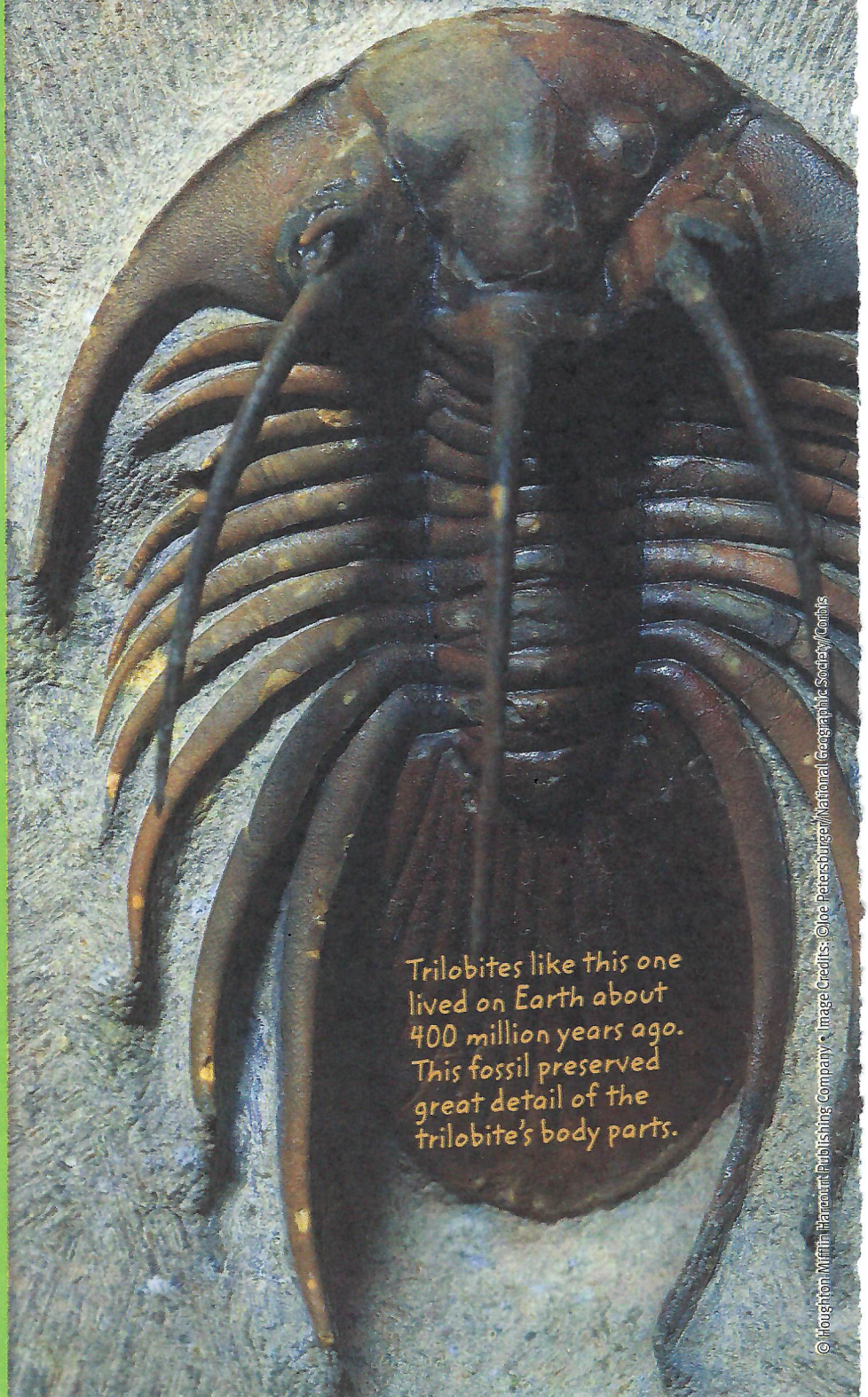


The History of Life on Earth

ESSENTIAL QUESTION

How has life on Earth changed over time?

By the end of this lesson, you should be able to describe the evolution of life on Earth over time, using the geologic time scale.



Trilobites like this one lived on Earth about 400 million years ago. This fossil preserved great detail of the trilobite's body parts.

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Quick Labs

- How Do We Know What Happened When?
- Investigate Relative and Absolute Age

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

- | | | |
|--------------------------|--------------------------|--|
| T | F | |
| <input type="checkbox"/> | <input type="checkbox"/> | A mass extinction occurs when a large number of species go extinct during a relatively short amount of time. |
| <input type="checkbox"/> | <input type="checkbox"/> | The largest division of the geologic time scale is the era. |
| <input type="checkbox"/> | <input type="checkbox"/> | We currently live in the Cenozoic era. |
| <input type="checkbox"/> | <input type="checkbox"/> | Fossils show that the first living things were very tiny. |

2 Draw Imagine you find a fossil of a fish. Which parts of the fish could you see in the fossil? Draw what you think you would see below.

Active Reading

3 Apply Use context clues to write your own definition for the words *fossil record* and *extinction*.

Example sentence

Scientists develop hypotheses about Earth's history based on observable changes in the fossil record.

fossil record:

Example sentence

Endangered species are protected by law in an effort to preserve them from extinction.

extinction:

Vocabulary Terms

- fossil
- extinction
- fossil record
- geologic time scale

4 Identify As you read, place a question mark next to any words that you don't understand. When you finish reading the lesson, go back and review the text that you marked. If the information is still confusing, consult a classmate or a teacher.

Uncovering Clues

How do we learn about ancient life?

Paleontologists look for clues to understand what happened in the past. These scientists use fossils to reconstruct the history of life.

A **fossil** is a trace or imprint of a living thing that is preserved by geological processes. Fossils of single-celled organisms date as far back as 3.8 billion years.

What can we learn from fossils?

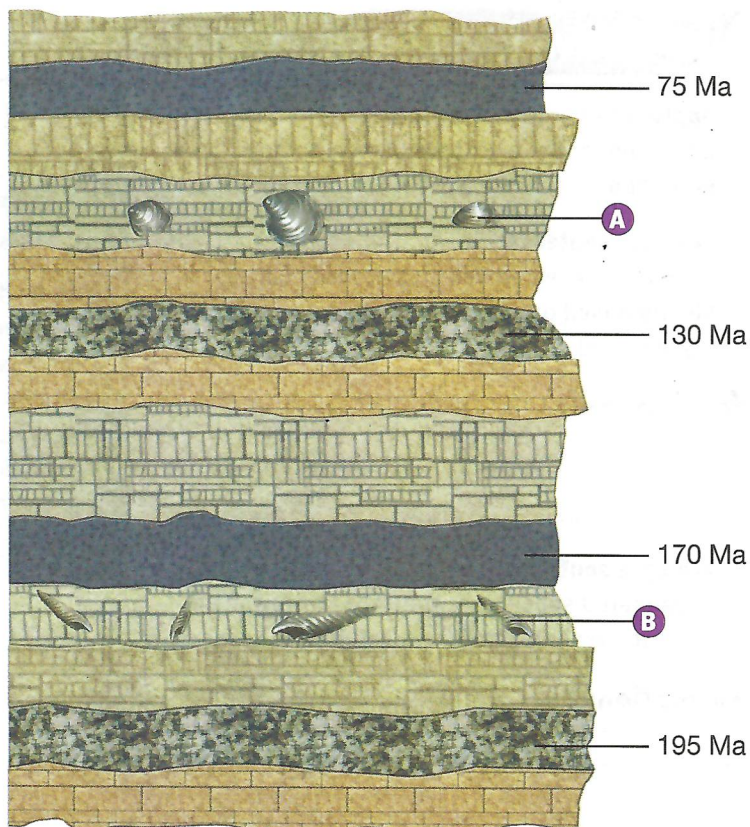
All of the fossils that have been discovered worldwide make up the **fossil record**. By examining the fossil record, scientists can identify when different species lived and died. There are two ways to describe the ages of fossils. *Relative dating* determines whether a fossil formed before or after another fossil. When an organism is trapped in mud or sediment, the resulting fossil becomes part of that sedimentary layer of rock. In rock layers that are not disturbed, newer fossils are found in layers of rock that are above older fossils. *Absolute dating* estimates the age of a fossil in years. Estimations are based on information from radioactive elements in certain rocks near the fossil.

Visualize It!

The abbreviation Ma stands for mega annum. A mega annum is equal to 1 million years. Ma is often used to indicate “million years ago.”

5 Infer What does relative dating tell you about fossil A?

6 Solve What does absolute dating tell you about fossil A?



385 Ma

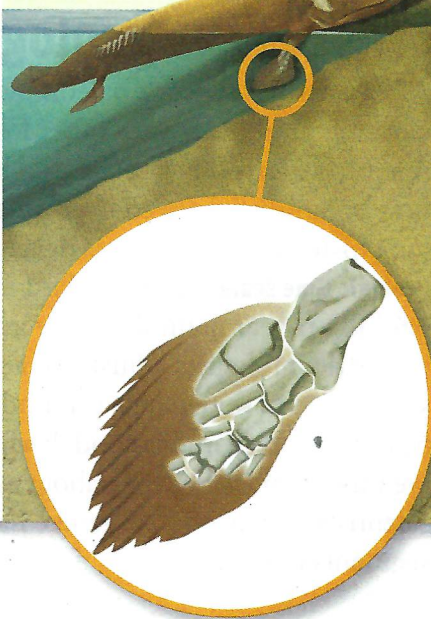
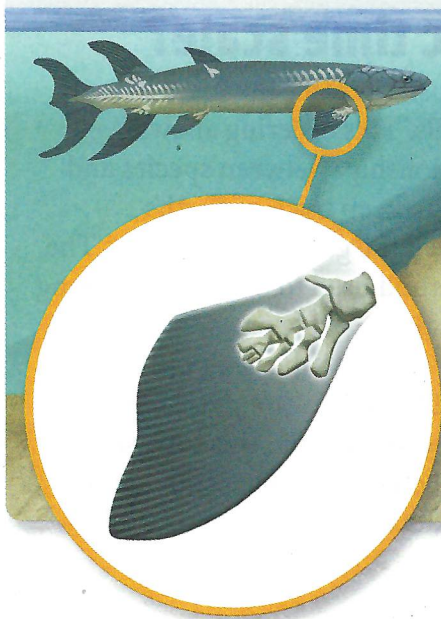
365 Ma

Eusthenopteron

Tiktaalik

Ichthyostega

Fossils (names of the species shown above) indicate changes in limb structure as adaptations allowed movement on land.



How Life Forms Have Changed over Time

The fossil record gives evidence of many of the different organisms that have lived during Earth's long history. Each fossil gives information about a single organism. But the overall fossil record helps us understand larger patterns of change.

Over many generations, populations change. These changes can be preserved in fossils. For example, fossils show the gradual change in limb structure, over many millions of years, of animals such as the ones shown in the drawing above.

Some species are present in the fossil record for a relatively short period of time. Other species have survived for long time spans without much change. The hard-plated horseshoe crab, for example, has changed little over the last 350 million years.

When Extinctions Occurred

An **extinction** happens when every individual of a species dies. A mass extinction occurs when a large number of species go extinct during a relatively short amount of time. Gradual environmental changes can cause mass extinctions. Catastrophic events, such as the impact of an asteroid, can also cause mass extinctions.

Extinctions and mass extinctions are documented in the fossil record. Fossils that were common in certain rock layers may decrease in frequency and eventually disappear altogether. Based on evidence in the fossil record, scientists form hypotheses about how and when species went extinct.

Visualize It!

7 Describe What changes do you see in the limb structure of the three animals above?

Active Reading

8 Describe How can the extinction of an organism be inferred from evidence in the fossil record?

Way Back When

What is the geologic time scale?

Active Reading

9 Identify Underline one reason why it is hard for scientists to study the early history of Earth.

After a fossil is dated, a paleontologist can place the fossil in chronological order with other fossils. This ordering allows scientists to hypothesize about relationships between species and how organisms changed over time. To keep track of Earth's long history, scientists have developed the geologic time scale. The **geologic time scale** is the standard method used to divide Earth's long 4.6-billion-year natural history into manageable parts.

Paleontologists adjust and add details to the geologic time scale when new evidence is found. The early history of Earth has been poorly understood, because fossils from this time span are rare. As new evidence about early life on Earth accumulates, scientists may need to organize Earth's early history into smaller segments of time.

Visualize It!

10 Identify When did the Paleozoic era begin and end?

Precambrian time (4600 Ma to 542 Ma)

| EONS | |
|------------|-------------|
| Hadean eon | Archean eon |
| 4600 Ma | 2500 Ma |

Ma = million years ago

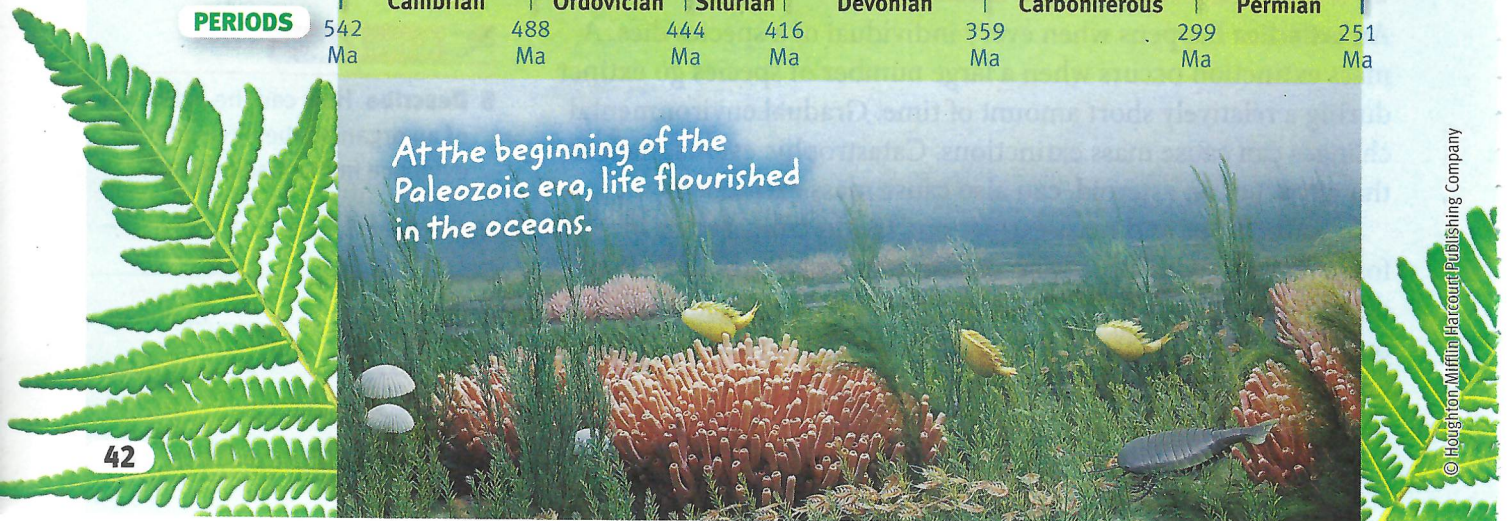
ERAS

Paleozoic era

PERIODS

| Cambrian | Ordovician | Silurian | Devonian | Carboniferous | Permian |
|----------|------------|----------|----------|---------------|---------|
| 542 Ma | 488 Ma | 444 Ma | 416 Ma | 359 Ma | 299 Ma |
| | | | | | 251 Ma |

At the beginning of the Paleozoic era, life flourished in the oceans.



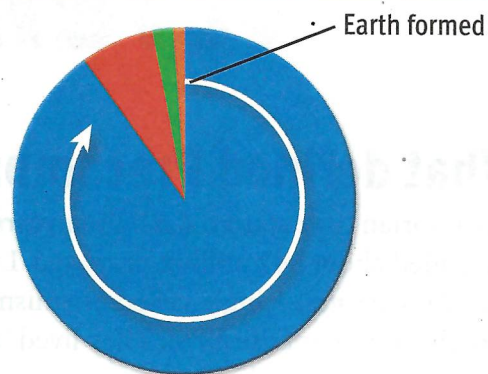
A Tool to Organize Earth's History

Boundaries between geologic time intervals correspond to significant changes in Earth's history. Some major boundaries are defined by mass extinctions or significant changes in the number of species. Other boundaries are defined by major changes in Earth's surface or climate.

The largest divisions of the geologic time scale are eons. Eons are divided into eras. Eras are characterized by the type of organism that dominated Earth at the time. Each era began with a change in the type of organism that was most dominant. Eras are further divided into periods, and periods are divided into epochs.

The four major divisions that make up the history of life on Earth are Precambrian time, the Paleozoic era, the Mesozoic era, and the Cenozoic era. Precambrian time is made up of the first three eons of Earth's history.

Geologic Time Up Until Today

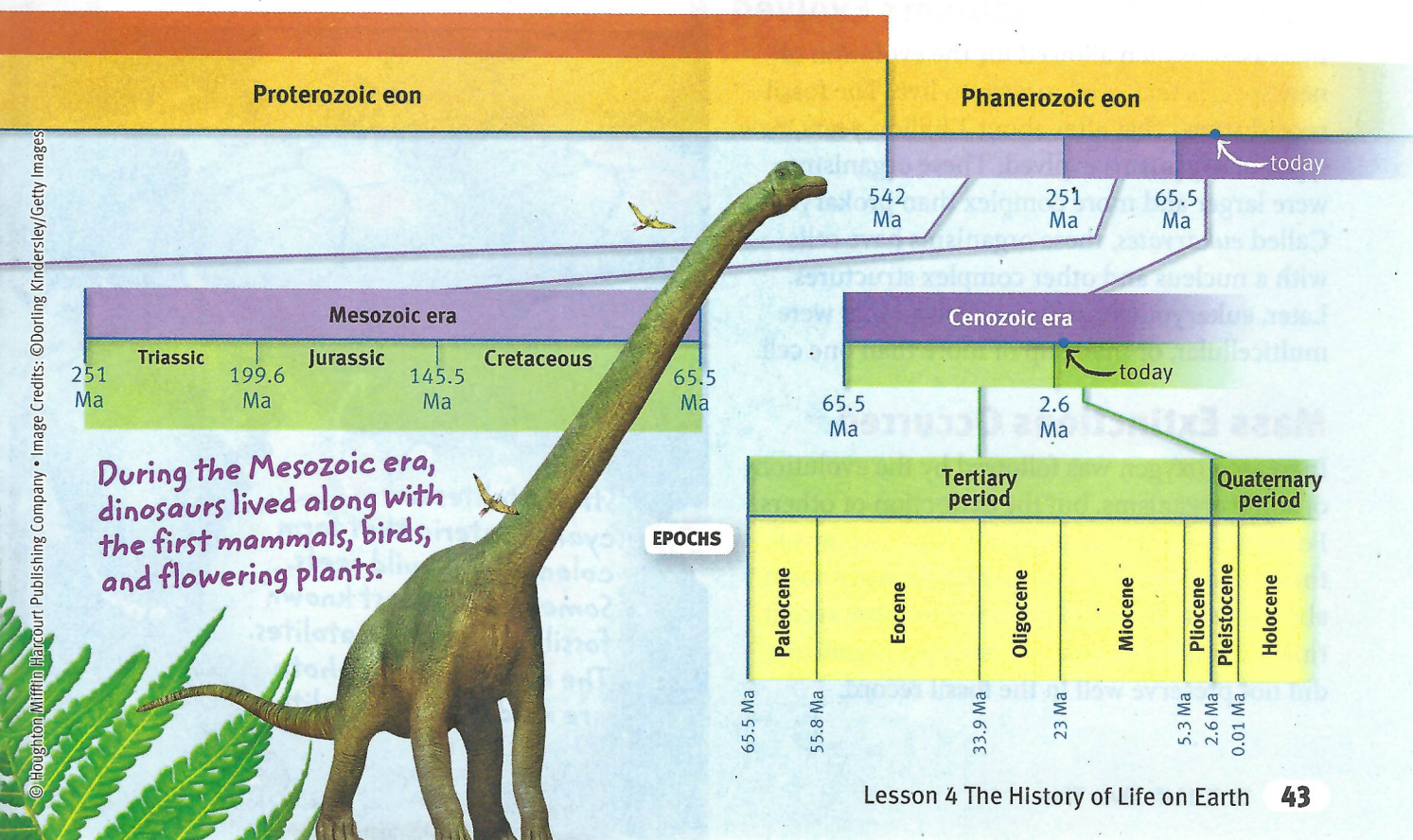


■ Precambrian time ■ Mesozoic era
■ Paleozoic era ■ Cenozoic era

A circle graph can be used to illustrate the divisions of geologic time. As you can see above, most of Earth's past is Precambrian time. Today's era, the Cenozoic era, makes up just a very small percentage of Earth's history.

Visualize It!

11 List Which three periods make up the Mesozoic era?



Ancient Wisdom

What defined Precambrian time?

Precambrian time started 4.6 billion years ago, when Earth formed, and ended about 542 million years ago. Life began during this time. *Prokaryotes*—single-celled organisms without a nucleus—were the dominant life form. They lived in the ocean. The earliest prokaryotes lived without oxygen.

Life Began to Evolve and Oxygen Increased

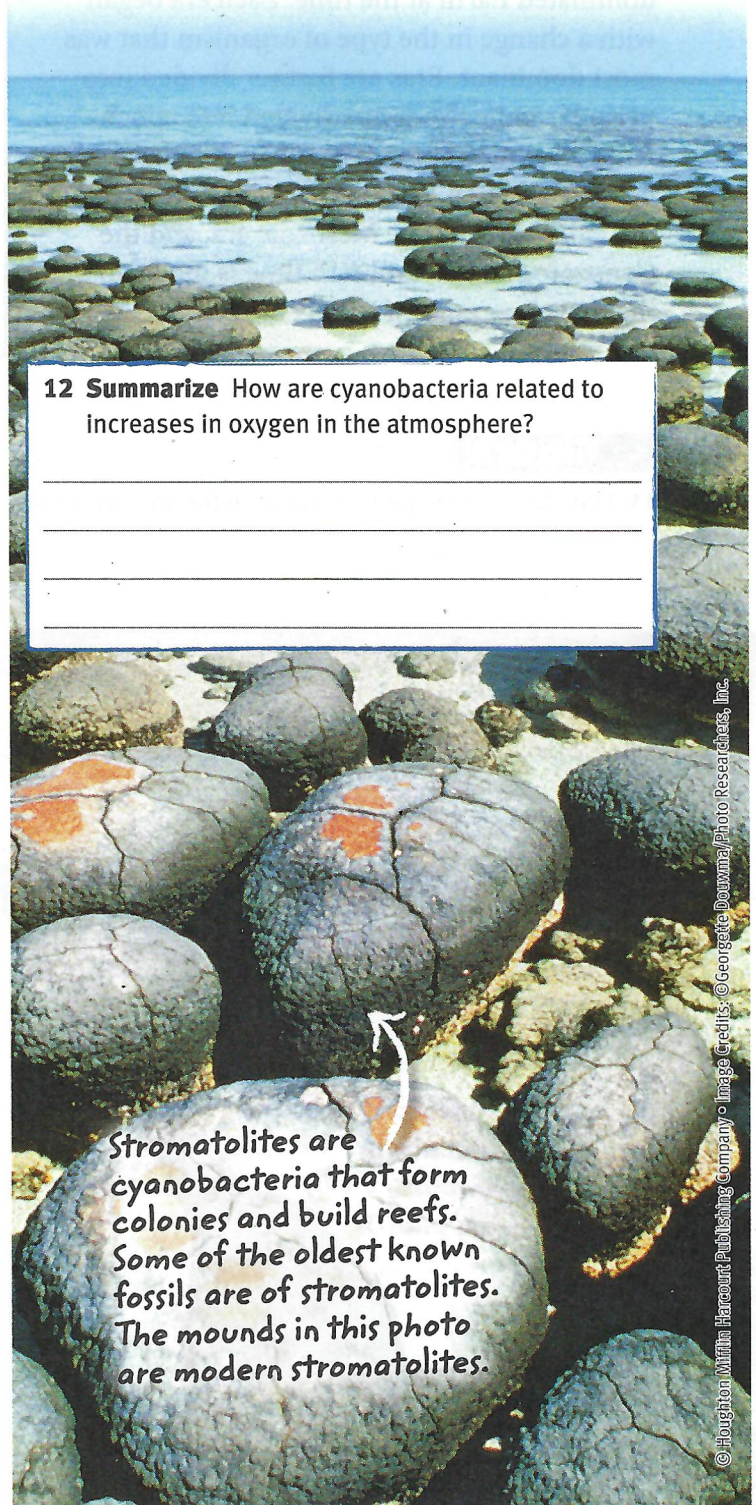
Fossil evidence suggests that prokaryotes called *cyanobacteria* appeared over 3 billion years ago. Cyanobacteria use sunlight to make their own food. This process releases oxygen. Before cyanobacteria appeared, Earth's atmosphere did not contain oxygen. Over time, oxygen built up in the ocean and air. Eventually, the oxygen also formed *ozone*, a gas layer in the upper atmosphere. Ozone absorbs harmful radiation from the sun. Before ozone formed, life existed only in the oceans and underground.

Multicellular Organisms Evolved

Increased oxygen allowed for the evolution of new species that used oxygen to live. The fossil record shows that after about 1 billion years, new types of organisms evolved. These organisms were larger and more complex than prokaryotes. Called *eukaryotes*, these organisms have cells with a nucleus and other complex structures. Later, eukaryotic organisms evolved that were multicellular, or made up of more than one cell.

Mass Extinctions Occurred

Increased oxygen was followed by the evolution of some organisms, but the extinction of others. For some organisms, oxygen is toxic. Many of these organisms became extinct. Less is known about Precambrian life than life in more recent time intervals, because microscopic organisms did not preserve well in the fossil record.



12 Summarize How are cyanobacteria related to increases in oxygen in the atmosphere?

Stromatolites are cyanobacteria that form colonies and build reefs. Some of the oldest known fossils are of stromatolites. The mounds in this photo are modern stromatolites.

What defined the Paleozoic era?

The word *Paleozoic* comes from Greek words that mean “ancient life.” When scientists first named this era, they thought it was the time span in which life began.

The Paleozoic era began about 542 million years ago and ended about 251 million years ago. Rocks from this era are rich in fossils of animals such as sponges, corals, snails, and trilobites. Fish, the earliest animals with backbones, appeared during this era, as did sharks.

Life Moved onto Land

Plants, fungi, and air-breathing animals colonized land during the Paleozoic era. Land dwellers had adaptations that allowed them to survive in a drier environment. All major plant groups except flowering plants appeared. Crawling insects were among the first animals to live on land, followed by large salamander-like animals. By the end of the era, forests of giant ferns covered much of Earth, and reptiles and winged insects appeared.

A Mass Extinction Occurred

The Permian mass extinction took place at the end of the Paleozoic era. It is the largest known mass extinction. By 251 million years ago, as many as 96% of marine species had become extinct. The mass extinction wiped out entire groups of marine organisms such as trilobites. Oceans were completely changed. Many other species of animals and plants also became extinct. However, this opened up new habitats to those organisms that survived.

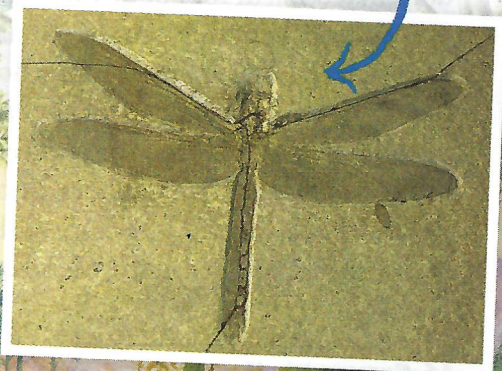
Think Outside the Book Inquiry

13 Compose Select one of the organisms that lived during the Paleozoic era and find out more about it. Make a poster with information about the organism.

Visualize It!

14 Describe Based on this drawing, describe the landscape that existed during the Carboniferous period of the Paleozoic era.

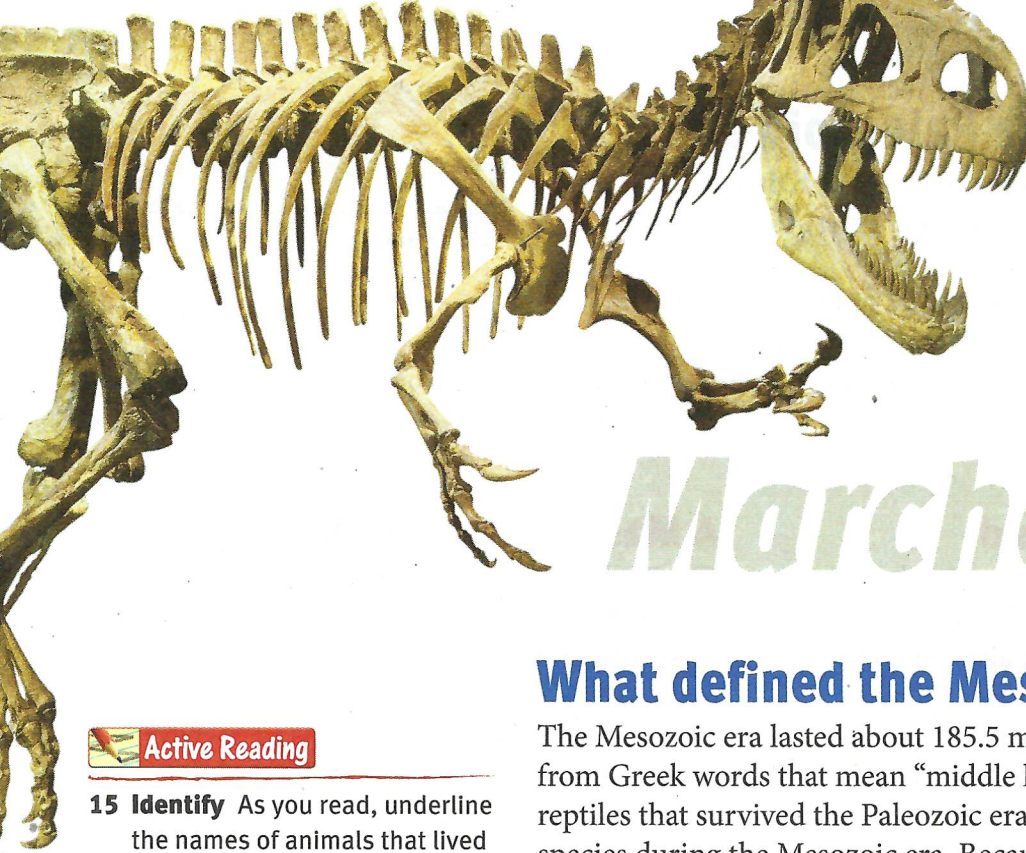
Giant winged insects such as this one were common during the Carboniferous period.



This drawing is an artist's impression of life during the Carboniferous period.



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Time Marches On

Active Reading

15 Identify As you read, underline the names of animals that lived in the Mesozoic era.

What defined the Mesozoic era?

The Mesozoic era lasted about 185.5 million years. *Mesozoic* comes from Greek words that mean “middle life.” Scientists think the reptiles that survived the Paleozoic era evolved into many different species during the Mesozoic era. Because of the abundance of reptiles, the Mesozoic era is commonly called the *Age of Reptiles*.

Dinosaurs and Other Reptiles Dominated Earth

Dinosaurs are the most well-known reptiles that evolved during the Mesozoic era. They dominated Earth for about 150 million years. A great variety of dinosaurs lived on Earth, and giant marine lizards swam in the ocean. The first birds and mammals also appeared. The most important plants during the early part of the Mesozoic era were conifers, or cone-bearing plants, which formed large forests. Flowering plants appeared later in the Mesozoic era.

A Mass Extinction Occurred

Why did dinosaurs and many other species become extinct at the end of the Mesozoic era? Different hypotheses are debated. Evidence shows that an asteroid hit Earth around this time. A main hypothesis is that this asteroid caused giant dust clouds and worldwide fires. With sunlight blocked by dust, many plants would have died. Without plants, plant-eating dinosaurs also would have died, along with the meat-eating dinosaurs that ate the other dinosaurs. In total, about two-thirds of all land species went extinct.

16 Summarize Make a cause-and-effect chart to explain the chain of events that, according to a main hypothesis, resulted in a mass extinction at the end of the Mesozoic era.

| | | | | |
|-------|---|-------|---|-------|
| _____ | → | _____ | → | _____ |
| _____ | | _____ | | _____ |
| _____ | | _____ | | _____ |
| _____ | | _____ | | _____ |
| _____ | | _____ | | _____ |

What defines the Cenozoic era?

The Cenozoic era began about 65 million years ago and continues today. *Cenozoic* comes from Greek words that mean “recent life.” More is known about the Cenozoic era than about previous eras, because the fossils are closer to Earth’s surface and easier to find.

Birds, Mammals, and Flowering Plants Dominate Earth

We currently live in the Cenozoic era. Mammals have dominated the Cenozoic the way reptiles dominated the Mesozoic. Early Cenozoic mammals were small, but larger mammals appeared later. Humans appeared during this era. The climate has changed many times during the Cenozoic. During ice ages, many organisms migrated toward the equator. Other organisms adapted to the cold or became extinct.



Primates evolved during the Cenozoic era.

Primates Evolved

Primates are a group of mammals that includes humans, apes, and monkeys. Primates’ eyes are located at the front of the skull. Most primates have five flexible digits, one of which is an opposable thumb.

The ancestors of primates were probably nocturnal, mouse-like mammals that lived in trees. The first primates did not exist until after dinosaurs died out. Millions of years later, primates that had larger brains appeared.

17 Hypothesize How might the mass extinction that occurred at the end of the Mesozoic era relate to the dominance of mammals in the Cenozoic era?

The Cenozoic era has been dominated by mammals. Woolly mammoths were well-adapted to surviving in a cold climate.

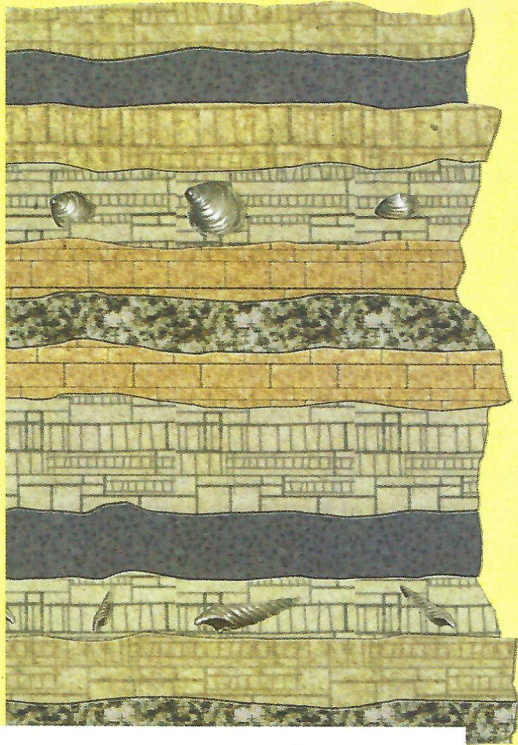


Visual Summary

To complete this summary, circle the correct word. Then, use the key below to check your answers. You can use this page to review the main concepts of the lesson.



The fossil record provides evidence of ancient life.



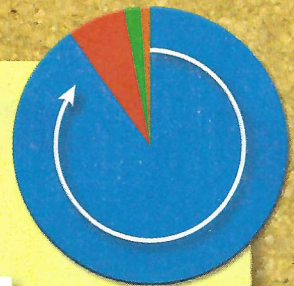
18 *Absolute/Relative* dating estimates the age of a fossil in years.

The geologic time scale divides Earth's history into eons, eras, periods, and epochs.

19 *Epochs/Eras* are characterized by the type of organism that dominated Earth at the time.

The History of Life on Earth

Four major divisions of Earth's past are Precambrian time, the Paleozoic era, the Mesozoic era, and the Cenozoic era.



20 *Primates* evolved during the Mesozoic era/Cenozoic era.

Answers: 18 Absolute; 19 Eras; 20 Cenozoic era

21 **Synthesize** Starting with Precambrian time, briefly describe how life on Earth has changed over Earth's long history.

Lesson Review

Vocabulary

Draw a line to connect the following terms to their definitions.

- | | |
|-----------------------|--|
| 1 fossil | A all of the fossils that have been discovered worldwide |
| 2 geologic time scale | B death of every member of a species |
| 3 fossil record | C trace or remains of an organism that lived long ago |
| 4 extinction | D division of Earth's history into manageable parts |

Key Concepts

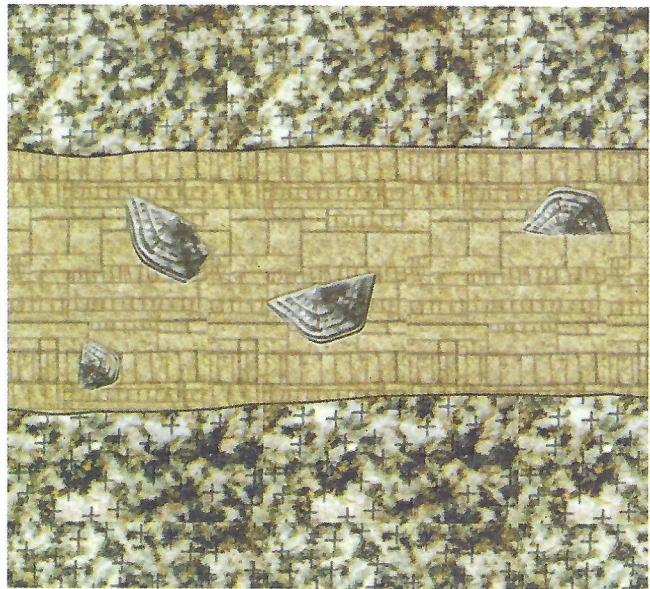
5 List What four major divisions make up the history of life on Earth in the geologic time scale?

6 Explain What is one distinguishing feature of each of the four major divisions listed in your previous answer?

Critical Thinking

7 Contrast How do the atmospheric conditions near the beginning of Precambrian time contrast with the atmospheric conditions that are present now? Which organism is largely responsible for this change?

Use this drawing to answer the following question.



8 Explain The fossils shown are of a marine organism. In which of the three rock layers would you expect to find fossils of an organism that went extinct before the marine organism evolved? Explain your answer.
