound.
24	Horse migrates to Asia, elephant to America. Grasses, grazing animals thrive.	North America joined to Asia. Volcanism in northwestern U.S., Columbia Plateau.
34	Mammals progress. Cats and dogs develop and diverge. Elephants in Africa.	Volcanism in western U.S. as Alps and Himalayas forming.
55	Pygmy ancestors of modern horse, other mammals. First whales. Diatoms, flowering plants thrive.	Coal forming in western U.S.
65	Many new mammals appear.	Uplift in western U.S. continues.
144	Dinosaurs, ammonites die out. Mammals, birds show new adaptations. Flowering plants, hardwoods rise.	Uplift of Rockies begins. Colorado Plateau raised. Coal swamps in westem U.S. Intrusion of Sierra Nevada batholith.
206	Giant dinosaurs. First birds. Conifers and cycads abundant. Earliest mammals.	West-central North America under huge sea. Gulf of Mexico, Atlantic Ocean begin to form.
248	Reptiles thrive. Forests of conifers and cycads.	Volcanism and faulting along East Coast. Palisades of the Hudson River formed.
290	Mass extinction of existing species. Trilobites, seed ferns, scale trees die out. Corals abundant.	Final uplift in Appalachians. Salt-forming deserts in western U.S. while an ice age in South America.
323	First reptiles. Many giant insects. Spore-bearing plants, amphibians flourish.	Great coal-forming swamps in North America (and Europe).
354	Sharks, amphibians, and crinoids flourish. Seed ferns, conifers abundant.	Extensive submergence of continents.
417	First amphibians; fishes abound. First forests.	Mountain building continues in New England and Canada. White Mountains raised.
443	First land plants and animals (spiders, scorpions). Fishes develop; marine invertebrates thrive.	Salt and gypsum deserts forming in eastern U.S.
490	Marine invertebrates thrive: mollusks, trilobites, graptolites.	Beginning of Appalachian mountain building. Taconic and Green Mountains form. Half of North America submerged.
543	First vertebrates (fish). Many marine invertebrates (first trilobites, shelled animals). Many seaweeds.	Extensive deposition of sediments in inland seas.
2,500	No life on land. Simple marine organisms (algae, fungi, worms). Stromatolites dominant. Other life probably existed, but fossil evidence is lacking.	Great volcanic activity, lava flows, metamorphism of rocks. Formation of iron, copper, and nickel ores.
3,800?		Formation of Earth's crust.

INVESTIGATIONS
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How Has Life Changed over Geologic Time? Analyze patterns in the fossil and rock records to construct an evolutionary timeline.
Keycode: ES3002

Evolution

The fossil record indicates that the first organisms were simple in structure. Over the millions of years since their appearance, organisms have developed an astonishing variety in size and structure. The rocks of one place, the Grand Canyon in Arizona, reveal a great deal about the history of such changes. The youngest rocks, near the canyon's top, contain imprints of land reptiles, ferns, and insects. A quarter of the way down the canyon, a sedimentary rock layer contains marine fossils, including fish. Deeper layers contain only a few shells and traces of worms. The oldest rock layers, at the bottom of the canyon, have no fossils at all.

The rock record repeatedly shows the disappearance of organisms and the appearance of different organisms. The evidence indicates a changing, or evolving, pattern of life forms. This process of change that produces new life forms over time is called **evolution.** The theory of evolution provides a scientific explanation for the past and present diversity of life. At one time, most people thought that life forms were fixed and unchanging. However, no theory could account for the fossils of dinosaurs that no longer existed on Earth. Then, in the 1800s, scientists proposed explanations for the changes evident in the fossil record. Charles Darwin, a British naturalist, suggested in 1859 that **natural selection** accounts for the changes that produce new species. The theory of natural selection states that the organisms that survive to produce offspring are those that have inherited

CAREER

Natural History Museum Curator

Where was the first place you saw a dinosaur's skeleton? For many people, the answer is in a natural history museum. The museum's curators most likely spent much time and effort to present that specimen of Earth's history to the public. Museum curators use their imagination and research skills to create exhibits that are both exciting and educational. At the beginning of the process, curators brainstorm ideas for interesting exhibits. Once a topic is chosen, they do extensive research to ensure that each detail is accurate. Curators then put their ideas into action by coordinating the loan or the purchase of exhibit items and by supervising their assembly. Once the exhibit is open to the public, they often provide lectures on the exhibit's topic.

Natural history museum curators usually have at least a bachelor's degree in a specific area of interest, such as anthropology. Aspiring curators also gain a competitive edge by volunteering at local museums and participating in student internships. For positions above entry level, curators often find advanced degrees necessary. One rewarding aspect of the career is the opportunity to learn continuously about fascinating topics and share that knowledge with the public. ■

MUSEUM CURATORS not only educate the public but also preserve valuable scientific material for researchers.

CAREERS
CLASSZONE.COM

Learn more about a career as a museum curator.
Keycode: ES3003

the most favorable traits for surviving in a particular environment. Darwin's theory is still the best explanation for most of the existing evidence for evolution.

From his years of observations, Darwin concluded that a species is adapted to its environment because it has evolved gradually for generations. If so, the fossil record should show a series of organisms that undergo small changes over geologic time, eventually resulting in modern life forms. But few organisms have a complete, unbroken fossil record.

Instead, evolution may occur in short, "rapid" bursts. Much of the fossil record shows that some organisms existed essentially unchanged for very long periods. Then, suddenly—in a million years or less—new populations of different but related organisms appear in the fossil record. (Remember, a million years is a relatively short period of geologic time.) There is considerable debate among scientists about whether evolution follows a steady, gradual path of minor changes or is interrupted by short periods of dramatic change.

Scientific Thinking

INFER

Scientists theorize that species which do not adapt readily to a changing environment are more likely to become extinct than those that do adapt. One such environmental change is the introduction of a new species which then competes with the original inhabitants for the same resources—food, nesting areas. What other situations, of either natural or human causes, could lead to such competition?

ADAPTATION Note the different shell structures of these Galapagos tortoises show adaptations to their respective environments. Above the neck, the shell of the brushlands tortoise (right) is higher, which allows the tortoise to reach food higher above the ground.

30.1 Section Review

1. Name the three most recent eras. What is the current epoch?
2. How was oxygen (O_2) introduced into Earth's atmosphere?
3. **CRITICAL THINKING** *Gradualism* and *punctuated equilibrium* are two theories of evolution. Based on what you have learned about evolutionary processes in this section, how would you define *gradualism* and *punctuated equilibrium*? Explain.
4. **GENETICS** Suppose that two populations of rabbits live in an area with a mild climate. One group has brown fur, and the other has white fur. Based on their ability to hide from predators, which group is favored by natural selection? Would that be true if the climate became colder and winters lasted longer? Explain.

SCIENCE & Society

Biodiversity

What's being done to conserve the vast array of plant and animal species on Earth? Are some locations on Earth more important to that quest than others? As large tracts of Earth's wilderness are being developed by a burgeoning human population, scientists and world leaders are facing the threats to the planet's biological diversity.

How can we best preserve Earth's biological wealth?

Biodiversity is the variety of life on Earth in all its forms, levels, and combinations. Millions of years in the making, Earth's rich biodiversity cannot be taken for granted. Nearly 11,000 years ago, North America held a spectacular array of big animal species, including three species of elephant, saber-toothed cats, giant beavers and wolves, hippo-sized ground sloths, and condors with five-meter-long wingspans. All of these species are now extinct.

Earth has undergone five episodes of mass extinction, probably due to major and rapid changes in the environment that destroyed the habitats for many species. Among the explanations hypothesized for those extinctions are glaciation, oxygen depletion in the oceans, large-scale volcanism, asteroid or comet impacts, and even supernova explosions.

The acronym HIPPO explains the reasons species become extinct today: habitat destruction, introduction of exotic species, population growth, pollution, and overconsumption. Today's extinction rate is alarming enough that some scientists say the planet is experiencing its sixth episode of mass extinction.

ENDANGERED sea turtles are just one species of Earth's biological diversity that faces extinction without preservation of their habitat.

Now, however, people are developing effective new strategies for preserving endangered species. These focus on preserving ecosystems filled with interdependent species. The challenge is how to preserve enough habitats while the human population is growing so quickly. Many international, national, and state environmental laws now mandate the identification and preservation of critical habitats. The U.S. Endangered Species Act has been increasingly focused on habitat conservation. ■

CONSERVATIONISTS in Miami Beach, Florida, relocate sea turtle eggs from a nest on a public beach to a safer site.

Extension

SCIENCE NOTEBOOK

Consider the acronym HIPPO, which explains the factors contributing to species extinction today. Which factor do you think is most important to deal with? Explain why.

DATA CENTER
CLASSZONE.COM

Learn more about endangered species and the efforts to save them.

Keycode: ES3004

The Precambrian and Paleozoic

30.2

The majority of Earth's history is encompassed by Precambrian time and the Paleozoic Era. While organisms in these early environments may seem different compared with today's life forms, the organisms that appeared during these times gave rise to all modern life, including humans.

KEY IDEAS

Precambrian time is characterized by active plate movement, simple life forms, and glaciation. The Paleozoic Era is noted for a rapid increase in the numbers and types of life forms, extensive swamps and forests, and, at times, climates similar to today's.

KEY VOCABULARY

- Precambrian
- shield
- stromatolite
- trilobite
- graptolite
- eurypterid
- crinoid
- foraminifera

Precambrian Time

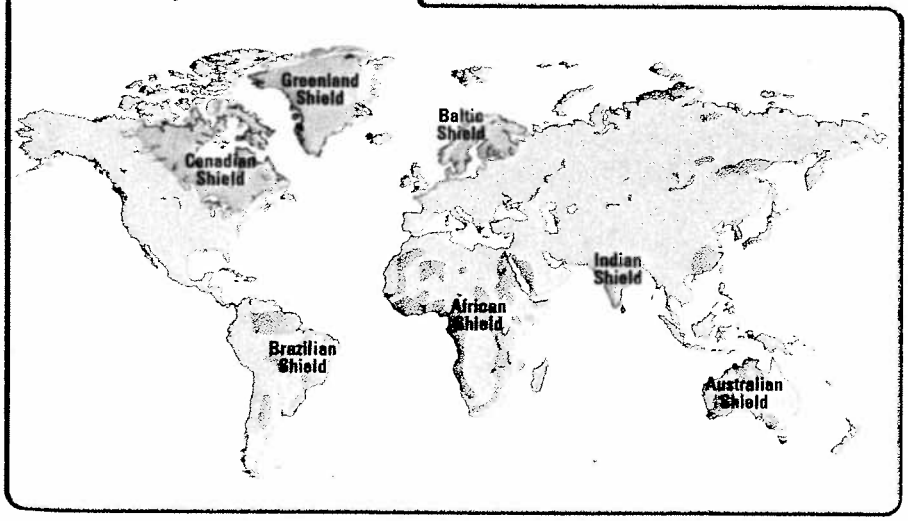
Precambrian time includes all geologic time before the start of the Cambrian period in the Paleozoic Era. It is not a unit of geologic time but a common way to refer to the Proterozoic and Archean Eons. These eons cover the majority of Earth's past, nearly 4 billion years. The Archean Eon began with the formation of Earth's first rocks, about 3.9 billion years ago, and ended about 2.5 billion years ago with the beginning of the Proterozoic Eon. The Proterozoic lasted almost 2 billion years.

The Precambrian rock record is difficult to interpret. Not only does the record cover an enormous time period, but also Precambrian rocks are often severely bent and folded. The rocks generally lack index fossils, making correlation difficult.

Despite these problems, geologists have determined that processes such as plate movement, erosion, and deposition occurred during the Precambrian. As you may recall from Chapter 8, the craton is the oldest continental rock. Most rocks that have survived since Precambrian time are in the craton, the remains of Precambrian mountains and highlands. An exposed area of the craton is called a **shield.** The North American craton experienced at least four orogenies, or mountain-building episodes, due to plate movements. The last Precambrian orogeny, known as the Grenville Orogeny, occurred about 1 billion years ago when a landmass, possibly South America, collided with eastern North America. Today's Adirondack Mountains of New York were formed by this collision.

Precambrian rocks can be economically important. Iron, copper, gold, silver, uranium, and other minerals are mined from Precambrian rocks. However, Precambrian rocks have relatively few fossils. Many Precambrian

Global map of shield areas



PRECAMBRIAN SHIELDS About one-fifth of the surface rocks of the continents date back to Precambrian time.

rocks are metamorphic or igneous. Igneous rocks do not contain fossils, and metamorphic processes often destroy any plant or animal remains. Also, many Precambrian organisms were tiny or microscopic and lacked the hard shells or skeletons that are more readily fossilized and less easily overlooked. Despite these factors, the first evidence of life is found in Archean rocks.

The African and Australian rocks containing these fossils are about 3.5 billion years old. Some of the early organisms resembled today's bacteria including the bacteria called cyanobacteria. Mats of cyanobacteria and trapped sediments formed layered domes or columns, called **stromatolites.** Stromatolites make up the greatest number of

STROMATOLITES such as these (photograph, right) at Hamelin Pool, Australia, are mostly found in intertidal zones or in shallow waters near shore. Precambrian stromatolites probably formed in similar environments. A section through a stromatolite (illustration, above) reveals the layers formed by the cyanobacteria and trapped sediments.

Precambrian fossils, but other Precambrian fossils exist. Some Proterozoic fossils from the Ediacara Hills in Australia resemble modern jellyfish, worms, and sponges.

Although stromatolites are thought to have lived in tropical waters, formations similar to varves and glacial till indicate that ice ages occurred several times during the Precambrian. The first may have taken place early in the Proterozoic. A later glaciation was nearly worldwide, affecting Europe, North America, Africa, China, and Australia.

Scientific Thinking

HYPOTHESIZE

Could today's animals have survived prior to the appearance of Precambrian cyanobacteria? Write a hypothesis statement to explain how the first photosynthetic organisms contributed to atmospheric change.

Paleozoic Era

The Paleozoic Era includes six periods—Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. This era marks the beginning of an abundant fossil record, in part because of the rapid increase in life forms sometimes called the Cambrian explosion. In addition, many Paleozoic organisms had hard body parts that were readily preserved as fossils.

Several separate continents existed at the beginning of the Paleozoic. The continent that later became North America was on the equator, with what is now the Arctic facing eastward. This continent's climate was warm, with few seasonal changes. In what is now Greenland, tropical plants and animals could be found. However, the continents were moving. By the

Ordovician Period, the landmass including today's continents of Africa, Antarctica, South America, Australia, and parts of Asia and Europe had moved to the area over the South Pole.

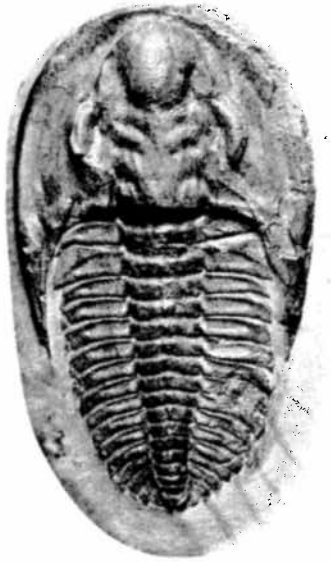
VISUALIZATIONS
CLASSZONE.COM
Observe the breakup of Pangaea.
Keycode: ES3005

Cambrian Period

The most commonly preserved Cambrian animal is the **trilobite,** a crablike invertebrate. Another common Cambrian fossil, the brachiopod, resembles a clam. Evidence for Earth's first vertebrates also appears in rocks formed late in the Cambrian. These are pieces of the bony "skin" of ostracoderms (AHS-truh-kah-DURMZ), a type of primitive fish.

Evidence from the Burgess Shale, a Cambrian rock formation in Canada, indicates that soft-bodied animals still existed during this period. Here, worms and other invertebrates were preserved in remarkable detail. More than 120 types of animals have been found. One of them is so strange and different from current life forms that it was named *Hallucigenia.*

Little mountain-building occurred during the Cambrian. Warm oceans covered much of what is now North America, and marine life flourished. In fact, all Cambrian fossils are of life forms that lived in the oceans. No evidence of Cambrian land plants or animals has been found.



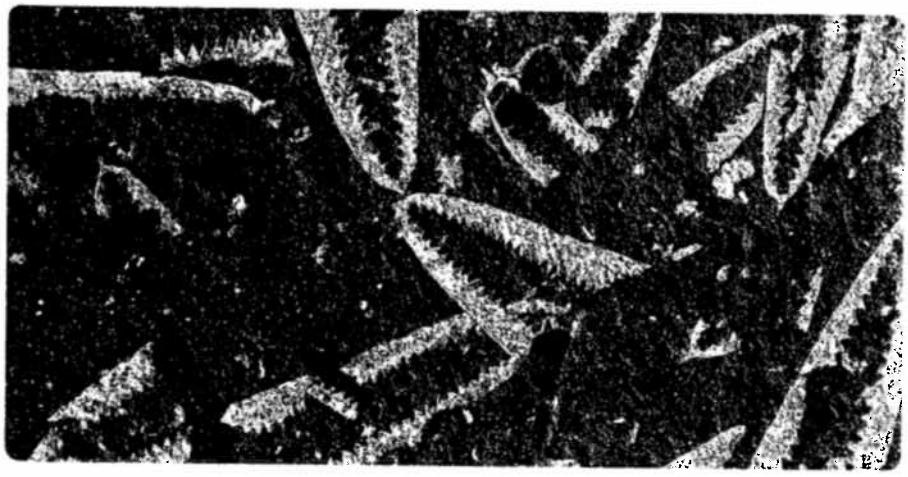
TRILOBITES such as this were once common throughout Earth's oceans. This fossil dates from the Cambrian Period, over 500 million years ago.

Ordovician Period

Many Ordovician fossils are the same as or similar to common Cambrian invertebrates, but the **graptolite** is a useful index fossil of the Ordovician. Graptolites were tiny animals that lived in colonies, or groups, throughout the world's oceans. Although a few date from other periods, their greatest numbers and distribution occurred during the Ordovician.

As in the Cambrian, all Ordovician animals lived in the ocean. Brachiopods became more numerous than trilobites. Colonial animals called bryozoans appeared. Cephalopods (relatives of the nautilus), gastropods (snails), and echinoderms (relatives of sea stars) were common. Corals and pelecypods (puh-LEHS-uh-PAHDZ), the group to which clams belong, first appeared.

During the Ordovician, a volcanic island arc similar to modern-day Japan collided with North America, causing the Taconic Orogeny. Vermont's Green Mountains and New York's Taconic Mountains are the remnants of that collision.



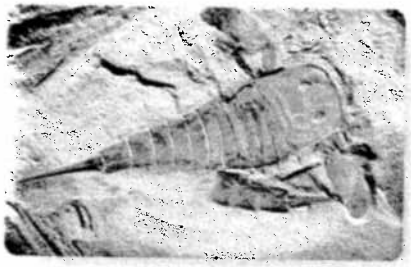
FOSSIL GRAPTOLITES These organisms lived in oceans during the Ordovician Period.

Silurian Period

An interesting animal common in Silurian oceans was the **eurypterid,** sometimes called a *sea scorpion.* Some eurypterids, which may be distantly related to trilobites, were more than two meters long. Yet these animals are not unique to the period; in general, most Silurian life forms resembled those of the Ordovician. Bryozoans, brachiopods, echinoderms, and corals were all common. The most significant event was the appearance of terrestrial animals. The first land animals included distant relatives of spiders, millipedes, and scorpions.

The Silurian record of land plants is also unmistakable. While photosynthetic algae lived along ocean shores during the Cambrian and Ordovician periods, plants such as club mosses spread over the land during the Silurian. Some of these plants still exist today.

During the late Silurian, the climate of what is now the northern United States became very dry. Shallow seas in eastern North America evaporated continuously, leaving thick beds of rock salt and gypsum in a belt that extends from central New York State to Lake Michigan. The salt deposits near Detroit, Michigan, and Syracuse, New York, are part of this belt.



EURYPTERIDS may have first appeared during the Ordovician. These marine organisms were especially abundant during the Silurian.

Devonian Period

The Devonian Period, often called the Age of Fishes, is known for the appearance of many types of fish. Jawless fish, similar to today's lamprey, and jawed fish covered with heavy plates were common. Some armored fish were giants of the Devonian seas, reaching lengths of up to nine meters. The first fossils of lungfish are also found in Devonian rocks. Before this period ended, a group of fish similar to lungfish developed very strong fins. With these fins, they could crawl out of the water and live briefly on land. These lobe-finned fish may be the ancestors of the first amphibians.

The first forests date to the Devonian Period, during which land plants multiplied in number and variety. Archaeologists have uncovered fossils of types of ferns, giant rushes, and primitive conifers. Trees with scaly bark appeared in the Devonian Period.

Landmass movements during the Devonian include the collision of North America with a continental fragment. These landmasses had been moving toward each other during earlier periods. The collision, known as the Acadian Orogeny, raised mountains from Newfoundland to the Appalachian region.

Carboniferous Period

The Carboniferous Period is sometimes divided into the Mississippian and Pennsylvanian Periods. Crinoids, or sea lilies, and foraminifera are two common fossils of the Mississippian Period. **Crinoids** (CRY-noydz), which look like plants, are actually invertebrate animals related to sea stars. **Foraminifera** (fuh-RAM-uh-NIHF-ur-uh) are one-celled organisms with tiny calcite shells.

LUNGFISH Modern Australian lungfish share characteristics with fossils of Devonian lungfish.

OKEFENOKEE SWAMP, GEORGIA When sea levels rose during the Pennsylvanian, freshwater swamps similar to this became inland seas. Coal formation stopped and sediments accumulated, eventually becoming sandstone, shale, or limestone.

The later Pennsylvanian Period is marked by the appearance of reptiles, the first true land vertebrates. Insects increased in number and variety; the Pennsylvanian is sometimes called the Age of Cockroaches. This period is also known for its huge freshwater swamps, formed when interior basins of what is now the eastern United States became flooded. Millions of years later, these swamps became the coal deposits of Pennsylvania, West Virginia, Ohio, Kentucky, Indiana, and Illinois. Parts of the Appalachians are a result of the Allegheny Orogeny of the Carboniferous.

Permian Period

The Permian Period is noted for its dry climate. In addition, a great ice age took place, covering parts of South America, Australia, South Africa, and India with ice. Widespread mountain building caused by continental collisions occurred toward the end of the period. By the time the Permian ended, most continental crust had merged to form the supercontinent Pangaea.

Corals, algae, and sponges thrived in Permian seas. Yet by the close of the Paleozoic Era, nearly half of all known animal groups had become extinct, and the number and diversity of other groups plummeted. The worst losses were among marine invertebrates; trilobites and eurypterids, abundant in earlier periods, became extinct. Among land plants, almost all seed ferns, scale trees, and early conifers of the Carboniferous swamps were extinct by the end of the period. Marine cephalopods and reptiles were among the survivors, however, and would become important in the Mesozoic Era.

30.2 Section Review

- In what rock formation would you first look for Precambrian rocks?
- Create a time line that shows one major event for each Paleozoic period.
- CRITICAL THINKING If igneous and metamorphic rocks did not exist, where would you expect to find Archean fossils? Explain.
- BIOLOGY CONNECTION Many of today's oxygen-dependent organisms could not have survived in the Archean atmosphere. Yet organisms similar to the earliest life forms still exist today. Describe an environment in which you might find such organisms.

30.3

KEY IDEA

The Mesozoic Era is characterized by the rise and fall of dinosaurs, the breakup of Pangaea, and the development of a wide variety of plant life.

KEY VOCABULARY

- dinosaur
- ammonite

VOCABULARY STRATEGY

The word *dinosaur* comes from the Greek words *deinos*, meaning "monstrous," and *sauros*, meaning "lizard."

VISUALIZATIONS CLASSZONE.COM

Observe an animation of an asteroid impact at the end of the Cretaceous Period.
Keycode: ES3006

CYCAD Modern cycads, such as this tree in Walpoua Forest, New Zealand, resemble those common during the Mesozoic.

The Mesozoic

The Mesozoic Era began about 248 million years ago and ended 65 million years ago. The era is divided into the Triassic, Jurassic, and Cretaceous Periods.

The climate was mild during much of the Mesozoic. Some evidence indicates that the poles were free of glacial ice and that the ocean surface temperature there was 10°C or warmer. For example, forests grew in polar regions, and coral grew in what is now Europe.

The era may be best known for a now extinct group of animals called **dinosaurs.** Although scientists are debating exactly what types of animals dinosaurs were, there is no question that they were the dominant form of animal life at the time. Dinosaurs lived on all continents, but many excellent fossil sites in the western United States and Canada indicate that these areas probably were particularly favorable environments for dinosaurs.

As interesting as it is, the rise and fall of the dinosaurs was not the only Mesozoic event. Other groups of animals and plants continued to evolve, and new species appeared. Some of these groups, like the dinosaurs, were extinct by the end of the era; others continued to flourish into the Cenozoic Era.

Triassic Period

The Triassic Period lasted from about 248 million to 206 million years ago, during which dinosaurs made their first appearance on land. Some of the first dinosaurs were about the size of a cat. Many dinosaurs were small, moved swiftly, and walked on their hind legs. Some groups of dinosaurs became adapted to life in the seas during the Triassic, and marine reptiles developed in a variety of sizes and shapes. The largest ichthyosaurs (IHK-thee-uh-SAWRZ), reptiles that resembled dolphins, were over 15 meters long. Some long-necked plesiosaurs (PLEE-see-uh-SAWRZ), which lived in oceans of the late Triassic, were nearly 5 meters in length.

Cephalopods, relatives of squid, were common in the Ordovician Period, but the cephalopods called **ammonites** are an important index fossil of the Triassic. Many types of ammonites occurred worldwide during the Triassic and then almost became extinct by the end of the period. The survivors gave rise to even more varieties in the Jurassic and Cretaceous Periods.

Triassic plants, including tree ferns, spore-bearing ferns, and rushes, showed few changes from the plants of the Permian Period. Plants ranged in size from smaller ferns to the midrange cycads and the taller conifers. Forests of cycads, trees with cones and palmlike leaves, and cone-bearing conifers were common. Well-known remains of Triassic conifers can be found in Arizona's Petrified Forest National Park.

During most of the Triassic, almost all of Earth's land was joined as the supercontinent Pangaea. Starting late in the period, faulting and igneous activity in Europe, North and South America, and Africa began to split Pangaea apart. The northern part, Laurasia, included what are now North America and Eurasia. The southern part, Gondwanaland, held the remaining continents. In the area that is now the United States, several areas of geologic interest formed during the Triassic. New Jersey's Palisades Sill and the igneous rocks of other East Coast locations formed.

Jurassic Period

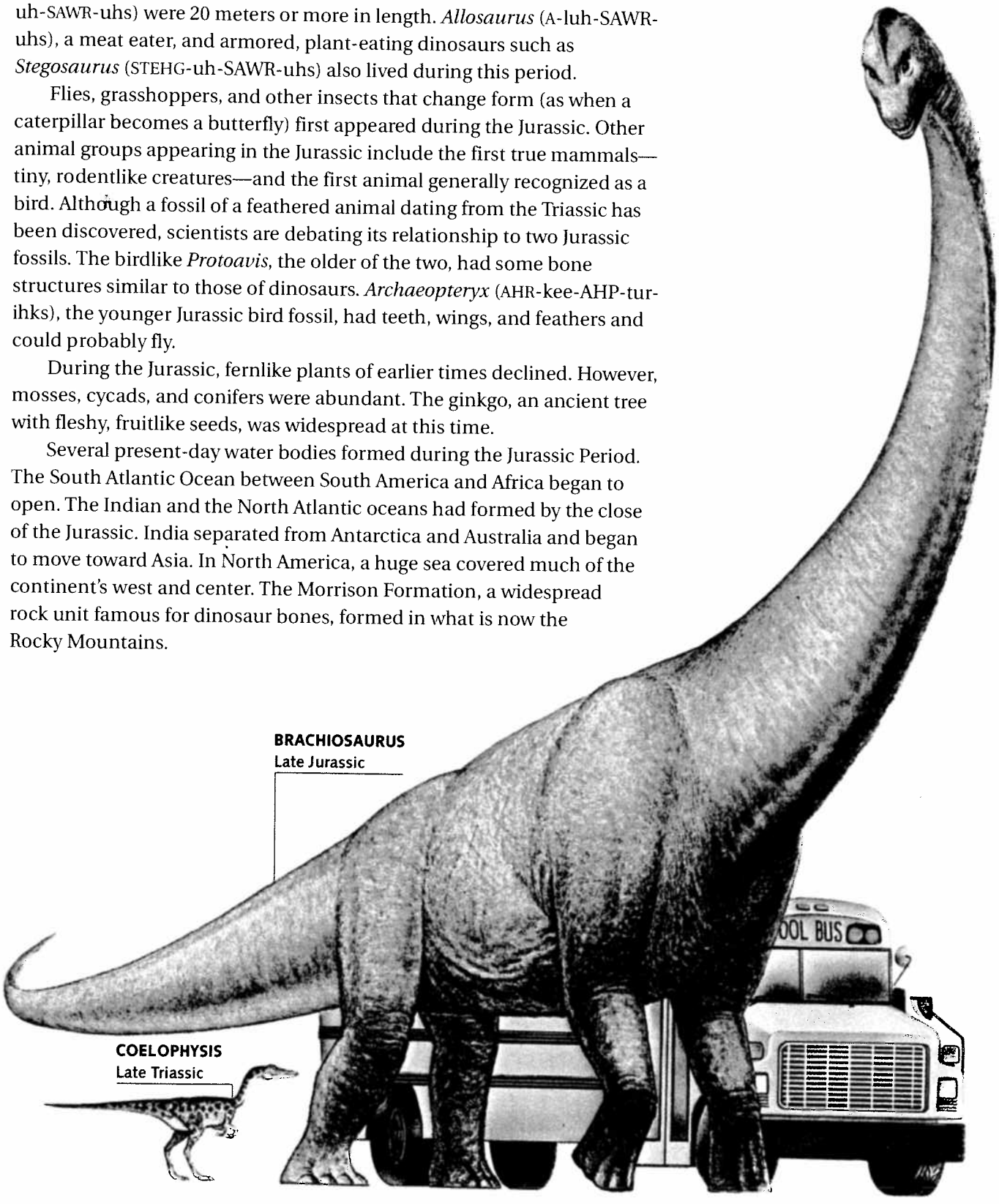
The rock record of the Jurassic Period, spanning from about 206 million to 144 million years ago, is remarkable for its dinosaur fossils. During this period, large dinosaurs were not uncommon, and the number of types of dinosaurs increased. Large plant eaters such as *Brachiosaurus* (BRAY-kee-uh-SAWR-uhs) were 20 meters or more in length. *Allosaurus* (A-luh-SAWR-uhs), a meat eater, and armored, plant-eating dinosaurs such as *Stegosaurus* (STEHG-uh-SAWR-uhs) also lived during this period.

Flies, grasshoppers, and other insects that change form (as when a caterpillar becomes a butterfly) first appeared during the Jurassic. Other animal groups appearing in the Jurassic include the first true mammals—tiny, rodentlike creatures—and the first animal generally recognized as a bird. Although a fossil of a feathered animal dating from the Triassic has been discovered, scientists are debating its relationship to two Jurassic fossils. The birdlike *Protoavis*, the older of the two, had some bone structures similar to those of dinosaurs. *Archaeopteryx* (AHR-kee-AHP-tur-ihks), the younger Jurassic bird fossil, had teeth, wings, and feathers and could probably fly.

During the Jurassic, fernlike plants of earlier times declined. However, mosses, cycads, and conifers were abundant. The ginkgo, an ancient tree with fleshy, fruitlike seeds, was widespread at this time.

Several present-day water bodies formed during the Jurassic Period. The South Atlantic Ocean between South America and Africa began to open. The Indian and the North Atlantic oceans had formed by the close of the Jurassic. India separated from Antarctica and Australia and began to move toward Asia. In North America, a huge sea covered much of the continent's west and center. The Morrison Formation, a widespread rock unit famous for dinosaur bones, formed in what is now the Rocky Mountains.

SIZE COMPARISON A Jurassic *Brachiosaurus*, a Triassic *Coelophysis*, and a school bus. The dinosaurs were from different time periods, and all dinosaurs were extinct before modern humans evolved.



20-Minute

Mini LAB

Continental Isolation's Effect on Species

Materials

- bag of colored beads

Procedure

1. Randomly take out 5 beads and set aside. Do this four times: keep each set separate. Record the colors in each set.
2. Repeat Step 1 with 15 beads.

Analysis

As the continents separated, their species evolved based on the genes available from the individuals present. Here, each bead color represents a fur color gene, and each set represents the individuals of the species isolated on a continent. Would the distribution of fur color be the same on all continents? Would evolution based on a large sampling lead to more or fewer similarities among species on different continents? Explain.

MAGNOLIA, a flowering deciduous plant of the Mesozoic. Flowers produce seeds. Many food crops on which humans depend—such as zucchini and oranges—come from flowering plants.

Cretaceous Period

The Cretaceous is the final period of the Mesozoic Era, lasting from about 144 million to 65 million years ago. The largest dinosaurs lived during this period, often exceeding 25 meters in length; one plant eater found in Argentina may have been over 45 meters long. *Tyrannosaurus* may no longer be the largest-known meat eater of the Cretaceous; recent findings reveal that *Carcharodontosaurus* had a larger skull.

Evergreen conifers are found throughout the Mesozoic fossil record, but the appearance of flowering plants is perhaps the greatest event. Deciduous trees eventually crowded the forests. First came magnolia, sassafras, and fig. Oak, maple, birch, and other modern trees developed later. The sequoia, ancestor of California's giant redwoods, also appeared.

By the end of the Mesozoic, the South Atlantic had become a major ocean and the continents appeared much as they do today. However, Australia and Antarctica were still joined, as were North America and Eurasia. Significant geological events in North America include the birth of the Rocky Mountains and the re-elevation of the Appalachians. The Dakota Sandstone, the famous aquifer of the Great Plains, also dates to the Cretaceous.

The Mesozoic Period ends with a mystery. What caused the mass extinction of much of the life on Earth, including the dinosaurs? Scientists estimate that over 50 percent of Earth's plant and animal groups were wiped out. Many hypotheses have been proposed to explain the mass extinction, including a change in climate, the rise of mammals, a drop in global sea level, and massive volcanic eruptions. The most widely accepted explanation is that a large asteroid struck Earth 65 million years ago near the present-day Yucatán Peninsula in Mexico. Dust from the impact could have blocked sunlight for years. Land plants and marine plankton that needed sunlight to survive would have died, starving the animals that fed on them.

30.3 Section Review

1. List the Mesozoic periods in order, from most recent to oldest.
2. Write a brief summary of how dinosaurs changed from the beginning of the Triassic to the end of the Cretaceous.
3. Create a table that summarizes the major changes to life forms and landmasses that occurred over the three periods of the Mesozoic.
4. CRITICAL THINKING Debate about the origins of a group of animals—birds, for example—is relatively common. What factors can contribute to the debate over when a species "first appears"?
5. GEOLOGY During fieldwork, a geologist finds several ammonite fossils in a rock layer said to be over 300 million years old. Do you agree with the date assigned to the rock layer? Explain your answer.

Earth's Recent History

30.4

KEY IDEA

The Cenozoic Era, which includes Earth's most recent history, covers the time from 65 million years ago to the present. The era includes the history of humans.

KEY VOCABULARY

- hominid
- bipedal

The Cenozoic Era began 65 million years ago. Geologists divide the era into three periods. The oldest, the Paleogene, lasted about 41 million years; the middle period, the Neogene, about 22 million years. The most recent period, the Quaternary, spans from about 2 million years ago to the present. Some sources refer to the Paleogene and the Neogene as the Tertiary. Either method further divides the periods into epochs. They are, from oldest to most recent, the Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene. The Cenozoic is the most recent era, and more is known about it than any other era. Scientists have information about significant events that characterize each epoch.

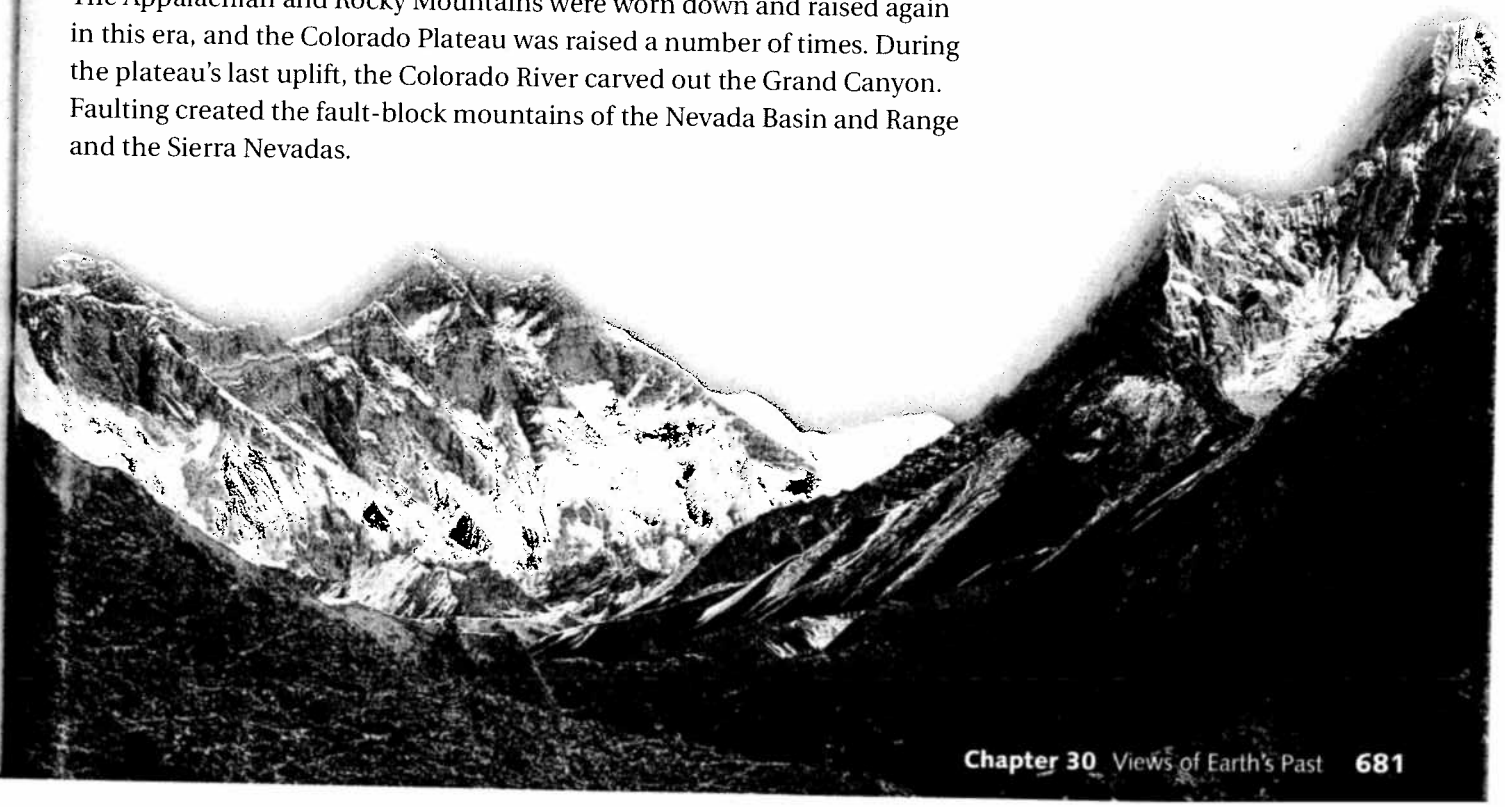
The early Cenozoic climate was warm and humid, much like the climate of the Mesozoic. However, global temperatures steadily decreased as the era progressed. By the beginning of the Quaternary Period, great sheets of ice covered about one-fourth of all land.

Life in the Cenozoic is characterized by the rise of mammals. Tiny mammals that survived extinction at the end of the Mesozoic Era evolved into today's familiar animals. Modern plants also evolved. Plate movements that began with the Mesozoic breakup of Pangaea continued through the Cenozoic, bringing the continents to their current locations. The appearance and disappearance of land bridges (such as the one connecting the Americas) affected the distribution of land and marine organisms.

The Paleogene and the Neogene

Nearly all major mountain ranges present today, including the Rockies, the Alps, and the Himalayas, existed or began to form during the Paleogene and Neogene Periods. The Himalayas, today's highest mountains, were pushed up as India began to collide with Asia during the Oligocene Epoch. The Alps were formed as the African Plate pushed into the Eurasian Plate. The Appalachian and Rocky Mountains were worn down and raised again in this era, and the Colorado Plateau was raised a number of times. During the plateau's last uplift, the Colorado River carved out the Grand Canyon. Faulting created the fault-block mountains of the Nevada Basin and Range and the Sierra Nevadas.

CLIMATE AND LANDFORMS
Mountains dating from the Cenozoic, including the Himalayas, shown here, are now covered by only a fraction of the snow and ice that was present during the Pleistocene.



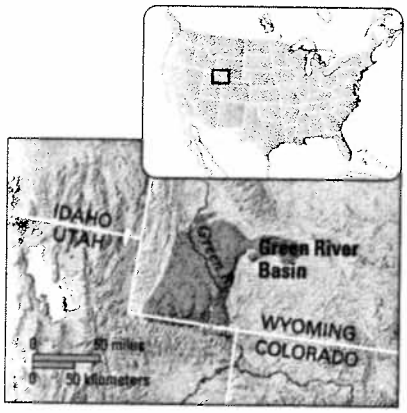
During the Paleogene, North America looked much as it does today. Only the Atlantic and Gulf coastal plains and parts of California were submerged. These areas were covered and uncovered by seawater several times during the Cenozoic Era. What is now the western United States was volcanically active during the end of the Paleogene. During the early Neogene, lava flows built up the Columbia Plateau in present-day Washington, Oregon, Idaho, and California. In the area that now includes Yellowstone National Park, lava and ash buried whole forests of trees several times. Later, minerals in groundwater petrified these trees.

Paleogene climates were similar to those of the Mesozoic, but temperatures dropped significantly by the end of the Eocene. In the Antarctic, ice sheets began a massive buildup through the last two epochs of the Paleogene. Global temperatures fluctuated throughout the Neogene until a sharp period of cooling near the end of the period.

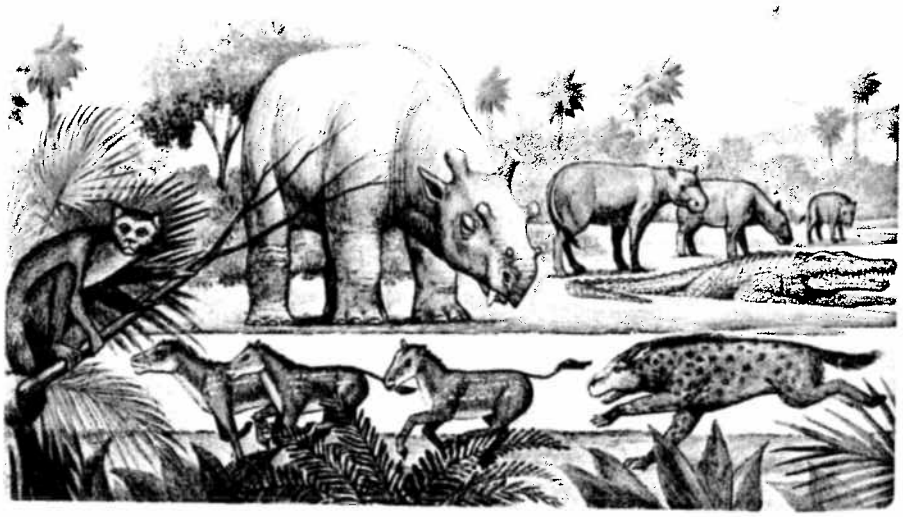
When the Paleogene Period began, the warm, humid climate favored the growth of tropical plants, even in what is now the northern United States. Palm, fern, fig, and camphor trees were common. Cypress and sequoia grew as far north as Greenland and northern Canada. As global temperatures dropped during the Neogene, tropical plants were driven south. Grasses that could survive cooler climates thrived. Some of these grasses were the wild ancestors of today's wheat, corn, barley, rye, oats, and rice. The appearance of grasses may have triggered the almost explosive evolution of grazing animals during the Neogene.

Cenozoic mammals have left an extensive fossil record. With the extinction of the dinosaurs at the end of the Mesozoic, mammals began to increase in number and variety. Early meat eaters called creodonts were among the first mammals of the Paleogene. Although creodonts are extinct, some animal groups that first appeared in the early Cenozoic are still present today. In almost every case, the first animal of each group to appear was much smaller than the modern animal descended from it. For example, the first horses to appear in the Eocene Epoch were about the size of large cats.

Spiders, centipedes, scorpions, and insects such as butterflies, bees, ants, and beetles continued to thrive throughout the era. Birds evolved that were similar to those of today. Modern forms of the horse, camel,



PALEOGENE PERIOD, 65 mya–24 mya The Green River Basin of the Eocene epoch was much warmer than it is today. Animals shown here (clockwise from bottom, left) include Smilodectes, Uintatherium, Palaeosyops, crocodile, Mesonyx, and Orohippus.



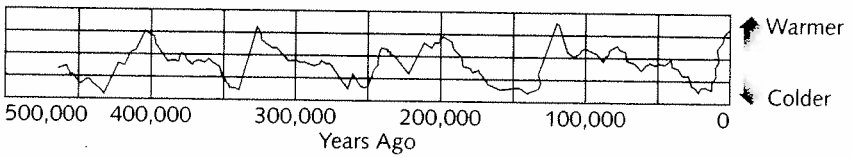
and elephant are just a few of the animals that first appeared in the Neogene.

Throughout the Paleogene and Neogene, the oceans were home to nearly the same invertebrate animals as today. Sponges, corals, starfish, and sand dollars were common. Mollusks such as clams, mussels, and snails also thrived. Many fish of these periods were similar to those of the late Mesozoic. For example, sharks and rays were still abundant.

Quaternary Period

The Quaternary Period covers the time from about 2 million years ago to the present. It is divided into the Pleistocene and Holocene Epochs. The Quaternary is a brief segment of geologic time and so is marked by relatively minor geologic activity. In South America, the existing Andes Mountains were raised even higher as the Nazca Plate was subducted under the South American Plate.

Global Cooling and Warming of the Quaternary



When ice builds up during an ice age, global temperatures drop. This can lower sea levels and alter the levels of isotopes in seashells. These and other data are used to predict relative changes during the last 450,000 years of the Quaternary Period.

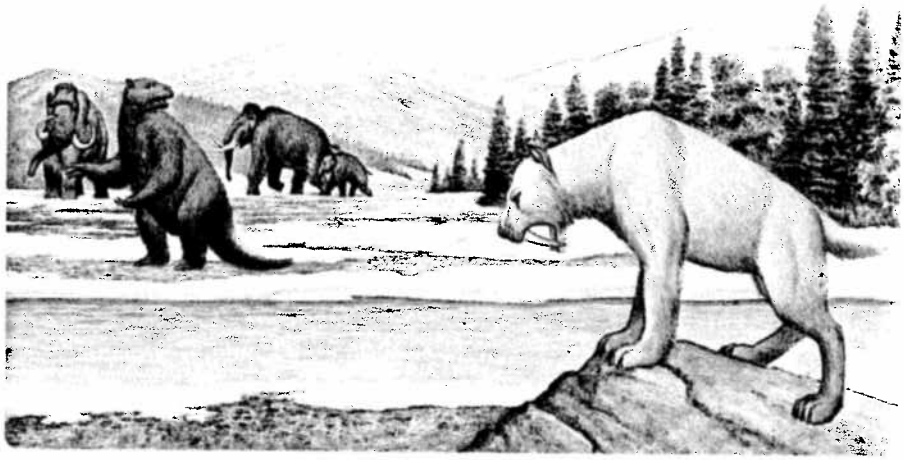
During the Quaternary Period, the climate underwent cycles of temperature changes that resulted in the forming and thawing of glacial ice. In fact, the Pleistocene, the first epoch of the period, is sometimes called the Great Ice Age, or Ice Age. Global temperatures had fallen by the start of the Quaternary. Ice covered large areas of North America, Europe, Asia, and all of Greenland and Antarctica. Only about one-tenth of that area remains covered today. The Pleistocene Epoch came to an end when the last ice sheets disappeared from North America, Europe, and Siberia about 10,000 years ago. That time marks the beginning of the Holocene Epoch.

Scientific Thinking

HYPOTHESIZE

Scientists theorize that many factors contribute to ice ages, periods of global cooling. These factors may include variations in Earth's orbit, continental movements, ocean currents, and the atmosphere.

The level of atmospheric carbon dioxide (CO_2) may be a key factor. Given what you know about the role of atmospheric CO_2 in Earth's heat balance, hypothesize how a graph of CO_2 levels might compare with the temperature graph at left. Would the "peaks and valleys" be the same? Different? In what way?



QUATERNARY PERIOD, 2 mya–present The Green River Basin experienced much cooler temperatures during the Pleistocene epoch. Animals shown here (left to right) include mammoth, giant ground sloth, and Smilodon.

As temperatures cooled late in the Cenozoic, tropical plants died off except in equatorial areas. By the Quaternary Period, these plants had disappeared from western North America. Only two types of the previously widespread sequoia trees are found there today: the giant sequoias and the redwoods. Scientists believe that the significant changes in climate throughout the Cenozoic Era may have led species to adapt more quickly to their environment. This change might have increased the rates of evolution and extinction. Many mammal species that may have competed for resources with human ancestors became extinct toward the end of the Ice Age. Their extinction could have led those early humans to broaden their territory, migrating to other continents and regions.

REDWOOD Cooler global temperatures affected the distribution of Quaternary plant life. Once widespread, trees like this naturally fallen redwood are now found only in California and Oregon.

"LUCY" is the name given to the skeleton of a young adult *Australopithecus* found in Africa in the early 1970s.

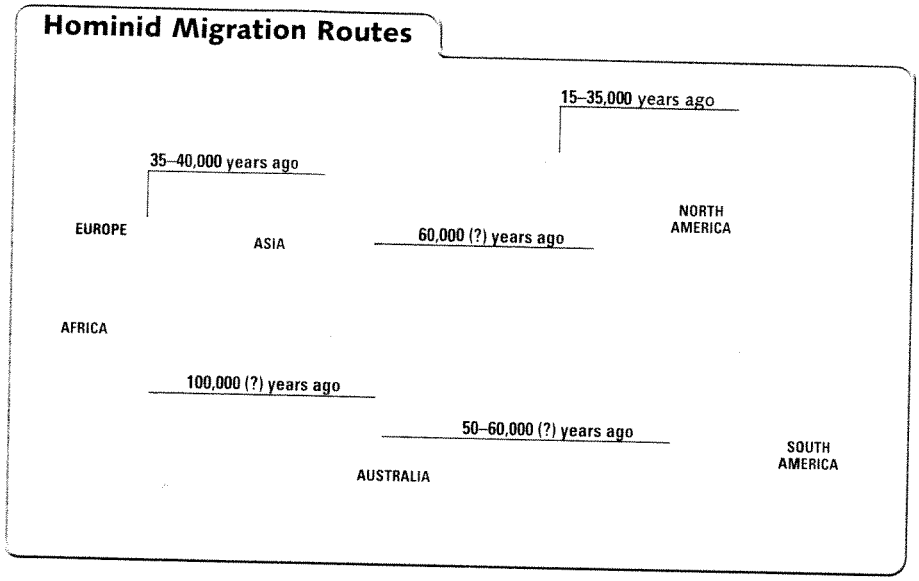
Rise of Humans

Hominid is the general name for a modern human or a recent humanlike ancestor. Scientists differentiate hominid fossils from similar apelike fossils by looking for several characteristics. For example, modern humans typically have larger brains than do apes. A human brain occupies a volume of about 1300 cubic centimeters. Another distinguishing trait is that humans are **bipedal;** that is, they walk upright on two legs.

The fossil record contains extensive traces of early human life. Thousands of fossils, consisting of jaws, teeth, skulls, and other bones, have been found. The oldest is probably about 4.5 million years old, although more recent finds may eventually prove to be as old as 6 million years. The oldest generally accepted hominid is *Australopithecus* (aw-STRAY-loh-PIHTH-ih-kuhs). These hominids had apelike brains and humanlike jaws and were bipedal. The fossil record beyond 4 million years ago is not perfectly clear, but it seems *Australopithecus* dates from 5 million years ago and possibly more.

In the 1960s and 1970s, hominid fossils were found with a brain size of about 700 cubic centimeters—much larger than that of *Australopithecus.* These hominids, named *Homo habilis,* were able to make and use simple tools. They probably lived from about 2 million to 1.5 million years ago.

Another hominid, *Homo erectus,* had a brain volume of about 1000 cubic centimeters. The species lived around 1.5 million years ago and was likely the first hominid to control fire.



HOMINID MIGRATION is difficult to determine, and the facts are constantly reviewed and debated. A map such as this is revised frequently to reflect new information gathered through research in laboratories and the field.

Hominid fossils from the last 400,000 to 300,000 years are called *Homo sapiens*, the group to which modern humans belong. Early *Homo sapiens* differed from those of today. For example, a group of *Homo sapiens* known as Neanderthals had shorter, more powerfully built skeletons than do most modern humans. Another group of early *Homo sapiens*, Cro-Magnons, had skeletons almost identical to those of modern humans.

Tracing human evolution from the fossil record is difficult. However, it is certain that humans have been on Earth a relatively short time on the geologic time scale. For example, dinosaurs roamed Earth for about 160 million years, whereas hominids have been around only for the last 2 million to 3 million years. The contrast is much greater when viewed from the history of Earth, which extends back 4 billion to 5 billion years. If the span of your arms, from left fingertip to right fingertip, represents Earth's entire geologic time scale, human existence is represented by the outermost edge of your right fingernail.

30.4

1. Identify a significant event—of climate, geology, or life—for each Cenozoic period. Be sure to identify the name of the period.
2. Why is the Cenozoic also known as the Age of Mammals?
3. List four hominid species in chronological order.
4. Suppose that climatic changes of the Cenozoic are cyclic. Predict the pattern of climatic change for the next 65 million years. What changes in plant life might occur?
5. The use of simple tools and fire influenced the course of human evolution. With a partner, brainstorm three other technological advances that have shaped human development.

CHAPTER 30 REVIEW

Summary of Key Ideas

30.1 The geologic time scale summarizes the major events of Earth's history as revealed in the rock record. Changes over the past 3.8 billion years include the formation of Earth's crust, the appearance and disappearance of landforms, atmospheric changes, and the appearance and evolution of life forms. Natural selection accounts for changes in species.

30.2 Precambrian time includes the Archean and Proterozoic Eons and covers nearly 4 billion years of Earth's history. Precambrian time is characterized by active plate movement, simple life forms, and glaciation. The Paleozoic Era covers about 295 million years and marks the beginning of an abundant fossil record.

30.3 The Mesozoic Era covers about 180 million years of Earth's history. It is characterized by the rise and fall of dinosaurs, the breakup of Pangaea, and the development of a variety of plant life.

30.4 The Cenozoic Era began about 65 million years ago and includes Earth's most recent events. Life in this era is characterized by the appearance of mammals, including humans.

KEY VOCABULARY

ammonite (p. 678)
bipedal (p. 684)
crinoid (p. 676)
dinosaur (p. 678)
eon (p. 666)
epoch (p. 667)
era (p. 666)
evolution (p. 670)
eurypterid (p. 676)
foraminifera (p. 676)
geologic time scale (p. 666)
graptolite (p. 675)
hominid (p. 684)
natural selection (p. 670)
period (p. 667)
Precambrian (p. 673)
shield (p. 673)
stromatolite (p. 674)
trilobite (p. 675)

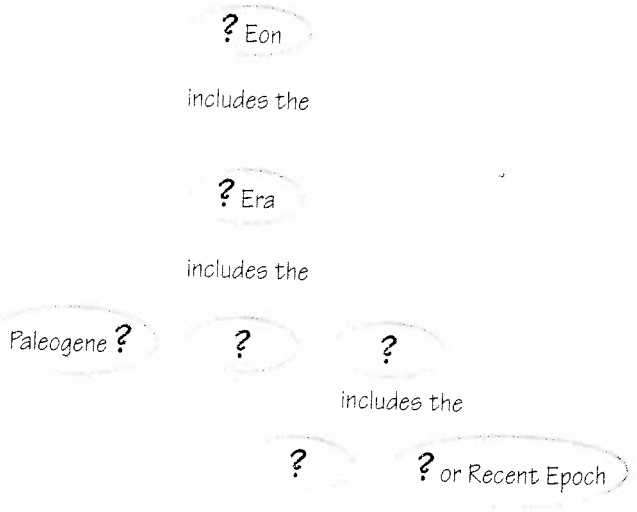
Vocabulary Review

Write the term from the key vocabulary list that best completes the sentence.

1. Together, the Archean and the Proterozoic Eons make up what is known as ___?___ time.
2. The most common fossil from the Precambrian is the ___?___ .
3. The crablike ___?___ is an important fossil of the Cambrian Period.
4. The sea scorpion, or ___?___ , is an index fossil of the Silurian Period.
5. Hominids such as Neanderthals were ___?___ .

Concept Review

6. Explain in what way(s) the geologic time scale is a useful tool.
7. Describe two ways evolution might occur.
8. Why are there no Precambrian coal beds?
9. How might index fossils provide evidence of a change of climate in a particular area?
10. **Graphic Organizer** Copy and complete the concept map below. Then continue the map, including all missing eras, periods, and epochs of this eon.



Critical Thinking

11. **Hypothesize** How might plant and animal life in North America appear today if Pangaea had not broken apart? Consider the roles of evolution, migration, and species distribution in your answer.

12. **Communicate** Imagine a swampy forest of the Pennsylvanian Period, then envision the exact same spot during the Cambrian Period. Describe how and why the views would differ.

13. **Hypothesize** Given what you learned in this chapter about climatic changes, write a hypothesis stating whether you expect global temperatures to remain the same, decrease, or increase over the next 100,000 years. Explain your reasoning.

14. **Draw Conclusions** Siberia and Alaska are separated by the Bering Strait, but evidence indicates that humans migrated to North America from Asia about 20,000 to 35,000 years ago. How was such migration possible without boats?

Internet Extension

INVESTIGATIONS

Where and When Did Dinosaurs Live? Use geologic evidence to determine the time period and conditions in which a species of dinosaur lived.

Keycode: ES3008

Writing About the Earth System

How did the state in which you live appear during the Jurassic Period? the Pliocene Epoch? Choose a time from the Phanerozoic Eon and then use a variety of resources to find information about your state's geologic past. Use the information to describe your area at that time. Note any significant differences in the spheres of the Earth system.

Interpreting Charts

The chart shows the occurrence of fossils in the rock record. Letters representing certain species are placed in the period during which that species is found in the rock record.

15. During which geologic period(s) did the trilobites of species A live?

16. What is the range of geologic periods for armored fish? for armored fish of species M?

17. Two brachiopods, species N and O, are listed. Neither can be used to identify a rock from the Mississippian. Why?

18. What is the probable age of a rock layer that contains species D and species K?

19. List the fossils (including the letter of any species) that could occur in a rock of Ordovician age.

Time Distribution of Fossils

	Cam	O	S	D	Carb	P	Tri	J	Cret	Tert	Q
Trilobites A, B, C	A	B		C							
Ammonites D				D							
Crinoids E, F			E	F							
Graptolites G, H		G H									
Dinosaurs I							I				
Eurypterids J, K			J	K							
Mammals L											L
Armored Fish M				M							
Brachiopods N, O			N	O							