Life and Geologic Time

as you read

What You'll Learn

- **Explain** how geologic time can be divided into units.
- **Relate** changes of Earth's organisms to divisions on the geologic time scale.
- **Describe** how plate tectonics affects species.

Why It's Important

The life and landscape around you are the products of change through geologic time.

Review Vocabulary
fossils: remains, traces, or imprints of prehistoric organisms

New Vocabulary
- geologic time scale
- eon
- era
- period
- epoch
- organic evolution
- species
- natural selection
- trilobite
- Pangaea

Geologic Time

A group of students is searching for fossils. By looking in rocks that are hundreds of millions of years old, they hope to find many examples of trilobites (TRI loh bites) so that they can help piece together a puzzle. That puzzle is to find out what caused the extinction of these organisms. **Figure 1** shows some examples of what they are finding. The fossils are small, and their bodies are divided into segments. Some of them seem to have eyes. Could these interesting fossils be trilobites?

Trilobites are small, hard-shelled organisms that crawled on the seafloor and sometimes swam through the water. Most ranged in size from 2 cm to 7 cm in length and from 1 cm to 3 cm in width. They are considered to be index fossils because they lived over vast regions of the world during specific periods of geologic time.

The Geologic Time Scale The appearance or disappearance of types of organisms throughout Earth's history marks important occurrences in geologic time. Paleontologists have been able to divide Earth's history into time units based on the life-forms that lived only during certain periods. This division of Earth's history makes up the **geologic time scale.** However, sometimes fossils are not present, so certain divisions of the geologic time scale are based on other criteria.

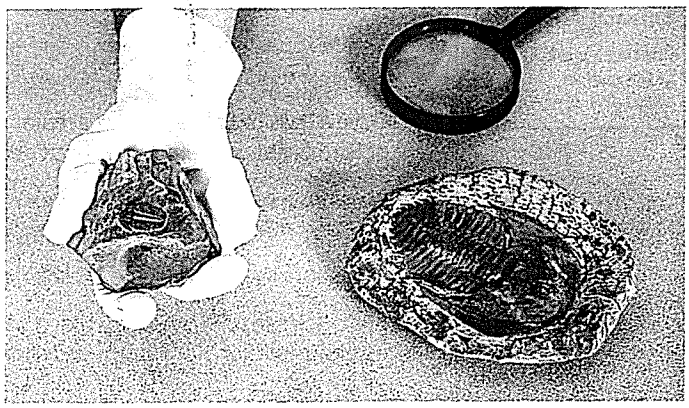


Figure 1 Many sedimentary rocks in the United States are rich in invertebrate fossils such as these trilobites.

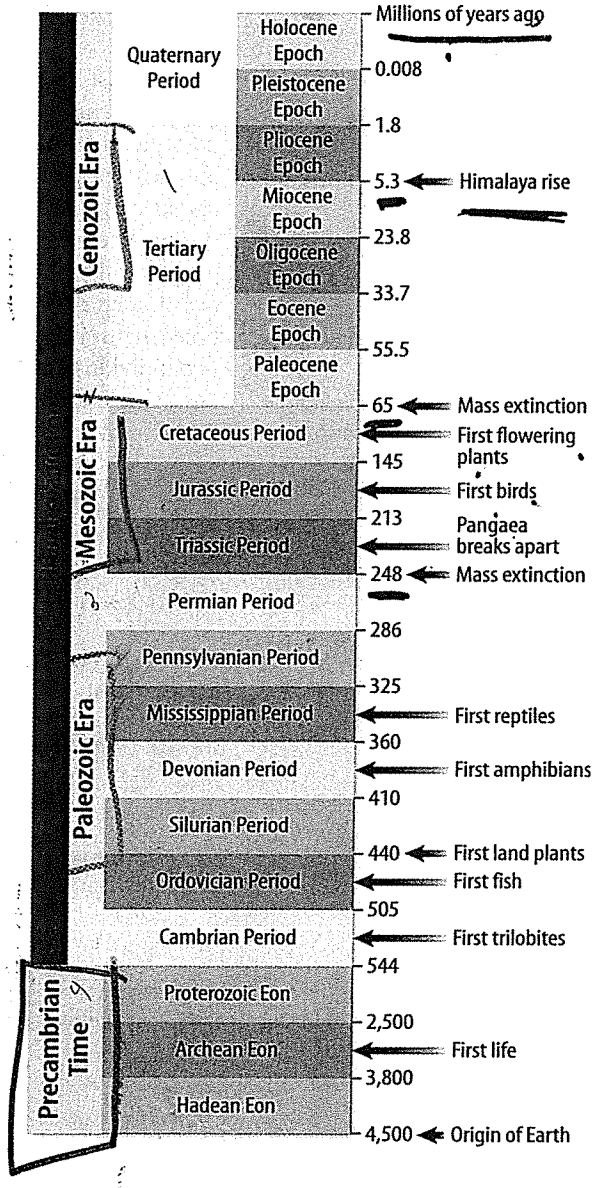
Section 1 Resource Manager

Chapter *FAST FILE* Resources
- Transparency Activity, pp. 42, 45–46
- Directed Reading for Content Mastery, pp. 17, 18
- Note-taking Worksheets, pp. 31–33
- Enrichment, p. 28
- Lab Activity, pp. 9–10
- Reinforcement, p. 25

Earth Science Critical Thinking/Problem Solving, pp. 1, 14, 18

Major Subdivisions of Geologic Time The oldest rocks on Earth contain no fossils. Then, for many millions of years after the first appearance of fossils, the fossil record remained sparse. Later in Earth's history came an explosion in the abundance and diversity of organisms. These organisms left a rich fossil record. As shown in **Figure 2,** four major subdivisions of geologic time are used—eons, eras, periods, and epochs. The longest subdivisions—**eons**—are based upon the abundance of certain fossils.

Figure 2 Scientists have divided the geologic time scale into subunits based upon the appearance and disappearance of types of organisms.
Explain *how the even blocks in this chart can be misleading.*



Reading Check *What are the major subdivisions of geologic time?*

Next to eons, the longest subdivisions are the **eras,** which are marked by major, striking, and worldwide changes in the types of fossils present. For example, at the end of the Mesozoic Era, many kinds of invertebrates, birds, mammals, and reptiles became extinct.

Eras are subdivided into periods. **Periods** are units of geologic time characterized by the types of life existing worldwide at the time. Periods can be divided into smaller units of time called **epochs.** Epochs also are characterized by differences in life-forms, but some of these differences can vary from continent to continent. Epochs of periods in the Cenozoic Era have been given specific names. Epochs of other periods usually are referred to simply as early, middle, or late. Epochs are further subdivided into units of shorter duration.

Dividing Geologic Time There is a limit to how finely geologic time can be subdivided. It depends upon the kind of rock record that is being studied. Sometimes it is possible to distinguish layers of rock that formed during a single year or season. In other cases, thick stacks of rock that have no fossils provide little information that could help in subdividing geologic time.

Curriculum Connection

Geography Periods on the geologic time scale are often named for regions where the rocks of that age were first studied or are widely exposed. Have students use inference to answer these questions. Where were rocks of the Pennsylvanian Period first studied or widely exposed? Pennsylvania Which period represents rocks first studied in the Jura Mountains between France and Switzerland? Jurassic Period L2

2 Teac

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Figure 2 What m
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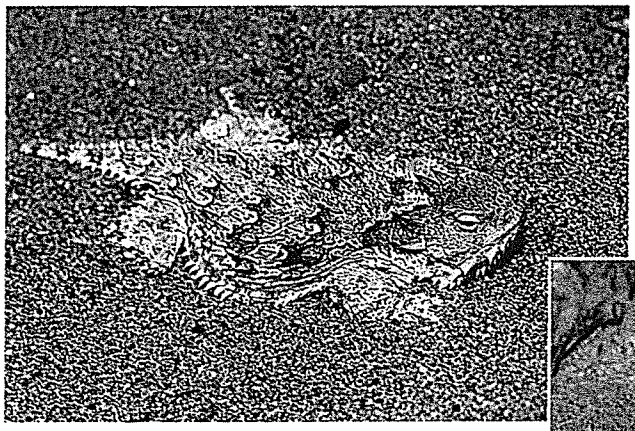
Organic Evolution

The fossil record shows that species have changed over geologic time. This change through time is known as **organic evolution.** According to most theories about organic evolution, environmental changes can affect an organism's survival. Those organisms that are not adapted to changes are less likely to survive or reproduce. Over time, the elimination of individuals that are not adapted can cause changes to species of organisms.

INTEGRATE Life Science **Species** Many ways of defining the term species (SPEE sheez) have been proposed. Life scientists often define a **species** as a group of organisms that normally reproduces only with other members of their group. For example, dogs are a species because dogs mate and reproduce only with other dogs. In some rare cases, members of two different species, such as lions and tigers, can mate and produce offspring. These offspring, however, are usually sterile and cannot produce offspring of their own. Even though two organisms look nearly alike, if the populations they each come from do not interbreed naturally and produce offspring that can reproduce, the two individuals do not belong to the same species. **Figure 3** shows an example of two species that look similar to each other but live in different areas and do not mate naturally with each other.

Figure 3 Just because two organisms look alike does not mean that they belong to the same species.
Describe *an experiment to test if these lizards are separate species.*

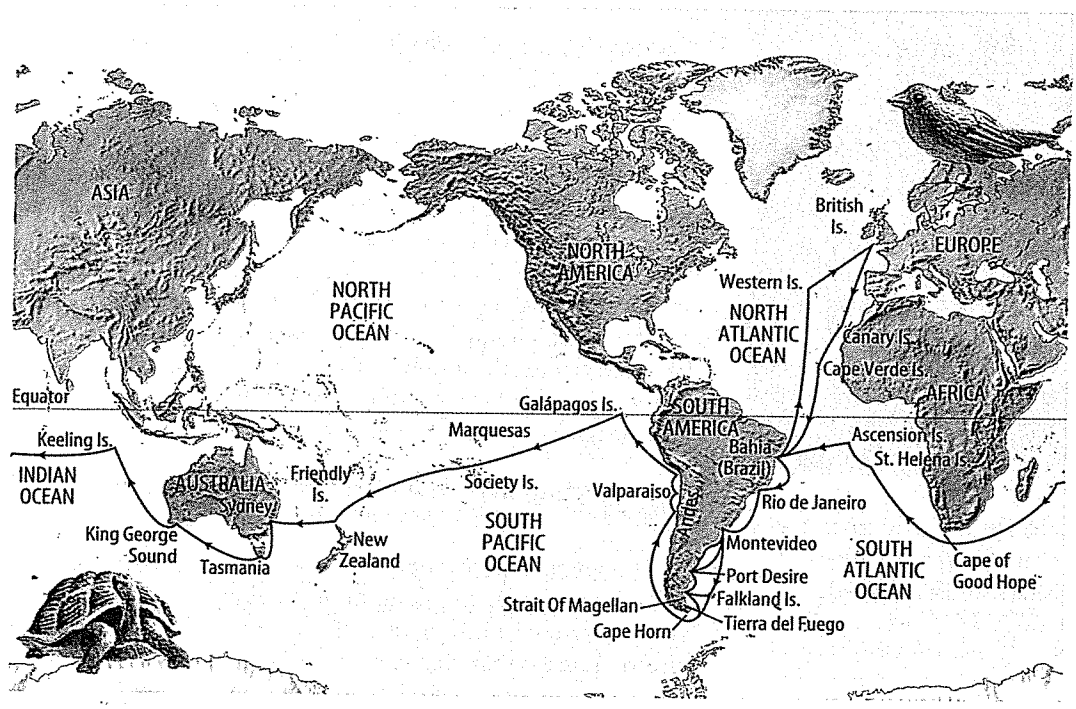


The coast horned lizard lives along the coast of central and southern California.

The desert horned lizard lives in arid regions of the southwestern United States.

Differentiated Instruction

Challenge Have students investigate Lamarck's ideas about acquired characteristics and describe how he explained change within a species. Then have students list the inadequacies of Lamarck's idea. Lamarck's hypothesis was that species evolve by keeping traits that their parents develop during their lives or losing traits that were not used. It's incorrect to think a trait acquired by a parent during its lifetime would be passed on. There is no identified mechanism by which an acquired trait can be passed on. There is also no evidence to back up Lamarck's assumption. For example, if a woman lifts weights, her children won't necessarily be stronger than children of women who do not lift weights. L3



Natural Selection Charles Darwin was a naturalist who sailed around the world from 1831 to 1836 to study biology and geology. **Figure 4** shows a map of his journey. With some of the information about the plants and animals he observed on this trip in mind, he later published a book about the theory of evolution by natural selection.

In his book, he proposed that **natural selection** is a process by which organisms with characteristics that are suited to a certain environment have a better chance of surviving and reproducing than organisms that do not have these characteristics. Darwin knew that many organisms are capable of producing more offspring than can survive. This means that organisms compete with each other for resources necessary for life, such as food and living space. He also knew that individual organisms within the same species could be different, or show variations, and that these differences could help or hurt the individual organism's chance of surviving.

Some organisms that were well suited to their environment lived longer and had a better chance of producing offspring. Organisms that were poorly adapted to their environment produced few or no offspring. Because many characteristics are inherited, the characteristics of organisms that are better adapted to the environment get passed on to offspring more often. According to Darwin, this can cause a species to change over time.

Figure 4 Charles Darwin sailed around the world between 1831 and 1836 aboard the HMS *Beagle* as a naturalist. On his journey he saw an abundance of evidence for natural selection, especially on the Galápagos Islands off the western coast of South America.

Science Journal

Theories of Organic Evolution Have students compare and contrast *gradualism* and *punctuated equilibrium* in their Science Journals. Both are theories of organic evolution; gradualism refers to a gradual, slow change in species; punctuated equilibrium describes sudden bursts of evolution separated by times of little change. L2
Linguistic P

Teacher FYI

Darwin Family Charles Darwin was the grandson of Erasmus Darwin. Erasmus was a noted physician and naturalist in his own right and had proposed his own theory of evolution in the 1790s.

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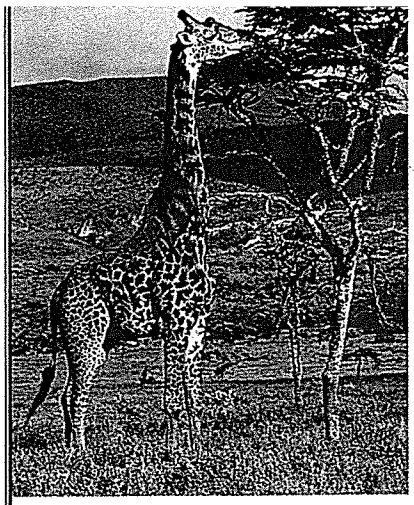


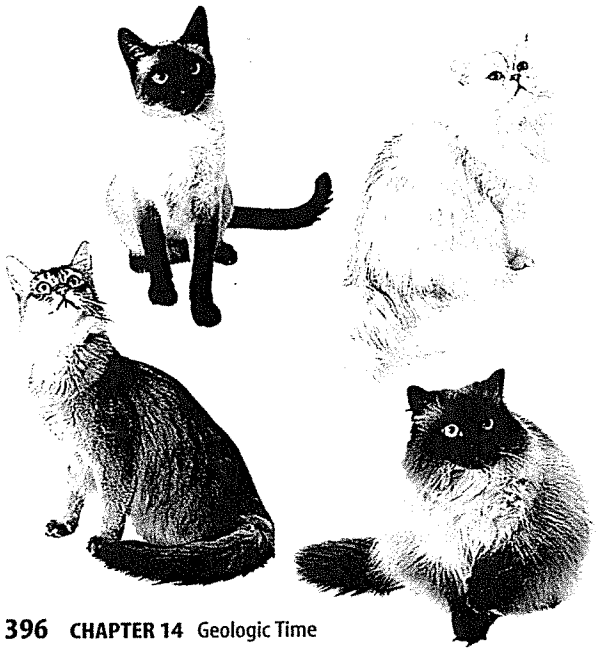
Figure 5 Giraffes can eat leaves off the branches of tall trees because of their long necks.

Natural Selection Within a Species Suppose that an animal species exists in which a few of the individuals have long necks, but most have short necks. The main food for the animal is the leafy foliage on trees in the area. What happens if the climate changes and the area becomes dry? The lower branches of the trees might not have any leaves. Now which of the animals will be better suited to survive? Clearly, the long-necked animals have a better chance of surviving and reproducing. Their offspring will have a greater chance of inheriting the important characteristic. Gradually, as the number of long-necked animals becomes greater, the number of short-necked animals decreases. The species might change so that nearly all of its members have long necks, as the giraffe in **Figure 5** has.

Reading Check *What might happen to the population of animals if the climate became wet again?*

It is important to notice that individual, short-necked animals didn't change into long-necked animals. A new characteristic becomes common in a species only if some members already possess that characteristic and if the trait increases the animal's chance of survival. If no animal in the species possessed a long neck in the first place, a long-necked species could not have evolved by means of natural selection.

Figure 6 Cat breeders have succeeded in producing a great variety of cats by using the principle of artificial selection.



Artificial Selection Humans have long used the principle of artificial selection when breeding domestic animals. By carefully choosing individuals with desired characteristics, animal breeders have created many breeds of cats, dogs, cattle, and chickens. **Figure 6** shows the great variety of cats produced by artificial selection.

The Evolution of New Species Natural selection explains how characteristics change and how new species arise. For example, if the short-necked animals migrated to a different location, they might have survived. They could have continued to reproduce in the new location, eventually developing enough different characteristics from the long-necked animals that they might not be able to breed with each other. At this point, at least one new species would have evolved.

Cultural Diversity

Domestication Domestication is the process of selectively breeding wild animals and plants into forms that better serve the needs of people. The first attempts at domestication were made as early as 9000 B.C. by tribes that engaged in hunting and in gathering wild edible plants. Dogs, goats, and possibly sheep were the first animals to be domesticated. Plants with tubers probably were domesticated before seed plants—cereals, legumes, and other vegetables. Some plants were domesticated for their fibrous stalks, which were used for making fishing nets. Suggest that interested students research some of the earliest domesticated plants and animals, such as wheat, dogs, sheep, cattle, horses, and chickens. Have them explain the different characteristics people were looking for as they bred these organisms. L2

Trilobites

Remember the trilobites? The term *trilobite* comes from the structure of the hard outer skeleton or exoskeleton. The exoskeleton of a **trilobite** consists of three lobes that run the length of the body. As shown in **Figure 7,** the trilobite's body also has a head (cephalon), a segmented middle section (thorax), and a tail (pygidium).

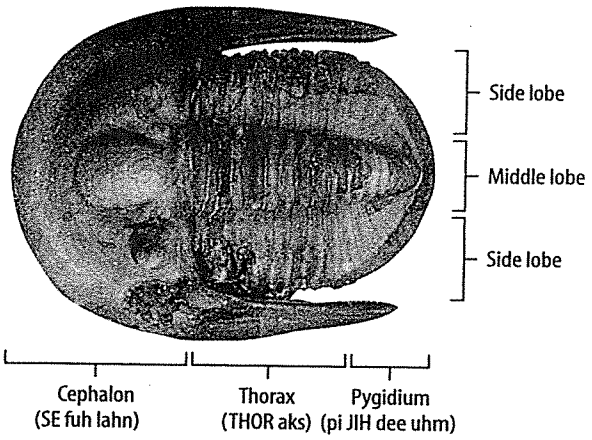


Figure 7 The trilobite's body was divided into three lobes that run the length of the body—two side lobes and one middle lobe.

Changing Characteristics of Trilobites Trilobites inhabited Earth's oceans for more than 200 million years. Throughout the Paleozoic Era, some species of trilobites became extinct and other new species evolved. Species of trilobites that lived during one period of the Paleozoic Era showed different characteristics than species from other periods of this era. As **Figure 8** shows, paleontologists can use these different characteristics to demonstrate changes in trilobites through geologic time. These changes can tell you about how different trilobites from different periods lived and responded to changes in their environments.

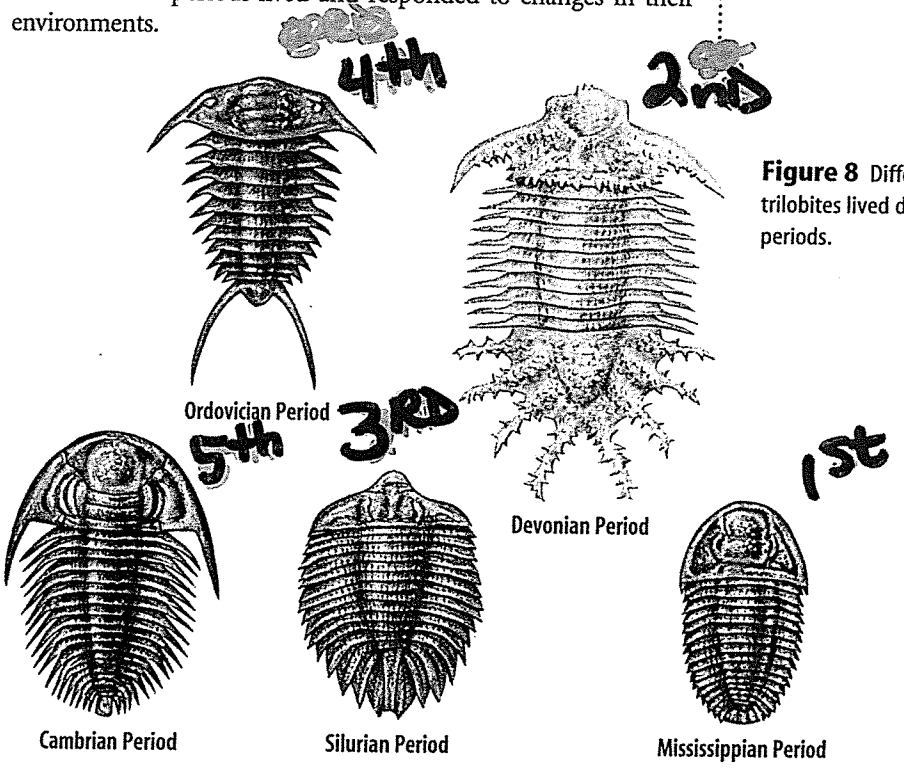


Figure 8 Different kinds of trilobites lived during different periods.

Differentiated Instruction

English-Language Learners Take five minutes to illustrate deep time. Keep track of a five-minute period that will represent the 4.5 billion years of Earth's history. At about 1 minute, 7 seconds, announce that life begins. At 4 minutes, 24 seconds, announce the start of the Paleozoic Era. At 4 minutes, 43 seconds, the Mesozoic Era begins, and at 4 minutes, 55 seconds, the Cenozoic Era begins. Announce the appearance of humans just before time expires. L2

Teacher

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Virtual Labs

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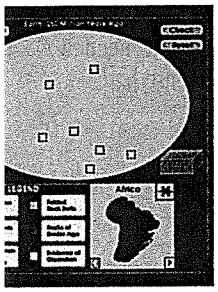


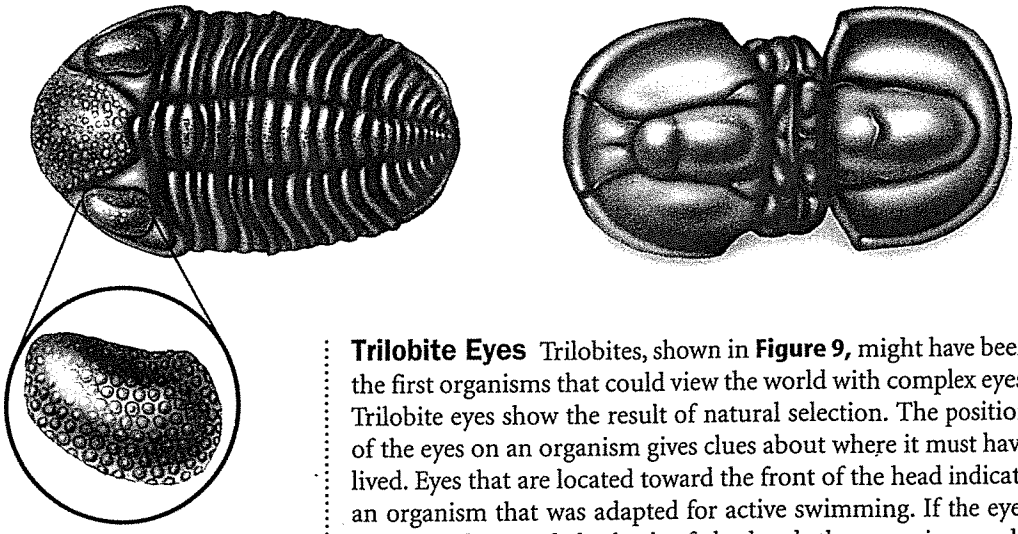
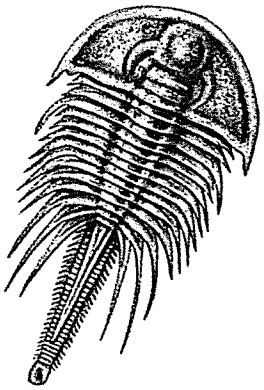


Figure 9 Trilobites had many different types of eyes. Some had eyes that contained hundreds of small circular lenses, somewhat like an insect. The blind trilobite (right) had no eyes.

Trilobite Eyes Trilobites, shown in **Figure 9,** might have been the first organisms that could view the world with complex eyes. Trilobite eyes show the result of natural selection. The position of the eyes on an organism gives clues about where it must have lived. Eyes that are located toward the front of the head indicate an organism that was adapted for active swimming. If the eyes are located toward the back of the head, the organism could have been a bottom dweller. In most species of trilobites, the eyes were located midway on the head—a compromise for an organism that was adapted for crawling on the seafloor and swimming in the water.

Over time, the eyes in trilobites changed. In many trilobite species, the eyes became progressively smaller until they completely disappeared. Blind trilobites, such as the one on the right in **Figure 9,** might have burrowed into sediments on the seafloor or lived deeper than light could penetrate. In other species, however, the eyes became more complex. One kind of trilobite, *Aeglina,* developed large compound eyes that had numerous individual lenses. Some trilobites developed stalks that held the eyes upward. Where would this be useful?

Figure 10 *Olenellus* is one of the most primitive trilobite species.



Trilobite Bodies The trilobite body and tail also underwent significant changes in form through time, as you can see in **Figure 8** on the previous page. A special case is *Olenellus,* shown in **Figure 10.** This trilobite, which lived during the Early Cambrian Period, had an extremely segmented body—perhaps more so than any other known species of trilobite. It is thought that *Olenellus,* and other species that have so many body segments, are primitive trilobites.

Fossils Show Changes Trilobite exoskeletons changed as trilobites adapted to changing environments. Species that could not adapt became extinct. What processes on Earth caused environments to change so drastically that species adapted or became extinct?

Curriculum Connection

Math Have students construct a circle graph showing the 4.5 billion years of Earth's history divided into four major units of geologic time. The Precambrian represents about 88.3%; the Paleozoic Era about 6.4%; the Mesozoic Era about 3.9%; and the Cenozoic Era about 1.4% of Earth's history. L2 LS **Logical-Mathematical**

Active Reading

Flow Chart A flow chart helps students logically sequence events. Have students write the geologic eras in a series of large rectangles. As students read the chapter, have them write major events that occurred in each era in smaller rectangles under the large rectangles. L2

Plate Tectonics and Earth History

Plate tectonics is one possible answer to the riddle of trilobite extinction. Earth's moving plates caused continents to collide and separate many times. Continental collisions formed mountains and closed seas caught between continents. Continental separations created wider, deeper seas between continents. By the end of the Paleozoic Era, sea levels had dropped and the continents had come together to form one giant landmass, the supercontinent **Pangaea** (pan JEE uh). Because trilobites lived in the oceans, their environment was changed or destroyed. **Figure 11** shows the arrangement of continents at the end of the Paleozoic Era. What effect might these changes have had on the trilobite populations?

Not all scientists accept the above explanation for the extinctions at the end of the Paleozoic Era, and other possibilities—such as climate change—have been proposed. As in all scientific debates, you must consider the evidence carefully and come to conclusions based on the evidence.

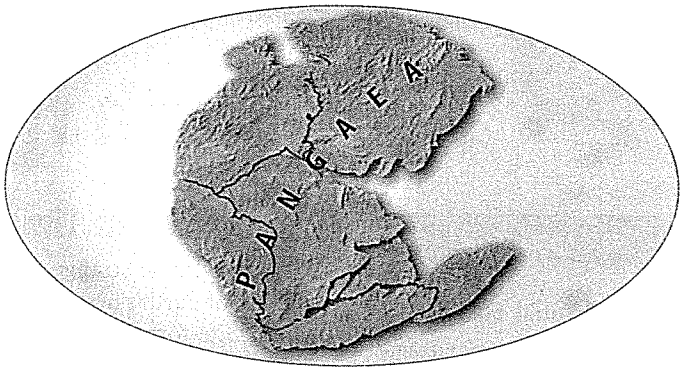


Figure 11 The amount of shallow water environment was reduced when Pangaea formed. **Describe** *how this change affected organisms that lived along the coasts of continents.*

section 1 review

Summary

Geologic Time

- Earth's history is divided into eons, eras, periods, and epochs, based on fossils.

Organic Evolution

- The fossil record indicates that species have changed over time.
- Charles Darwin proposed natural selection to explain change in species.
- In natural selection, organisms best suited to their environments survive and produce the most offspring.

Trilobites

- Trilobites were abundant in the Paleozoic fossil record and can be used as index fossils.

Plate Tectonics and Earth History

- Continents moving through time have influenced the environments of past organisms.

Self Check

1. **Discuss** how fossils relate to the geologic time scale.
2. **Infer** how plate tectonics might lead to extinction.
3. **Infer** how the eyes of a trilobite show how it lived.
4. **Explain** how paleontologists use trilobite fossils as index fossils for various geologic time periods.
5. **Think Critically** Aside from moving plates, what other factors could cause an organism's environment to change? How would this affect species?

Applying Skills

6. **Recognize Cause and Effect** Answer the questions below.
   a. How does natural selection cause evolutionary change to take place?
   b. How could the evolution of a characteristic within one species affect the evolution of a characteristic within another species? Give an example.

section 1 review

1. Appearance, disappearance, or change in abundance and diversity of fossil organisms can be used to subdivide geologic time.
2. Changes in Earth's surface that altered habitats could have caused organisms with traits less suited to the new habitat to become extinct.
3. no eyes: deep water, burrower; stalked eyes: burrower; eyes toward front of head: swimmer; eyes toward back of head: bottom-dweller
4. Trilobites lived over a wide area and during different short periods of geologic time.
5. Possible answer: Changes in climate; these changes could have caused organisms to evolve different structures and eventually result in a new species.
6. a. Organisms best suited to survive pass traits to young. Over time, the species evolves.
   b. Possible answer: If a evolves so that it ea food instead of ano that it preys on wo The prey species wo that traits that help would be emphasiz

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Figure 11 The habita isms would have char these organisms wou extinct if they could no

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Process Assess stud to observe and inf them look at phc anteaters and infe animals have long tongues. Use **P Assessment in t Classroom**, p. 89.