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19 History of Life

Key

Big idea Evolution

Q: How do fossils help biologists understand the history of life on Earth?

	WHAT I KNOW	WHAT I LEARNED
19.1 How do scientists use fossils to study Earth's history?	SAMPLE ANSWER: *Fossils give clues about how organisms have changed.*	SAMPLE ANSWER: *From the fossil record, paleontologists learn about the structure of ancient organisms, their environment, and the way they lived.*
19.2 What are some patterns in which evolution has occurred?	SAMPLE ANSWER: *Organisms have grown in complexity over time.*	SAMPLE ANSWER: *Evidence shows that evolution has often proceeded at different rates for different organisms at different times over the long history of life on Earth. Patterns of macroevolution include speciation, extinction, adaptive radiation, convergent evolution, and coevolution.*
19.3 What happened during Earth's early history?	SAMPLE ANSWER: *Earth's features, such as its ocean and atmosphere, formed during its early history.*	SAMPLE ANSWER: *Early Earth had little or no oxygen in its atmosphere. Around 2.2 billion years ago, photosynthetic organisms evolved and began producing oxygen. Early multicellular organisms underwent adaptive radiations that led to great diversity.*

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19.1 The Fossil Record

Lesson Objectives

- Explain what information fossils can reveal about ancient life.
- Differentiate between relative dating and radiometric dating.
- Identify the divisions of the geologic time scale.
- Describe how environmental processes and living things have shaped life on Earth.

Lesson Summary

Fossils and Ancient Life Fossils are preserved remains or traces of ancient life.

- Fossils are the most important source of information about extinct species. An **extinct** species is one that has died out.
- Most fossils are preserved in sedimentary rock. Sediments build up over time, and bury the remains and traces of dead organisms.
- Scientists who study fossils are called **paleontologists**.

Dating Earth's History Relative dating and radiometric dating are used to determine the age of fossils.

- **Relative dating** establishes the relative age of fossils. Fossils from deeper rock layers are assumed to be older than fossils from rock layers closer to the surface. **Index fossils** represent species that lived for a short period of time but over a wide geographic range. Index fossils can help determine the relative ages of rock layers and their fossils.
- **Radiometric dating** determines a fossil's approximate age in years by finding the proportion of radioactive to nonreactive isotopes in a sample. Radioactive isotopes in fossils and rock layers decay, or break down, at a steady rate, called a half-life. A **half-life** is the length of time needed for half of the radioactive atoms in a sample to decay. A fossil's age is calculated from the half-life and the amount of remaining radioactive atoms the fossil contains.

Geologic Time Scale The **geologic time scale** is a time line of Earth's history based on relative and absolute dating.

- The scale begins with the Precambrian.
- Geologic time is divided into four eons: the Hadean, Archean, Proterozoic, and Phanerozoic. The Phanerozoic eon is divided into three **eras**: the Paleozoic, Mesozoic, and Cenozoic.
- Each era is further divided into smaller lengths of time, called **periods**.

Life on a Changing Planet Climactic, geological, astronomical, and biological processes have affected the history of life on Earth.

- Earth's climate has changed often in the course of its history. Small temperature shifts can bring about heat waves and ice ages which have great effects on living things. **Plate tectonics** is a theory that Earth's outermost layer is divided into plates that move. The movement, called continental drift, has transformed life on Earth through the formation of mountain ranges, supercontinents, and other geologic features.
- The impact of objects from space has affected the global climate.

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Fossils and Ancient Life

For Questions 1–3, complete each statement by writing the correct word or words.

1. Species that died out are said to be ***extinct***.
2. Most fossils are found in layers of ***sedimentary*** rock.
3. Scientists who study fossils are called ***paleontologists***.
4. What is the fossil record?
   It is the total collection of fossils on Earth, plus the information about past life inferred from fossils.
5. What information does the fossil record provide?
   It provides evidence about the history of life on Earth including how organisms have changed over time. It tells about the structures of ancient organisms, their environment, and the way they lived.
6. Fill in the flowchart to explain how fossils are formed.

Water carries small rock particles to lakes and seas.

↓

Dead organisms are buried by layers of sediment, which forms new rock.

↓

The preserved fossil remains may later be discovered and studied.

Dating Earth's History

7. What is an index fossil? What do index fossils reveal about other material found with them?
   Index fossils are distinctive fossils used to establish and compare the ages of rock layers and the fossils they contain. Useful index fossils existed for a relatively short period of time and were distributed over a wide area. Anything found in a rock layer near an index fossil is assumed to have existed at approximately the same time.
8. Fossil A is found in a layer of rock above a layer containing Fossil B. Which fossil is probably older? Explain your answer. ***Fossil B is older. Newer layers of rock lie usually above older layers.***
9. List the two techniques paleontologists use to determine the age of fossils.
   relative dating, radiometric dating

10. What is a half-life? ***It is the length of time required for half of the radioactive atoms in a sample to decay.***

11. How do scientists calculate the age of a sample using radiometric dating? ***They measure the amount of remaining radioactive isotopes it contains. The smaller the amount is, the older the sample is.***

For Questions 12–13, write the letter of the correct answer on the line at the left.

A 12. A species that is easily recognizable, existed for a relatively short period of time, and covered a wide geographic area may be used as a(n)

A. index fossil.
B. fossil record.
C. microfossil.
D. macrofossil.

C 13. The same index fossil is found in rock layers A and B that are separated by several miles. What can you infer about the relationship between the rock layers?

A. Layer A is older than B.
B. The sediments in layer B were deposited before those in layer A.
C. Layers A and B are probably about the same age.
D. Layer B probably contains more radioactive isotopes than layer A.

Geologic Time Scale

14. Fill in the missing eras and periods in the geologic time scale below.

Time (millions of years ago)	Period	Era
1.8–present	Quaternary	***Cenozoic***
23–1.8	***Neogene***	
65.5–23	Paleogene	
146–65.5	***Cretaceous***	***Mesozoic***
200–146	Jurassic	
251–200	***Triassic***	
299–251	Permian	Paleozoic
359–299	***Carboniferous***	
416–359	Devonian	
444–416	***Silurian***	
488–444	Ordovician	
542–488	***Cambrian***	
4600–542	Precambrian Time	

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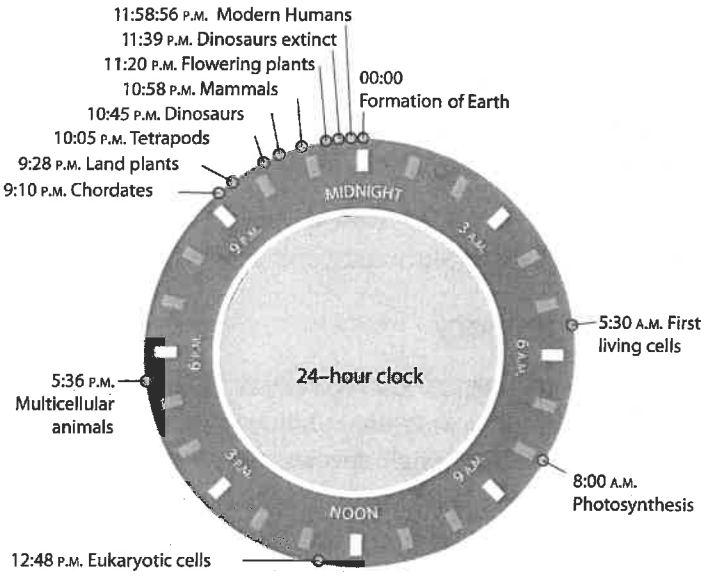
For Questions 15–16, refer to the Visual Analogy of life as a clock.

C 15. VISUAL ANALOGY Which of the following appeared on Earth most recently?

A. chordates
B. tetrapods
C. dinosaurs
D. single-celled algae



A 16. Dinosaurs appeared before

A. mammals.
B. photosynthesis.
C. chordates.
D. land plants.

Processes Affecting Life's History

17. How might an asteroid impact change Earth's climate?

When the asteroid strikes Earth, it would throw up a great deal of debris into the atmosphere. The debris would block much of the sun's light, thus causing global temperatures to fall and decreasing the amount of plant life that could survive on Earth.

18. Explain the theory of plate tectonics and tell how it has affected the distribution of fossils and organisms. ***According to the plate tectonics theory, Earth's outermost layer is divided into huge plates that have moved in the past and continue to move. The movement of the plates is called continental drift. Continental drift affected the distribution of fossils and living organisms. As the continents drifted apart, they carried organisms with them.***

Apply the Big idea

19. What are some aspects of a species' evolution that can't be studied using fossil evidence? Why don't fossils provide information about these characteristics?

SAMPLE ANSWER: Fossils can't usually provide information about the soft tissues of an organism because soft tissues rarely become fossilized. Also, fossils rarely provide information about interactions among organisms and thus tell us little about animal behavior.

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19.2 Patterns and Processes of Evolution

Lesson Objectives

- Identify the processes that influence survival or extinction of a species or clade.
- Contrast gradualism and punctuated equilibrium.
- Name two important patterns in macroevolution.
- Explain the evolutionary characteristics of coevolving organisms.

Lesson Summary

Speciation and Extinction

Macroevolutionary patterns are grand transformations in anatomy, phylogeny, ecology, and behavior that usually take place in clades larger than a single species.

- If the rate of speciation in a clade is equal to or greater than the rate of extinction, the clade will continue to exist. If the rate of extinction in a clade is greater than the rate of speciation, the entire clade will eventually become extinct.
- **Background extinction** is extinction caused by the slow process of natural selection. **Mass extinctions** affect huge numbers of species over a relatively short time.

Rate of Evolution

Evidence shows that evolution has occurred at different rates for different organisms at different times.

- The idea that evolution occurs slowly and gradually is called **gradualism**.
- In **punctuated equilibrium**, long periods of little or no change are interrupted by short periods of rapid change.

Adaptive Radiation and Convergent Evolution

Adaptive radiation is the process in which a single species evolves into diverse species that live in different ways. **Convergent evolution** is the process in which unrelated species come to look alike because they have evolved similar adaptations in response to similar environments.

Coevolution

Coevolution is the process by which two species evolve in response to changes in each other over time. For example, plants evolved poisons that protected them from insects. In response, insects evolved ways of protecting themselves from the poisons.

Speciation and Extinction

For Questions 1–4, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

1. ***macroevolutionary patterns*** Large-scale evolutionary changes that usually take place over long periods of time are referred to as <u>speciation</u>.
2. ***mass extinction*** Many species disappear rapidly during a <u>background extinction</u>.
3. ***True*** The <u>rate of speciation</u> in a clade must be equal to or greater than the rate of extinction in order for a clade to survive.
4. ***True*** Immediately after a mass extinction, <u>biodiversity</u> is dramatically reduced.

5. What are possible causes of mass extinction?

Some possible causes of mass extinction include a huge asteroid striking Earth, many large volcanoes erupting, continents changing position, and sea levels changing.

6. What effects have mass extinctions had on the history of life?

The disappearance of so many species leaves behind empty niches in an ecosystem. New species often evolve to fill these niches.

Rate of Evolution

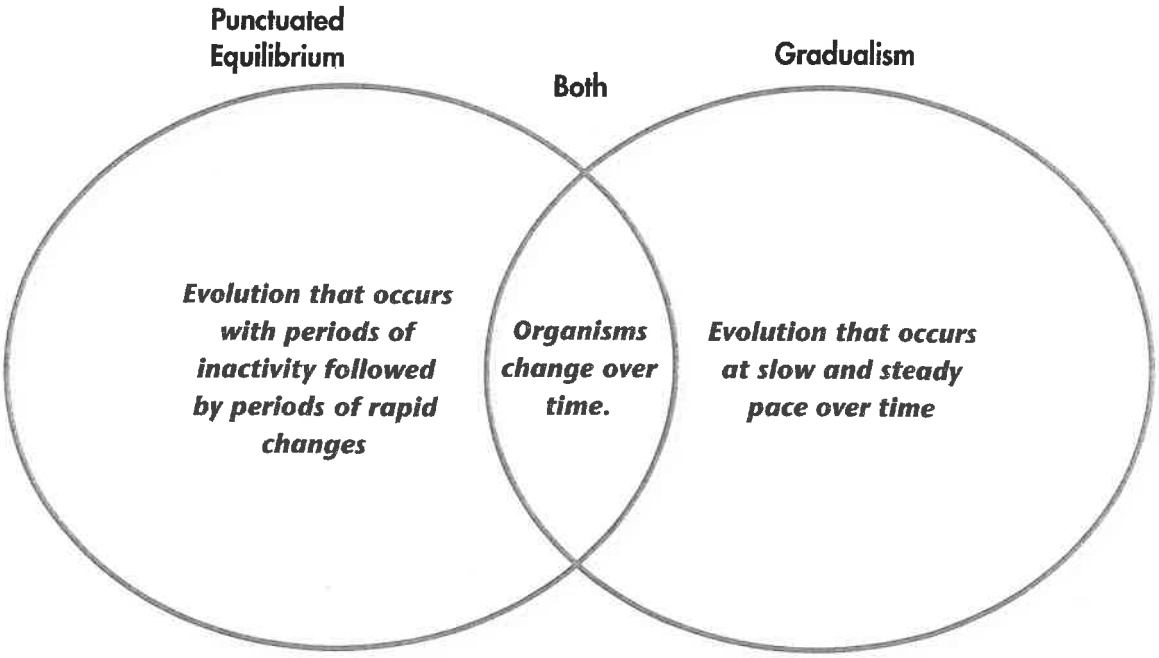
7. Horseshoe crabs have changed little in structure from the time they first showed up in the fossil record. Which pattern of evolution do horseshoe crabs likely follow—gradualism or punctuated equilibirum? Explain your answer.

Horsehoe crabs follow a punctuated equilibrium pattern. In punctuated equilibirum, there are long periods of little or no change interrupted by rapid change. If horseshoe crabs were following a gradualism pattern, you'd expect them to be changing slowly and constantly.

8. Why does rapid evolution occur more often in small populations?

Because genetic changes can spread more easily in small populations. This happens in both genetic drift and genetic bottlenecks.

9. Use the Venn diagram below to compare punctuated equilibrium with gradualism.



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Adaptive Radiation and Convergent Evolution

Write the letter of the correct answer on the line at the left.

C 10. The process in which a single species or a small group of species evolves into diverse forms that live in different ways is called
- A. coevolution.
- B. macroevolution.
- C. adaptive radiation.
- D. convergent evolution.

D 11. The process by which unrelated organisms come to resemble one another is
- A. coevolution.
- B. macroevolution.
- C. adaptive radiation.
- D. convergent evolution.

B 12. What contributed to the adaptive radiation of mammals?
- A. the evolution of plants
- B. the extinction of most dinosaurs
- C. the decrease in ocean depth
- D. continental drift

C 13. Which of the following is an example of convergent evolution?
- A. bird's wing and fish's fin
- B. human's arm and bird's wing
- C. shark's fin and dolphin's limb
- D. human's leg and dolphin's limb

Coevolution

14. What is coevolution? ***Coevolution is the process by which two species evolve in response to changes in each other over time.***

15. 'I'iwi birds have long, curved beaks that enable them to get nectar from tubular lobelia flowers. Explain how these two species might have coevolved. What might happen if the lobelia die out?
The beak of the 'i'iwi bird has coevolved to match the shape of the lobelia flowers. Over time 'i'iwi birds with long, curved beaks were more successful at surviving and producing offspring than birds without these traits. If the lobelia flowers die out, the 'i'iwi birds would have to adapt to a new food source or they would also die out.

Apply the Big idea

16. What is the relationship between environmental change and the following macroevolutionary patterns: speciation, mass extinction, and adaptive radiation?
The success of a new species depends on its ability to cope with the conditions of a changing environment. During mass extinctions, numbers of species become extinct when their environment suddenly changes drastically. Adaptive radiation is indirectly related to environmental change. Adaptive radiation may occur when species migrate to a new environment or after a large extinction clears the environment of a large number of organisms.

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19.3 Earth's Early History

Lesson Objectives

- Identify some of the hypotheses about early Earth and the origin of life.
- Explain the endosymbiotic theory.
- Explain the significance of sexual reproduction in evolution.

Lesson Summary

The Mysteries of Life's Origins Earth's early atmosphere contained toxic gases. The atmosphere also contained little or no oxygen.

- In the 1950s, Stanley Miller and Harold Urey set out to determine if organic molecules could assemble under eartly Earth conditions. They filled a container with water and gases that they thought represented the composition of Earth's early atmosphere. They passed electric sparks through the mixture to simulate lightning. Soon, organic compounds formed. The experiment showed that molecules needed for life could have arisen from simpler compounds.
- Under some conditions, large organic molecules form tiny bubbles called proteinoid microspheres. Structures similar to proteinoid microspheres might have become the first living cells. RNA and DNA also could have evolved from simple organic molecules.
- The first known life forms evolved about 3.5 billion years ago. They were single celled and looked like modern bacteria. Eventually, photosynthetic bacteria became common. During photosynthesis, the bacteria produced oxygen. The oxygen accumulated in the atmosphere. The rise of oxygen drove some life forms to extinction. At the same time, other life forms evolved that depended on oxygen.

Origin of Eukaryotic Cells The first eukaryotes, or organisms with nuclei, evolved from prokaryotes that began to develop internal cell membranes. One explanation for how eukaryotes evolved is the **endosymbiotic theory**. This theory proposes that smaller prokaryotes began living inside larger cells and evolved a symbiotic relationship with the larger cells.

Sexual Reproduction and Multicellularity Sexual reproduction evolved after eukaryotic cells. Sexual reproduction increased genetic variation, so evolution could occur more quickly. Several hundred million years after sexual reproduction evolved, multicellular life evolved.

The Mysteries of Life's Origins

1. What are protenoid microspheres?

   They are tiny bubbles formed from large organic molecules that have some characteristics of living cells.

2. Why do scientists think that RNA may have evolved before DNA?

   Experiments show that small sequences of RNA could have formed and replicated on their own in the conditions present on early Earth.

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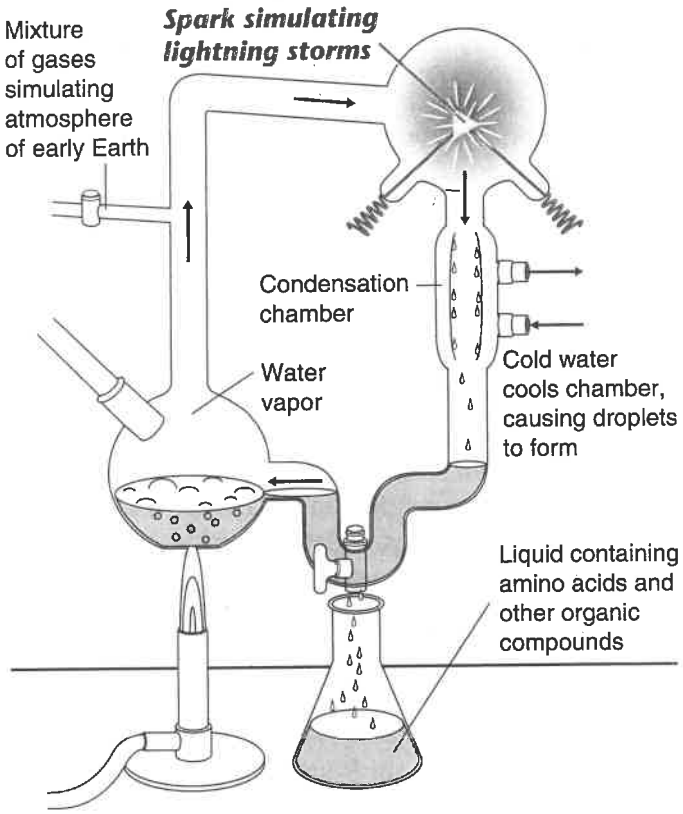
Use the diagram of the Miller-Urey experiment to answer Questions 3–5.



3. THINK VISUALLY Label the diagram to show which part of Miller and Urey's apparatus simulated lightning storms on early Earth.

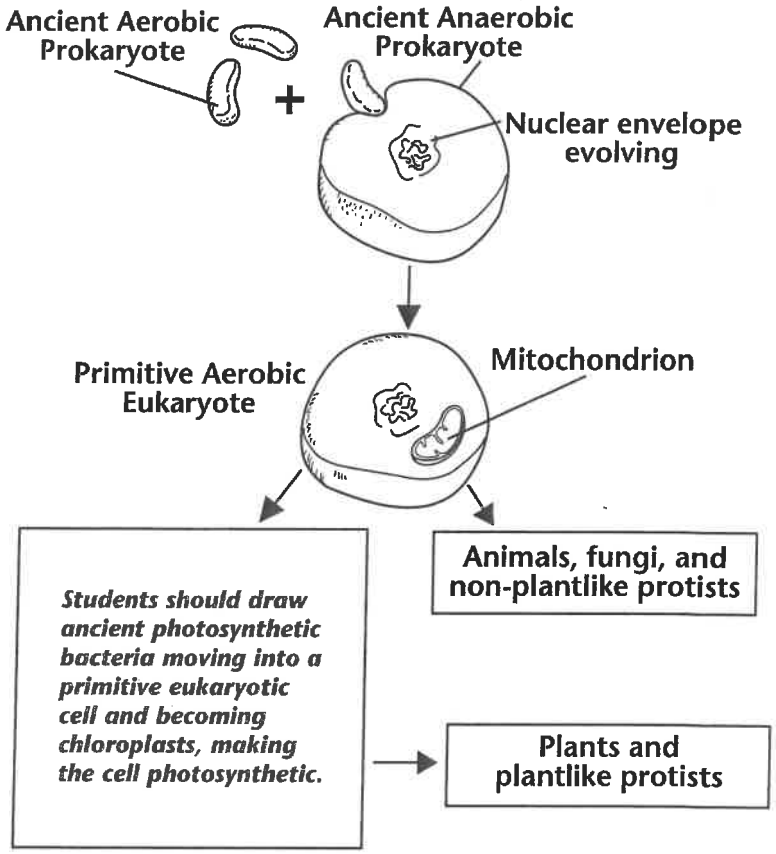
4. What was the purpose of Miller and Urey's experiment? ***to determine whether organic molecules could assemble under the conditions of early Earth***

5. Explain the results of the Miller-Urey experiment. What did these findings suggest? ***The experiment produced several amino acids, which suggested that mixtures of organic compounds could have arisen from substances found on early Earth. Evidence now suggests that the composition of Earth's early atmosphere was different from the one used in their experiment. However, more recent experiments with different mixes of gases have produced similar results.***

Origin of Eukaryotic Cells

6. Explain the endosymbiotic theory. ***The endosymbiotic theory proposes that prokaryotic cells entered early eukaryotic organisms. Over time a symbiotic relationship evolved between primitive eukaryotic cells and the prokaryotic cells within them.***

7. THINK VISUALLY Draw the step in the endosymbiotic theory that shows the origin of chloroplasts. Label the structures in your drawing.



Sexual Reproduction and Multicellularity

8. How did sexual reproduction speed up the evolutionary process?

Sexual reproduction shuffles and reshuffles genes in each generation. This increase in genetic variation greatly increases the chances of evolutionary change due to natural selection.

9. What is the most likely cause of the great amount of diversity currently seen in multicellular life forms? *Early multicellular life most likely underwent a series of adaptive radiations.*

Apply the Big idea

10. Once DNA evolved, what could have caused it to become the primary means of transmitting genetic information instead of RNA?

SAMPLE ANSWER: DNA was a more stable information-storing molecule than RNA.

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Chapter Vocabulary Review

Crossword Puzzle *Complete the puzzle by entering the term that matches the description.*

Across

1. time span shorter than an era
2. fossil used to compare the relative ages of fossils and rock layers
7. theory that eukaryotic cells arose from communities of several prokaryotes
9. measures evolutionary time: geologic time _____
10. span of geologic time that is subdivided into periods
11. the time required for half of the radioactive atoms in a sample to decay
12. a species dying out because of the slow but steady process of natural selection: background _____

Down

1. scientist who studies fossils
3. describes a species that no longer exists
4. method used to place rock layers and their fossils in a time sequence (2 words)
5. the process by which a species or group of species evolves into several different forms that live in different ways: _____ radiation
6. process by which two species evolve in response to changes in each other over time
8. disappearance of many species at the same time: _____ extinction