Careers & BIOLOGY

More than 99 percent of the species that ever lived are now extinct. If studying past life interests you, you might consider one of the following careers.

FOSSIL PREPARATOR

If you believe what you see in the movies, fossils are usually found perfectly preserved and intact. But the truth is that fossils are almost always found jumbled and encased in rock. Using microscopes and delicate hand tools, fossil preparators remove fossils from the surrounding rock. Preparators carefully reconstruct damaged pieces and record information about fossil position and rock composition.

MUSEUM GUIDE

Museum guides are educators. But instead of using books to teach, they use museum exhibits. A museum guide at a natural history museum, for example, might have fossils that visitors can touch and manipulate. Museum guides also perform demonstrations and give informal talks.

PALEONTOLOGIST

Paleontologists study extinct and ancient life. It is not all about fossils, however. Today paleontolgists use everything from biochemistry to computer modeling to understand the evolutionary relationships among organisms. Living animals are also sometimes used to study movement, behavior, or development.

CAREER CLOSE-UP:

Dr. Kristi Curry Rogers, Curator of Paleontology, Science Museum of Minnesota

Dr. Curry Rogers' work is big—very big. Dr. Curry Rogers is a paleontologist who studies how the giant long-necked sauropod dinosaurs grew. How can you study how an extinct animal grew over 65 million years ago? By studying microscopic bone structure, Dr. Curry Rogers can estimate how long it took the animal to reach full size. This kind of research can help scientists understand how dinosaurs regulated their body temperature. In addition to questions about sauropod growth, Dr. Curry Rogers is also investigating how different sauropods are related.

"Unlike many kids who go through a 'fossil phase,' I never grew out of it!"

WRITING Choose one of the careers described here. Explain why this career is important to understanding the history of life.

Biology In-Depth

CAREERS IN EARTH'S HISTORY

Fossil preparators collect, clean, reconstruct, and prepare fossil specimens for research or exhibit. A four-year degree in biology or geology is required for many positions.

A museum guide is often an unpaid, trained volunteer. Some guides also teach classes at museums. A degree in science is not required but is helpful. Guides receive training about the exhibits they show or the classes they teach.

Many paleontologists conduct research or teach at universities. They generally have a master's degree or doctorate in some aspect of geology or paleontology. Paleontologists are also employed by companies that drill for oil.

Teach

Lead a Discussion

Ask How do you think paleontologists determine where to find fossils? *(They determine the type and age of rock most likely to provide the kind of fossils they're interested in. Then, they go to a place where this kind of rock is exposed.)*

Ask Looking at the photo of Dr. Curry Rogers, you'll notice that the paleontologist doesn't appear to be digging. Do you think paleontologists dig, or look for fossils exposed to the surface? *(exposed at the surface)* What does this suggest about the types of places paleontologists go to look for fossils? *(they go where rock is exposed)*

Then, focus students' attention on the careers of museum guide and fossil preparator.

Ask Could the work of paleontologists happen without the work of fossil preparators? *(no, because fossil preparators carefully remove fossils from rock, enabling paleontologists to study the fossils in three dimensions)*

Ask How do museum guides help the work of scientists? *(They inform the public about the work in ways that nonscientists can understand.)*

DIFFERENTIATED INSTRUCTION

L3 **Advanced Students** Have a small group of students find out what kinds of fossils are found locally or in their state. Ask them to create a map showing the locations, types of fossils, and geologic periods from which the fossils come. Encourage students to include drawings or photos of the fossils.

Answers

WRITING

Sample answer: Paleontologists are important to understanding the history of life because they study the fossils and biochemistry of ancient organisms. Paleontologists work to understand the evolutionary relationships that existed between ancient organisms, and between ancient organisms and their modern descendants. They can help people understand what these organisms and their environments were like.

NATIONAL SCIENCE EDUCATION STANDARDS

UCP IV, V
CONTENT G.1
INQUIRY A.2.b

Teach

Use Visuals

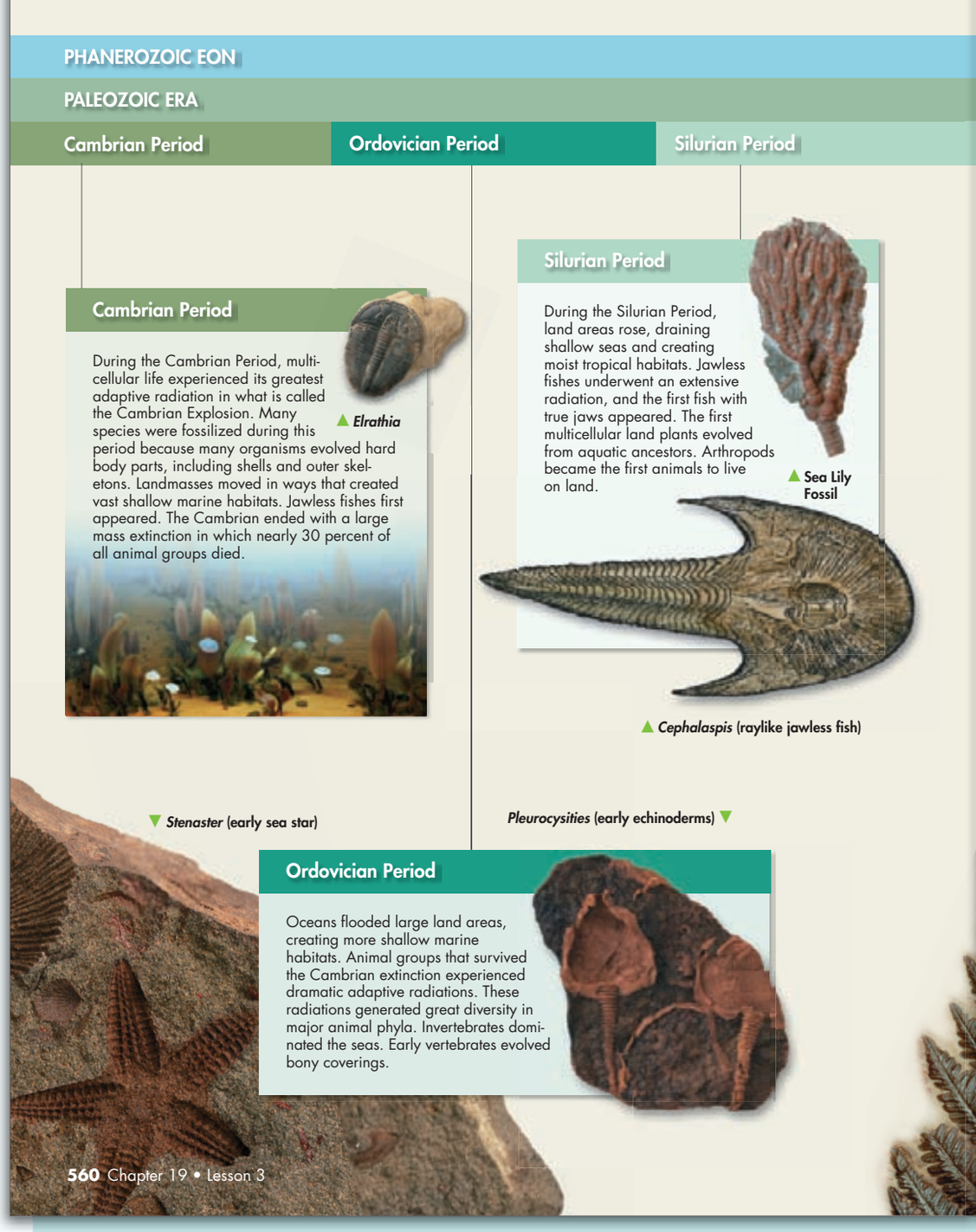
Use the following strategy to help students organize the information presented in this four-page feature on the geologic time scale. Have them read and take notes about each period, including the eon and era during which each period occurred. Then, after students have finished reading the information on all four pages, have them review their notes. Finally, call on volunteers to explain how the example organism shown for each period reflects the characteristics of the period.

DIFFERENTIATED INSTRUCTION

ELL **English Language Learners** Have students work in pairs, and assign each pair two geologic periods for which to create a **Cluster Diagram.** Each cluster diagram should include specific characteristics of the assigned geologic period. Call on students to share their diagrams as each period is discussed.

Study Wkbks A/B, Appendix S19, Cluster Diagram. **Transparencies,** GO2.

LPR **Less Proficient Readers** Help students understand the organization of information on these four pages. Point out the three-tiered band across the top of each page, identifying the eon, era, and periods. Have students connect the colors used for these bands to the colors used in the time scale in Lesson 19.1. Then, show students how the vertical lines connect to detailed information about each period.



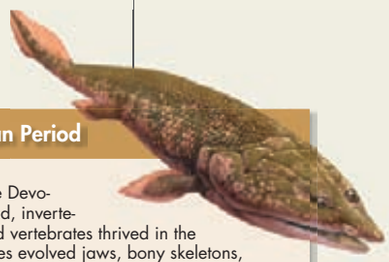
Quick Facts

THE BURGESS SHALE

One of the most significant collections of fossils in the world is the Burgess Shale in British Columbia, Canada. The shale contains perfectly preserved fossils of organisms from the "Cambrian explosion"—a period of rapid adaptive radiation among multicellular organisms. The site was discovered in 1909 by Charles Walcott, then the Secretary of the Smithsonian Institution. Walcott amassed a collection of more than 60,000 specimens, most now housed at the Smithsonian Institution in Washington, D.C.

The significance of the fossils is in how well they were preserved and in the tremendous variety of the organisms. Soft body parts rarely survive the decay process, but some of the Burgess fossils show evidence of muscles and gut contents.

Devonian Period | Carboniferous Period | Permian Period



Devonian Period

During the Devonian Period, invertebrates and vertebrates thrived in the seas. Fishes evolved jaws, bony skeletons, and scales. Sharks began their adaptive radiation. Certain groups of fishes evolved leglike fins, and some of these evolved into the first amphibians. Some land plants, such as ferns, adapted to drier areas. Insects began to radiate on land.

◀ Fossil Fern From Carboniferous Period

Permian Period

▲ Crinoid

During the Permian Period, invertebrates, vertebrates, and land plants continued to expand over Earth's continents. Reptiles experienced the first of several major adaptive radiations, which produced the ancestors of modern reptiles, dinosaurs, and mammals. The Permian Period ended with the biggest mass extinction of all time. More than 50 percent of terrestrial animal families and more than 95 percent of marine species became extinct.

Early Amphibian ▼

Carboniferous Period

During the Carboniferous Period, mountain building created a wide range of habitats, from swampy lowlands to drier upland areas. Giant ferns, club mosses, and horsetails formed vast swampy forests. Amphibians, insects, and land plants experienced major adaptive radiations. Winged insects evolved into many forms, including huge dragonflies and cockroaches. For early vertebrates, insects were food; for plants, insects were predators. The first reptiles evolved from ancient amphibians.

Lead a Discussion

Divide the class into three groups, and give each group an index card. Assign each group one of the geologic periods on this page. Give students a few minutes to skim the description of the period and write two questions on their index card. Encourage them to write one direct, factual question and one that begins with *why* or *what may have caused.* Collect the cards, and use them as a basis for a class discussion regarding the Devonian, Carboniferous, and Permian Periods.

DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** Draw a **Main Ideas and Details Chart** on the board. Model for students how this format can be used to organize information about geologic time periods by completing the chart on the board, using the Devonian Period as the main idea. Ask students to identify details, and write the details that students mention in the chart. Explain that students can use this format for any of the periods described in this feature. Encourage each student to complete at least one main ideas and details chart about a period other than the Devonian.

Study Wkbks A/B, Appendix S28, Main Ideas and Details Chart. **Transparencies,** GO13.

UbD Check for Understanding

ONE-MINUTE RESPONSE

Have students select one period from these two pages, and give them about a minute to write a sentence describing the geological changes that occurred during the period and the response of organisms living at that time to those changes.

ADJUST INSTRUCTION

If some students cannot distinguish the information on geology and the responses of organisms, simplify the directions to read: Describe what happened to the land during that period. Describe what happened to the plants and animals after the land changed.

Teach continued

Lead a Discussion

Help students understand the information on this page using the following questions.

Ask What three periods are part of the Mesozoic Era? *(Triassic, Jurassic, Cretaceous)*

Ask During which period did *Archaeopteryx* evolve? *(Jurassic)*

Ask During which period did the first dinosaurs evolve? *(Triassic)*

Ask During which period did the first mammals evolve? *(Triassic)*

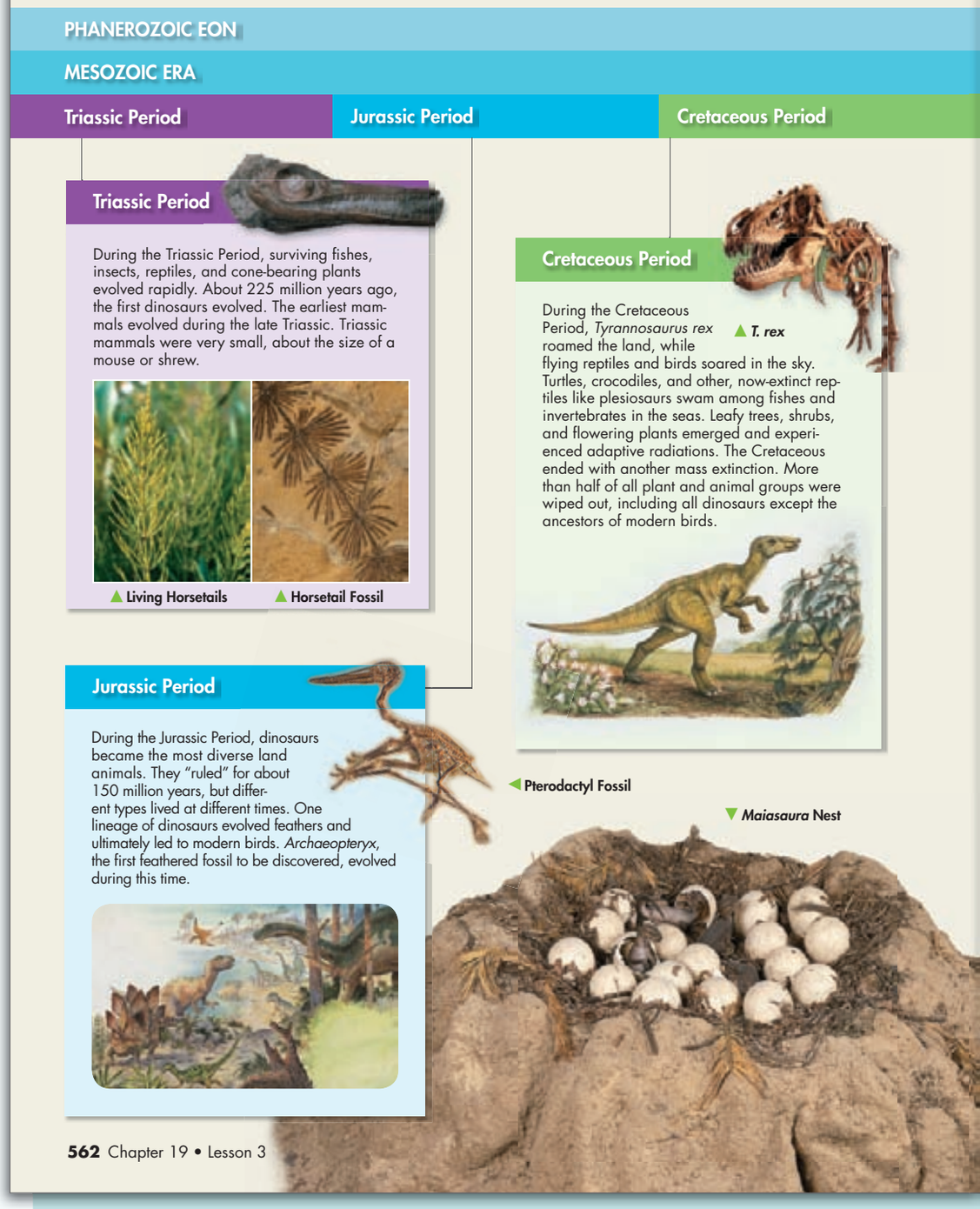
Ask During which period did flowering plants evolve? *(Cretaceous)*

DIFFERENTIATED INSTRUCTION

L3 **Advanced Students** Have students work in a small group to develop a set of mnemonic devices that other class members can use to remember main ideas about each period described on this page. After allowing time for the group to develop their mnemonic devices, have these students teach a short lesson in which they share the mnemonic devices with the class.

Address Misconceptions

Dinosaur Success Some students might think dinosaurs were not very successful in evolutionary terms because they became extinct at the end of the Cretaceous Period. Point out that dinosaurs lived on Earth for about 150 million years, while hominids have been in existence for less than 10 million years. Further, you can remind students that dinosaurs still live today—as birds!



Biology In-Depth

THE K/T EXTINCTION

The extinction at the end of the Mesozoic is often abbreviated as K/T after the symbols used for the Cretaceous (K) and Tertiary (T) Periods. (Note that the Tertiary Period is now an outdated term.) The cause of the K/T extinction is widely agreed upon. Approximately 65 million years ago, a 10-kilometer wide asteroid hit Earth in the present-day Gulf of Mexico. Scientists have found the crater, called Chicxulub, buried under 65 million years of accumulated sediment. Around the world, a layer of iridium (an element common in asteroids but rare on Earth) and shocked quartz (a form of quartz found only near meteor/asteroid impact sites and nuclear bomb test sites) marks the time of the impact and the beginning of the mass extinction.

CENOZOIC ERA

Paleogene Period | Neogene Period | Quaternary Period

Paleogene Period

During the Paleogene Period, climates changed from warm and moist to cool and dry. Flowering plants, grasses, and insects flourished. After the dinosaurs and giant marine reptiles went extinct, mammals underwent a major adaptive radiation. As climates changed, forests were replaced by open woods and grasslands. Large mammals—ancestors of cattle, deer, and sheep and other grazers—evolved and spread across the grasslands. In the sea, the first whales evolved.

▲ Early Mammal

Neogene Period

During the Neogene Period, colliding continents pushed up modern mountain ranges, including the Alps in Europe and the Rockies, Cascades, and Sierra Nevadas in North America. As mountains rose, ice and snow built up at high elevations and in the Arctic. Falling sea levels and colliding continents created connections between North and South America, and between Africa, Europe, and Asia. Those connections led to great movements of land animals between continents. Climates continued a cooling and drying trend, and grasslands continued to expand. Modern grazing animals continued to coevolve with grasses, evolving specialized digestive tracts to deal with tough, low-nutrient grass tissue.

◀ Neanderthal Skull

Quaternary Period

During the Quaternary Period, Earth cooled. A series of ice ages saw thick glaciers advance and retreat over parts of Europe and North America. So much water was frozen in glaciers that sea levels fell by more than 100 meters. Then, about 20,000 years ago, Earth's climate began to warm. Over thousands of years, glaciers melted, and sea levels rose. In the oceans, algae, coral, mollusks, fishes, and mammals thrived. Insects and birds shared the skies. Land mammals—among them bats, cats, dogs, cattle, and mammoths—became common. Between 6 and 7 million years ago, one group of mammals began an adaptive radiation that led to the ancestors and close relatives of modern humans.

▲ Cave paintings

Quick Facts

ADAPTIVE ADVANTAGE OF FRUITS

The development of fruits and seeds was a major evolutionary advance in the reproduction of plants, and many animals became agents for spreading seeds. However, if animals eat immature fruit, the seeds are not able to germinate. Natural selection appears to have solved this problem in an interesting and not so sweet way. Many unripe fruits are green and contain bitter-tasting chemical compounds. This discourages animals from eating them. In addition, the green color makes the unripe fruits more difficult to see among plant leaves. The unappetizing features of the fruits appear to benefit the seeds by giving them time to mature. As the bitter-tasting compounds break down, the seeds mature, and the fruits become laden with sugars. Simultaneously, many fruits change color from green to more visible shades of red, orange, yellow, or purple. This makes the fruits easier to see against the leafy green background.

Lead a Discussion

Give students about 5 minutes to meet in small groups to prepare for a review of characteristics of all the periods described in this feature using a round-robin discussion format. For example, you might begin by saying, "During the Cambrian Period, there was a great radiation of multicellular organisms." Call on students to provide statements that logically follow the previous statement. Continue until all the periods have been covered.

DIFFERENTIATED INSTRUCTION

ELL **English Language Learners** Students may have difficulty with a round-robin discussion format. Provide these students with a written copy of several statements you could use to start a round-robin discussion. Have students read these statements, look at the text, and develop written or spoken statements that logically follow the starter statements you have provided. Call on students to share their responses.

CHAPTER LAB

Pre-Lab

Introduce students to the concepts they will explore in the chapter lab by assigning the Pre-Lab questions.

Lab

Tell students they will perform the chapter lab *Using Index Fossils* described in **Lab Manual A.**

L1 **Struggling Students** A simpler version of the chapter lab is provided in **Lab Manual B.**

SAFETY

Caution students to direct the pointed end of the scissors away from themselves and others.

BIOLOGY.com Look online for **Editable Lab Worksheets.**

For corresponding pre-lab in the **Foundation Edition**, see page 470.

NATIONAL SCIENCE EDUCATION STANDARDS

UCP II, IV
CONTENT C.3.b, C.3.c, C.3.d
INQUIRY A.2.e

Forensics Lab

GUIDED INQUIRY

Pre-Lab: Using Index Fossils

Problem How can fossils be used to determine the relative ages of rock layers?

Materials scissors

Lab Manual Chapter 19 Lab

Skills Focus Interpret Visuals, Sequence, Draw Conclusions

Connect to the Big idea When detectives work on a case, they may look for items with a time stamp, such as parking tickets and credit card slips. Such items can help detectives piece together a sequence of events. Events related to a crime usually occur within a relatively short period of time. In contrast, the events that paleontologists study will have occurred over millions of years. Placing these events in their proper order can be challenging. The clues that a paleontologist uses to sequence events in the history of life are fossils buried in rock layers. In this lab, you will use fossils to place rock layers in order from oldest to youngest.

Background Questions

a. Review What is a fossil? What are the characteristics of a good index fossil?

b. Explain What characteristic of radioactive decay allows scientists to assign specific ages to rock layers?

c. Classify How do fossils help geologists decide where one division of geologic time should end and another division begin?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. Organize Data After you cut out the drawings of the rock layers, how will you begin the process of sorting the layers by age?

2. Infer *Desmatosuchus* was a crocodile relative that lived only during the Triassic Period. Horsetails are plants that first appeared in the Triassic Period and still exist. Which of these organisms would be more useful as an index fossil for the Triassic Period? Why?

3. Use Analogies Luke found a box of photos labeled 1970–1995. Each photo shows his entire extended family. No dates appear on the photos. Luke knows that his grandmother died in 1985 and his uncle was born in 1975. Luke's sister was born in 1990. How can Luke use this information to sort the photos into four batches? How are Luke's relatives similar to index fossils?

BIOLOGY.com Search Chapter 19 GO

Visit Chapter 19 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Go back in time with the Untamed Science crew to find out what fossils reveal.

Art in Motion View a short animation that shows how fossils form.

Art Review Review your understanding of the composition of Earth's early atmosphere as compared with the composition of Earth's current atmosphere.

Visual Analogy Compare geologic time to a 24-hour clock.

Data Analysis Correlate data on extinction events with other types of data to identify likely causes of extinction.

Pre-Lab Answers

BACKGROUND QUESTIONS

a. A fossil is the preserved remains of an ancient (usually extinct) organism. A good index fossil must be easy to identify. It must also come from a species that existed for a relatively short time over a wide geographic range.

b. Radioactive decay occurs at a steady rate over time.

c. Geologists noticed that major changes in the fossil record occurred at boundaries between certain rock layers. Those boundaries were used to divide geologic time into eons, eras, and periods.

PRE-LAB QUESTIONS

1. Sample answer: I will use the Key to Fossils to identify the fossils in each layer.

2. The crocodile relative would be more useful as an index fossil for the Triassic Period because it would not occur in rock layers from other periods.

3. Sample answer: Possible batches are photos with (1) grandmother only from 1970–1975, (2) grandmother and uncle from 1975–1985, (3) uncle only from 1985–1990, and (4) uncle and sister from 1990–1995. The people are like index fossils because they exist in specific time ranges relative to the overall range of the photos.