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Section 2 The Evolution of Cellular Life

Section 3 Life Invaded the Land

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Objectives

- **Summarize** how radioisotopes can be used in determining Earth's age.
- **Compare** two models that describe how the chemicals of life originated.
- **Describe** how cellular organization might have begun.
- **Recognize** the importance that a mechanism for heredity has to the development of life.

The Age of Earth

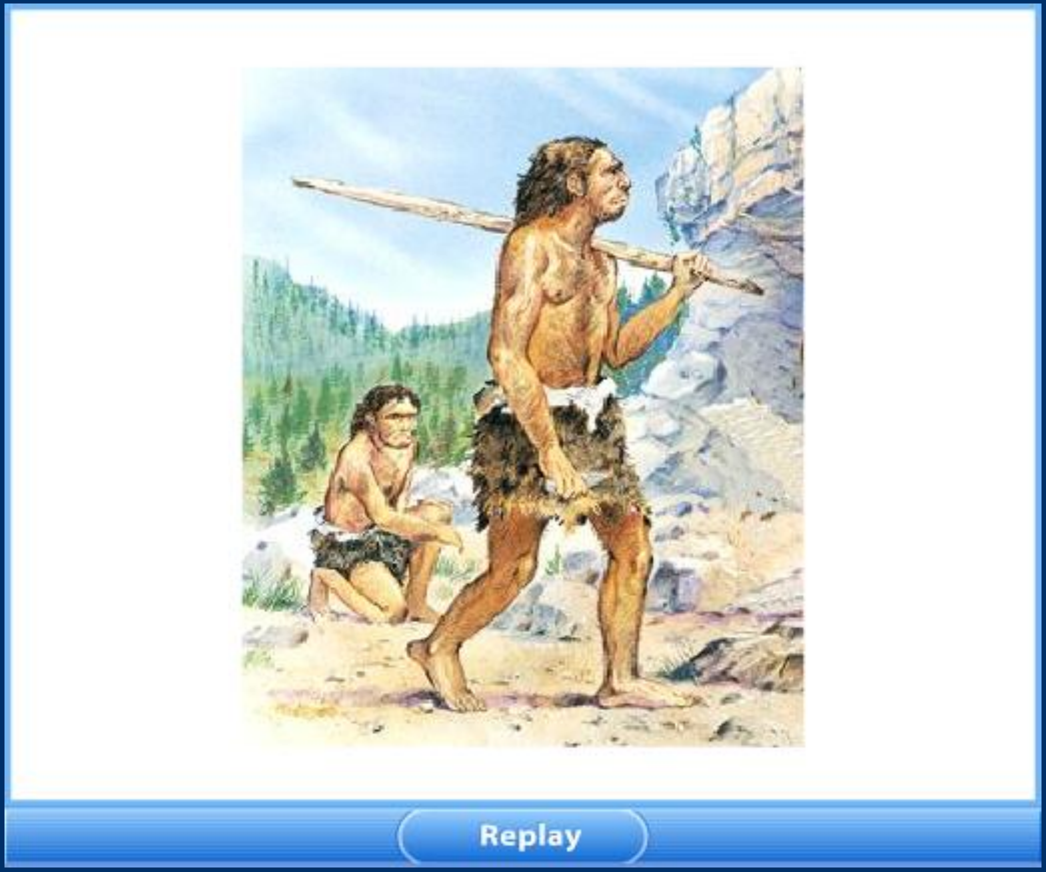
- When Earth formed, about 4.5 billion years ago, it was a fiery ball of molten rock.
- Eventually, the planet's surface cooled and formed a rocky crust. Water vapor in the atmosphere condensed to form vast oceans.
- Most scientists think life first evolved in these oceans and that the evolution of life occurred over hundreds of millions of years.

The Age of Earth, *continued*

Measuring Earth's Age

- Scientists have estimated the age of Earth using a technique called radiometric dating.
- **Radiometric dating** is the estimation of the age of an object by measuring its content of certain radioactive isotopes.
- Radioactive isotopes, or **radioisotopes,** are unstable isotopes that break down and give off energy in the form of charged particles (radiation).

Radiometric Dating



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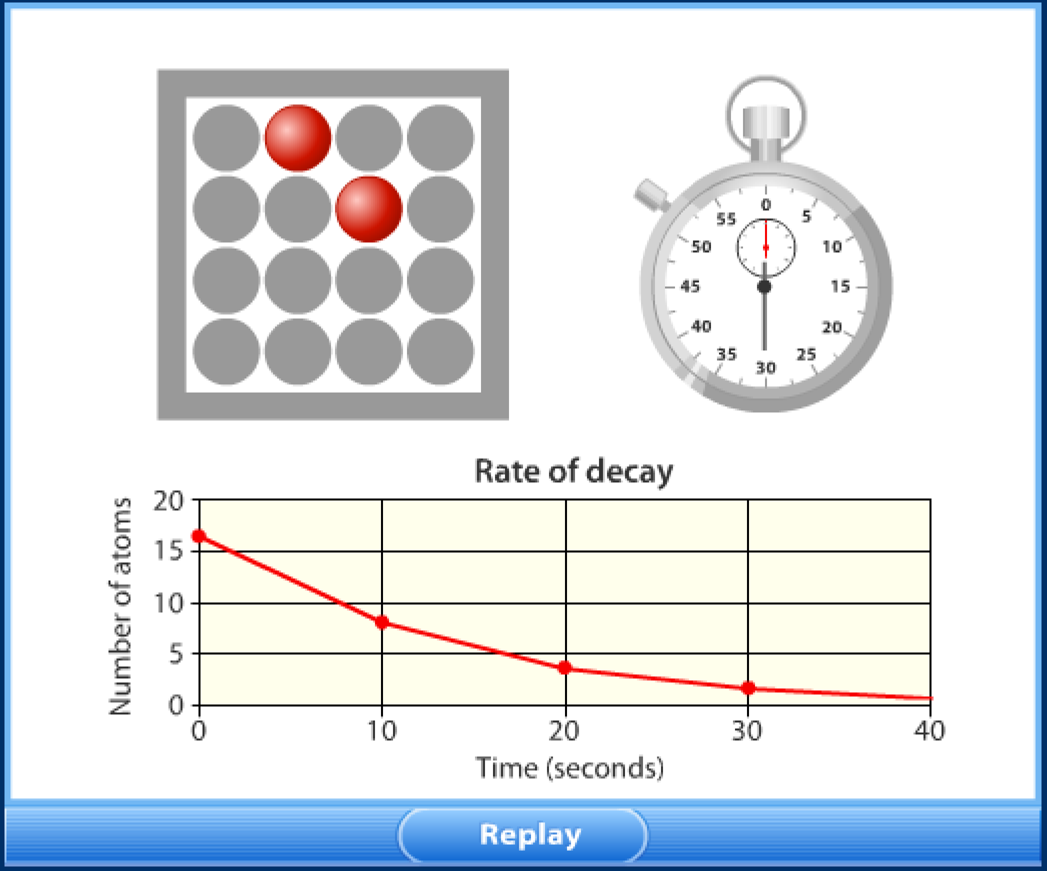
The Age of Earth, *continued*

Measuring Earth's Age

- The time it takes for one-half of a given amount of a radioisotope to decay is called the radioisotope's **half-life.**
- By measuring the proportions of certain radioisotopes and their products of decay, scientists can compute how many half-lives have passed since a rock was formed.

Half-Life



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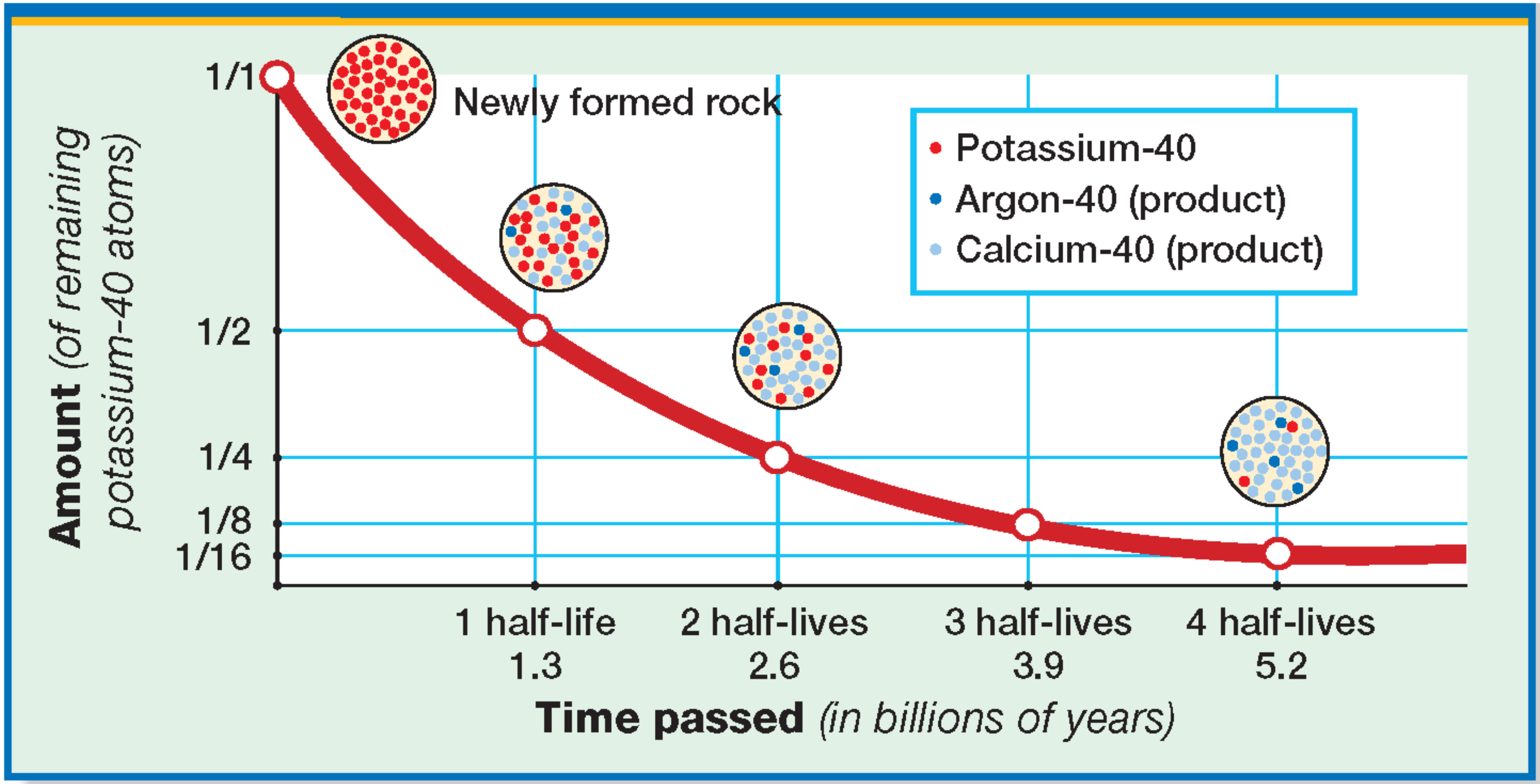
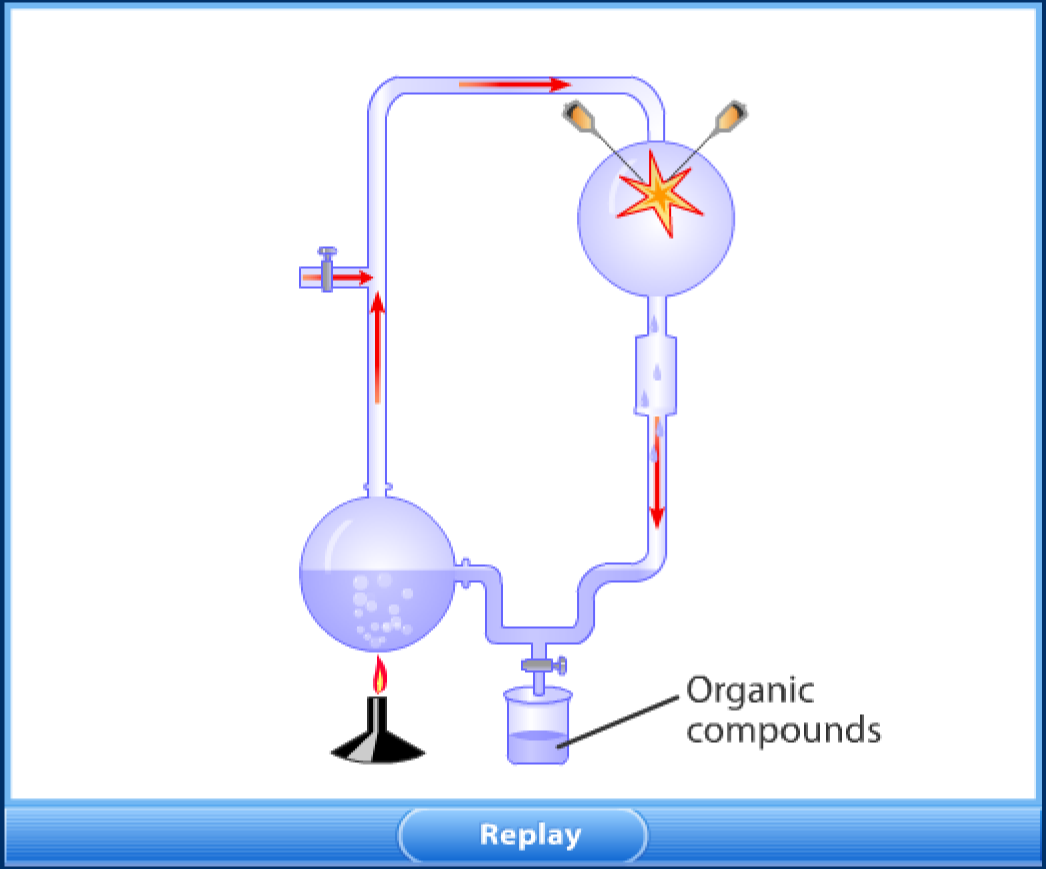
Radioactive Decay



Formation of the Basic Chemicals of Life

- Most scientists think that life on Earth developed through natural chemical and physical processes.
- It is thought that the path to the development of living things began when molecules of nonliving matter reacted chemically during the first billion years of Earth's history.
- The hypothesis that many of the organic molecules necessary for life can be made from molecules of nonliving matter has been tested and supported by results of laboratory experiments.

Spontaneous Origin



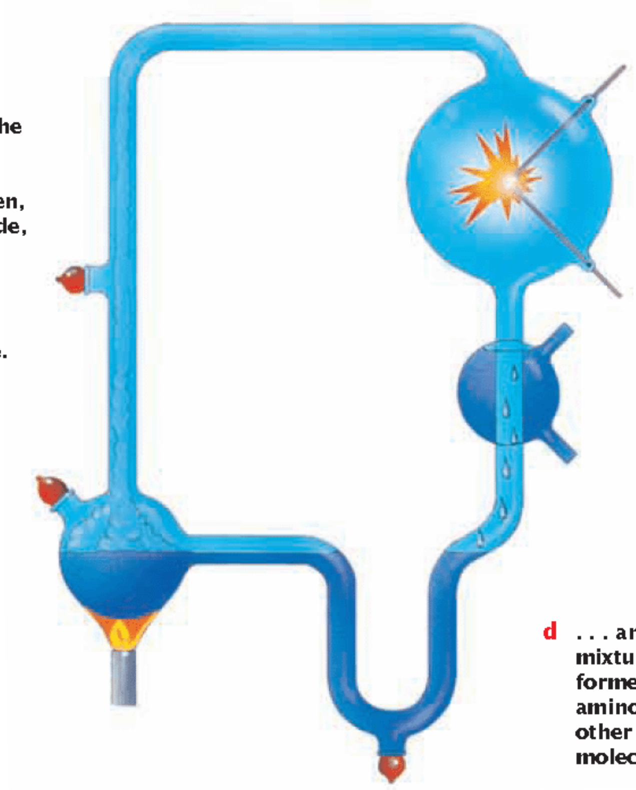
Formation of the Basic Chemicals of Life, *continued*

The "Primordial Soup" Model

- In the 1920s, the Russian scientist A. I. Oparin and the British scientist J.B.S. Haldane both suggested that the early Earth's oceans contained large amounts of organic molecules. This hypothesis became known as the primordial soup model.
- In 1953, the primordial soup model was tested by Stanley Miller, who was then working with Urey.
- These results support the hypothesis that some basic chemicals of life could have formed spontaneously under certain conditions.

Miller-Urey Experiment

This apparatus was used by Stanley Miller, when he was a graduate student studying under Harold Urey, to simulate the conditions present on a young Earth.



Formation of the Basic Chemicals of Life, *continued*

Reevaluating the Miller-Urey Model

- The mixture of gases used in Miller’s experiment could not have existed on early Earth.
- Four billion years ago, Earth did not have a protective layer of ozone gas, O_3.
- Without ozone, ultraviolet radiation would have destroyed any ammonia and methane present in the atmosphere. When these gases are absent from the Miller-Urey experiment, key biological molecules are not made.

Formation of the Basic Chemicals of Life, *continued*

The Bubble Model

- In 1986, the geophysicist Louis Lerman suggested that the key processes that formed the chemicals needed for life took place within bubbles on the ocean's surface. Lerman's hypothesis, also known as the bubble model, is summarized in five steps:

Step 1 Gases were trapped in underwater bubbles.

Step 2 Gases underwent chemical reactions.

Formation of the Basic Chemicals of Life, *continued*

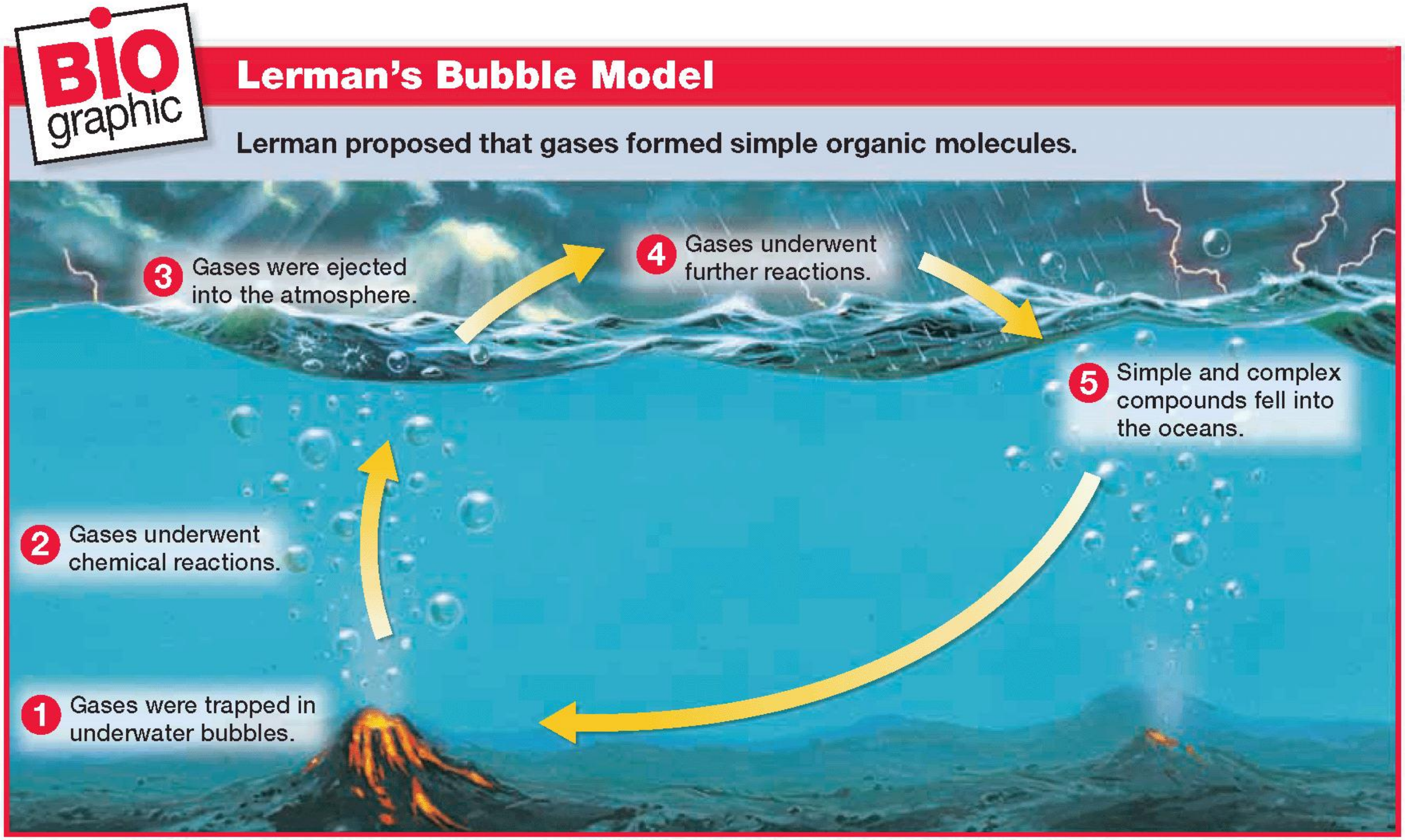
The Bubble Model

Step 3 Bubbles rose to the surface and burst, releasing simple organic molecules into the air.

Step 4 Carried upward by winds, the simple organic molecules were exposed to ultraviolet radiation and lightning, which provided energy for further reactions.

Step 5 More complex organic molecules that formed by further reactions fell into the ocean with rain, starting another cycle.

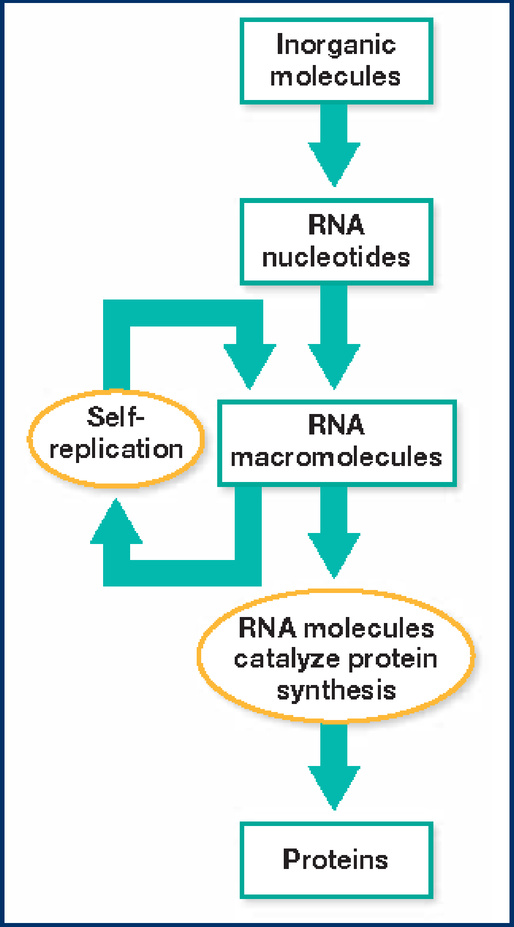
Lerman's Bubble Model



Precursors of the First Cells

- Most scientists accept that under certain conditions, the basic molecules of life could have formed spontaneously through simple chemistry.
- In the laboratory, scientists have not been able to make either proteins or DNA form spontaneously in water.
- However, short chains of RNA, the nucleic acid that helps carry out DNA's instructions, have been made to form on their own in water.

Precursors of the First Cells, *continued*



A Possible Role As Catalysts

- As a result of Thomas Cech's and Sidney Altman's work and other experiments showing that RNA molecules can form spontaneously in water, a simple hypothesis was formed: RNA was the first self-replicating information-storage molecule and it catalyzed the assembly of the first proteins.

Precursors of the First Cells, *continued*

Microspheres and Coacervates

- Laboratory experiments have shown that, in water, short chains of amino acids can gather into tiny droplets called **microspheres.**
- Another type of droplet, called a coacervate, is composed of molecules of different types, including linked amino acids and sugars.
- Scientists think that formation of microspheres might have been the first step toward cellular organization.

End of Slide

Precursors of the First Cells, *continued*

Origin of Heredity

- Although scientists disagree about the details of the origin of heredity, many agree that double-stranded DNA evolved after RNA and that RNA "enzymes" catalyzed the assembly of the earliest proteins.
- Many scientists also tentatively accept the hypothesis that some microspheres or similar structures that contained RNA developed a means of transferring their characteristics to offspring.
- But researchers do not yet understand how DNA, RNA and hereditary mechanisms first developed.

Objectives

- **Distinguish** between the two groups of prokaryotes.
- **Describe** the evolution of eukaryotes.
- **Recognize** an evolutionary advance first seen in protists.
- **Summarize** how mass extinctions have affected the evolution of life on Earth.

End Of Slide

The Evolution of Prokaryotes

- A **fossil** is the preserved or mineralized remains (bone, tooth, or shell) or imprint of an organism that lived long ago.
- The oldest known fossils, which are microscopic fossils of prokaryotes, come from rock that is 2.5 billion years old.
- Among the first prokaryotes to appear were marine **cyanobacteria,** photosynthetic prokaryotes.

End of Slide

The Evolution of Prokaryotes, *continued*

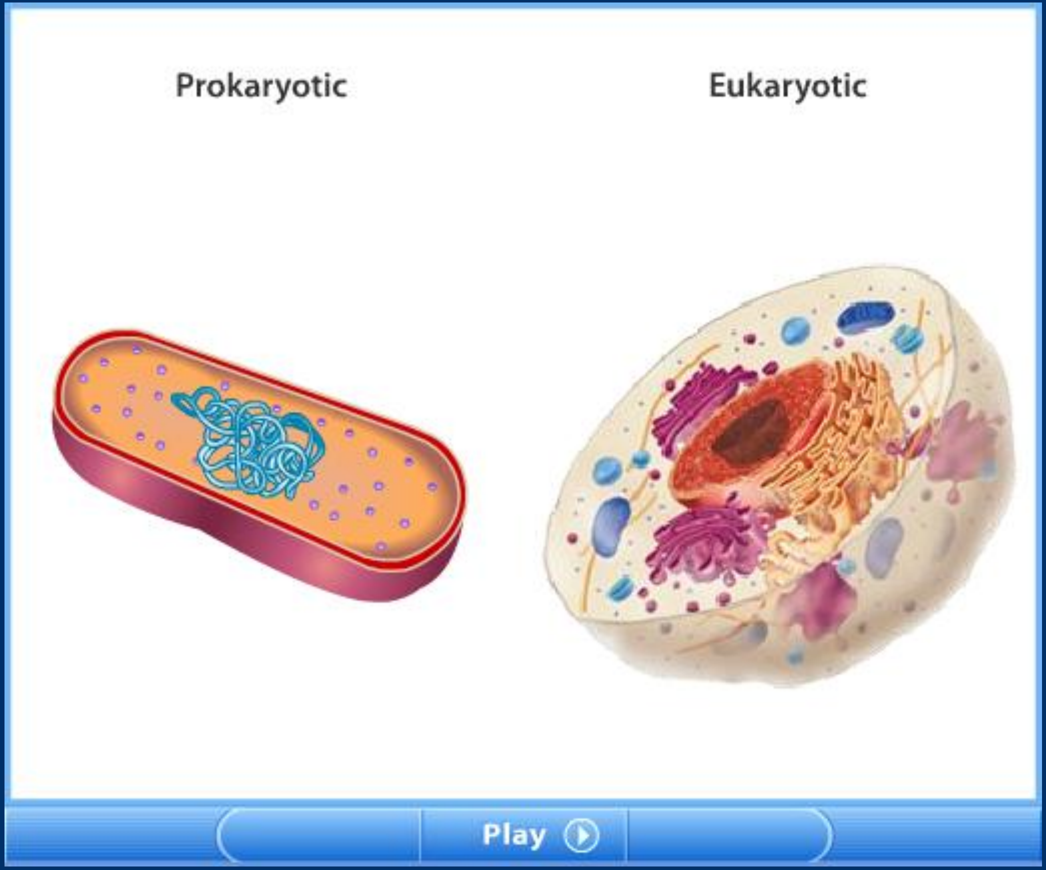
Two Groups of Prokaryotes

- Early in the history of life, two different groups of prokaryotes evolved—eubacteria (which are commonly called *bacteria*) and archaebacteria.
- **Eubacteria** are prokaryotes that contain a chemical called peptidoglycan in their cell walls.
- **Archaebacteria** are prokaryotes that lack peptidoglycan in their cell walls and have unique lipids in their cell membranes.

The Evolution of Eukaryotes

- About 1.5 billion years ago, the first eukaryotes appeared.
- A eukaryotic cell is much larger than a prokaryote is, has a complex system of internal membranes, and its DNA is enclosed within a nucleus.
- Almost all eukaryotes have mitochondria.

Comparing Prokaryotes and Eukaryotes



The Evolution of Eukaryotes, *continued*

The Origins of Mitochondria and Chloroplasts

- Most biologists think that mitochondria and chloroplasts originated as described by the theory of **endosymbiosis** that was proposed in 1966 by the American biologist Lynn Margulis.
- This theory proposes that mitochondria are the descendants of symbiotic, aerobic (oxygen-requiring) eubacteria and chloroplasts are the descendants of symbiotic, photosynthetic eubacteria.

The Evolution of Eukaryotes, *continued*

The Origins of Mitochondria and Chloroplasts

- The following four observations support the idea that mitochondria and chloroplasts descended from bacteria:

  1. Mitochondria are about the same size as most eubacteria, and chloroplasts are the same size as some cyanobacteria.

  2. Mitochondria and chloroplasts have circular DNA similar to the chromosomes found in bacteria.

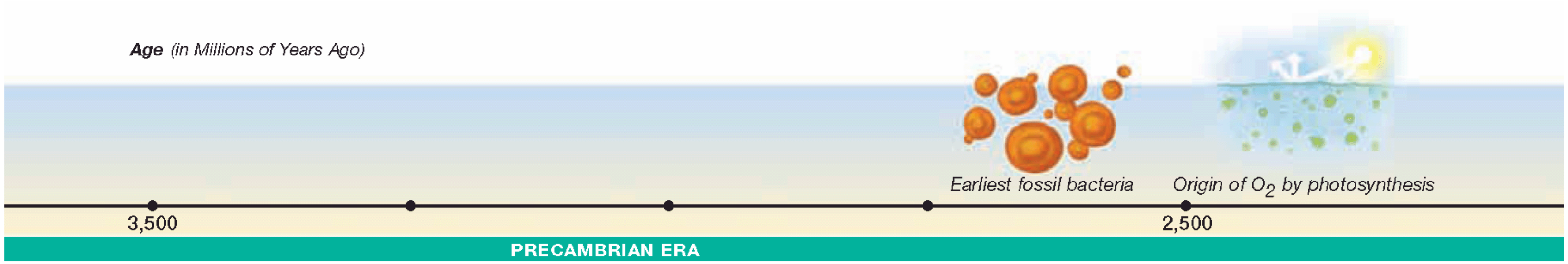
The Evolution of Eukaryotes, *continued*

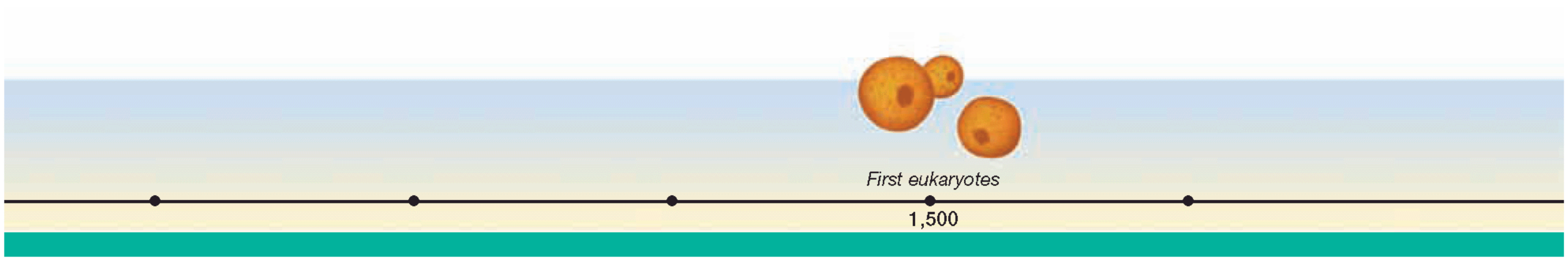
The Origins of Mitochondria and Chloroplasts

3. Mitochondrial and chloroplast ribosomes have a size and structure similar to the size and structure of bacterial ribosomes.

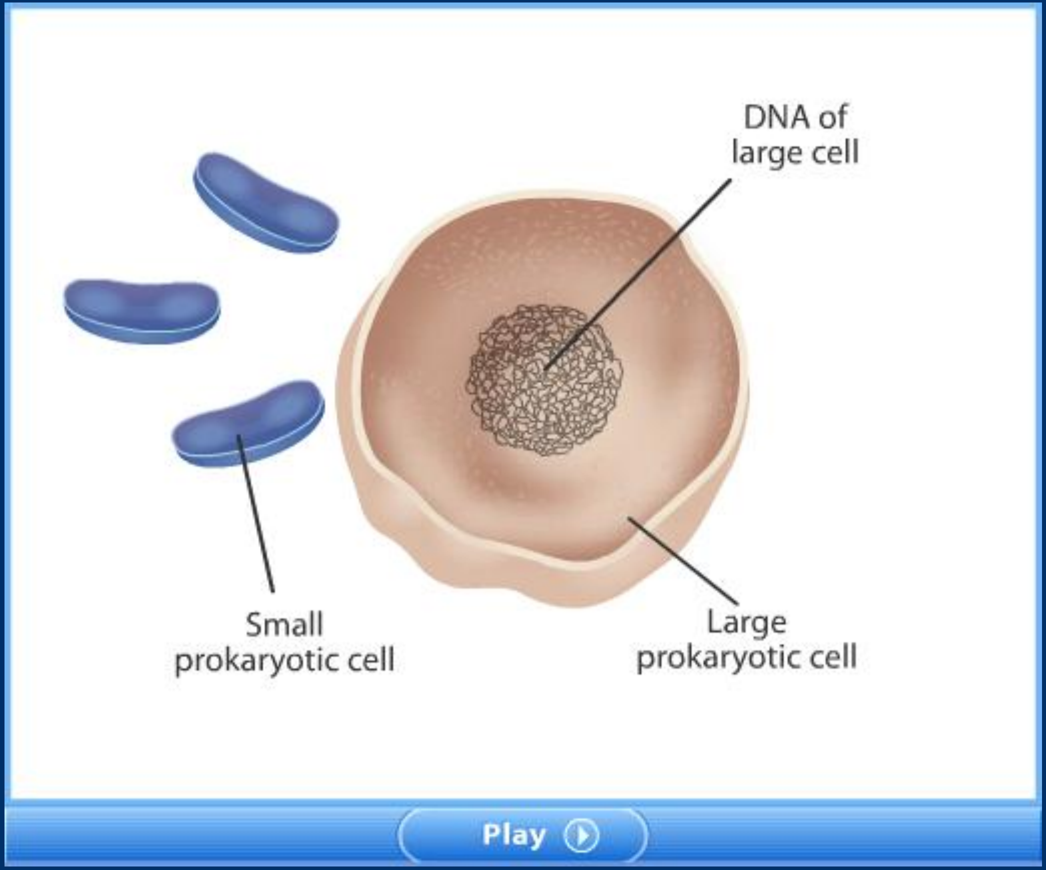
4. Like bacteria, chloroplasts and mitochondria reproduce by simple fission. This replication takes place independently of the cell cycle of the host cell.

Evolution of Eukaryotes

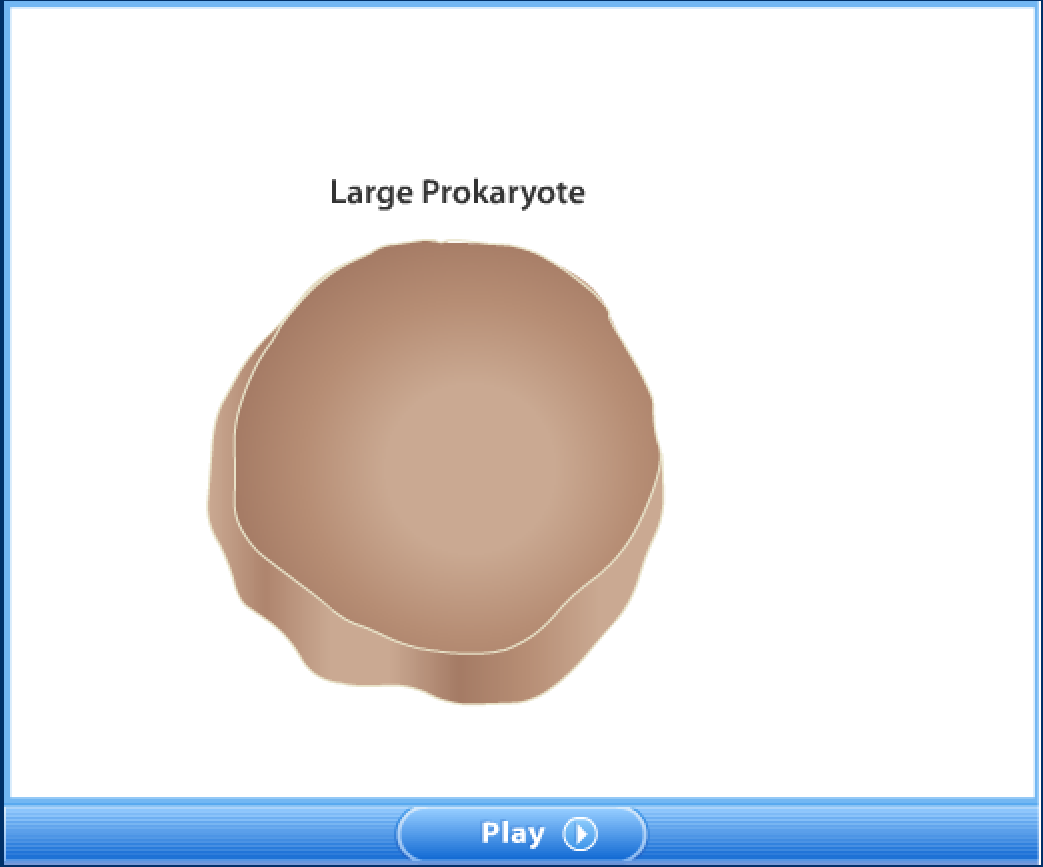




Origin of Eukaryotic Cells



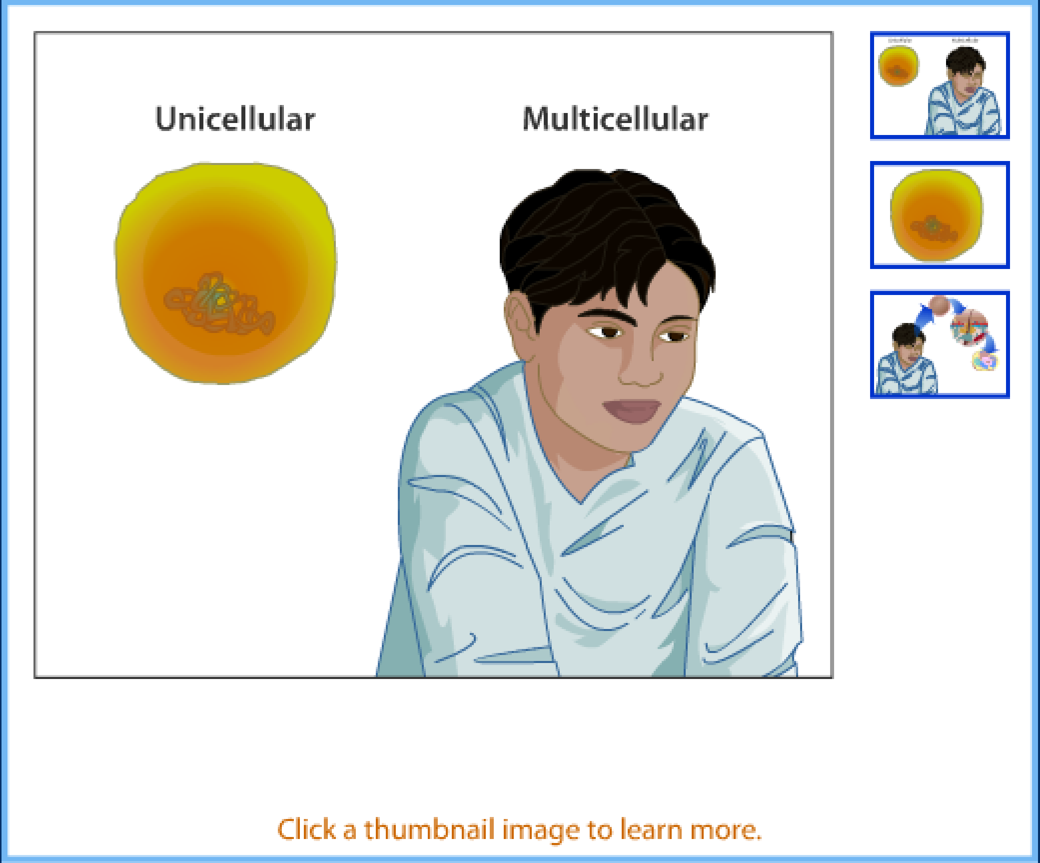
Endosymbiosis



Multicellularity

- **Protists** make up a large, varied group that includes both multicellular and unicellular organisms.
- The unicellular body plan has been very successful, with unicellular organisms today constituting about half the biomass on Earth, but a single cell must carry out all of the activities of the organism.
- The development of multicellular organisms of the kingdom Protista marked an important step in the evolution of life on Earth. The oldest known fossils of multicellular organisms were found in 700 million year-old rocks.

Comparing Organisms That Are Unicellular and Multicellular



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Multicellularity

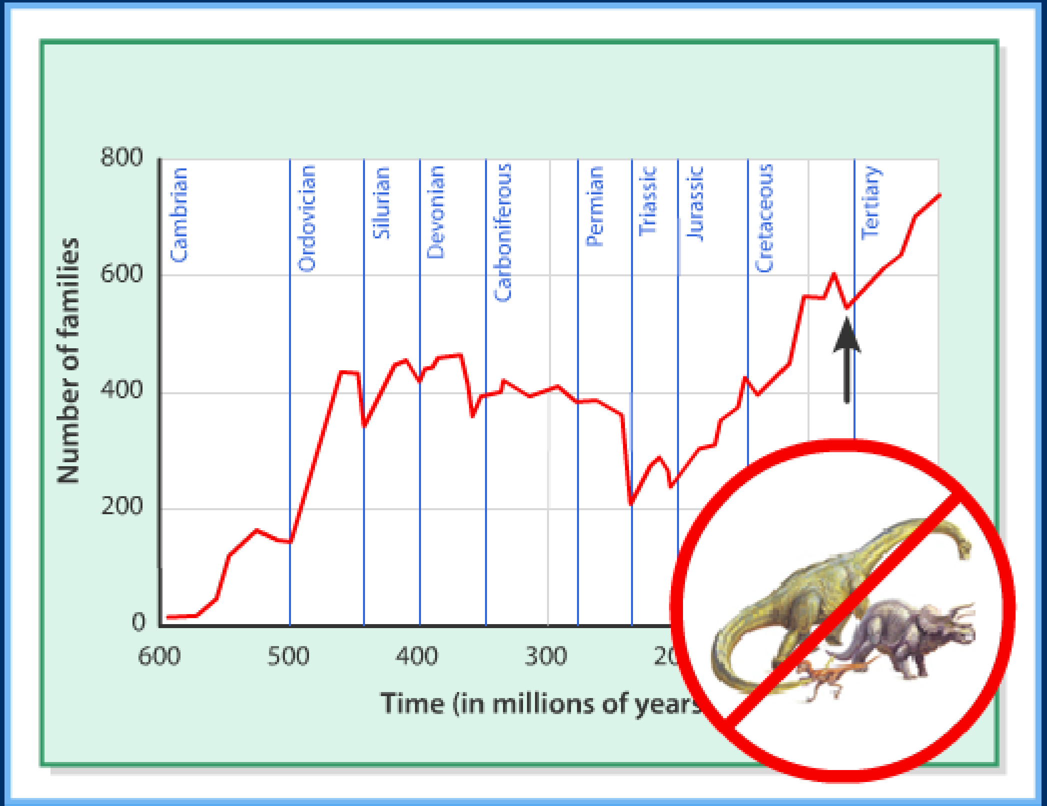
Origins of Modern Organisms

- Most phyla that exist today probably originated during the Cambrian period, which lasted from about 540 million to about 505 million years ago.
- The Ordovician period, which followed the Cambrian period, lasted from about 505 million to 438 million years ago. During this time, many different animals continued to abound in the seas.

Mass Extinctions

- **Extinction** is the death of all members of a species.
- A **mass extinction** is an episode during which large numbers of species become extinct.
- Five major mass extinctions that have occurred on Earth.

Mass Extinction



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Objectives

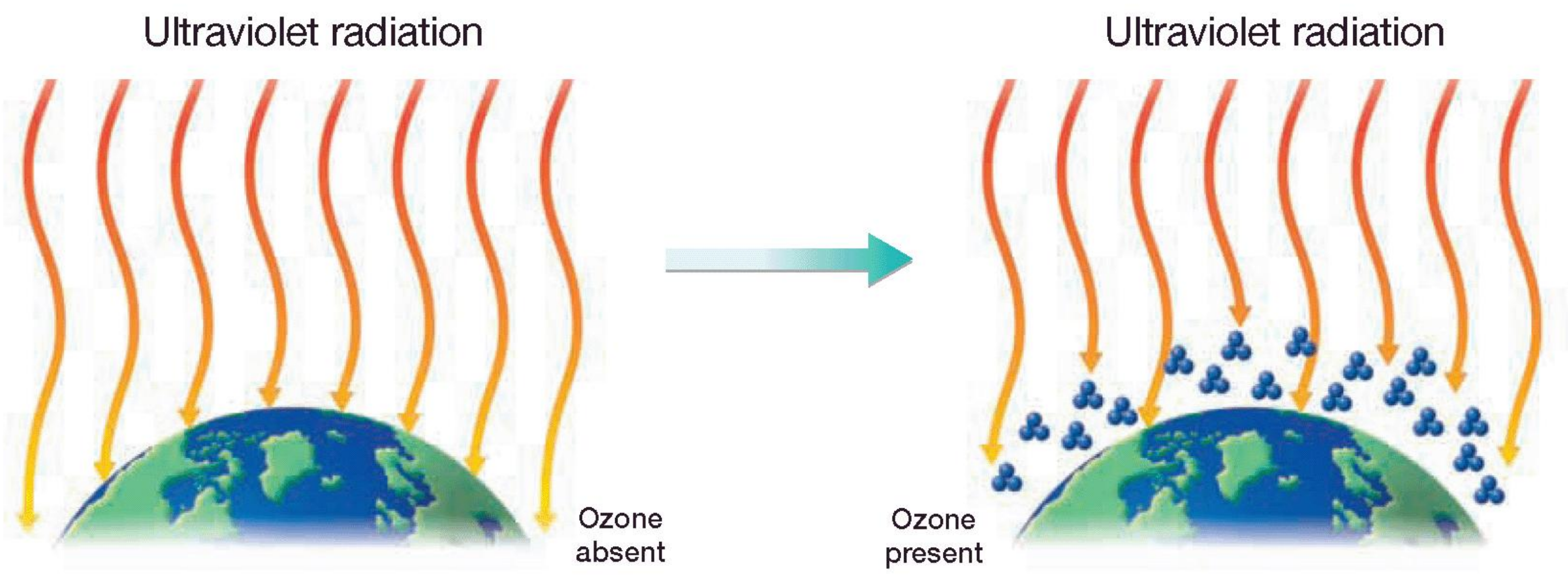
- **Relate** the development of ozone to the adaptation of life to the land.
- **Identify** the first multicellular organisms to live on land.
- **Name** the first animals to live on land.
- **List** the first vertebrates to leave the oceans.

The Ozone Layer

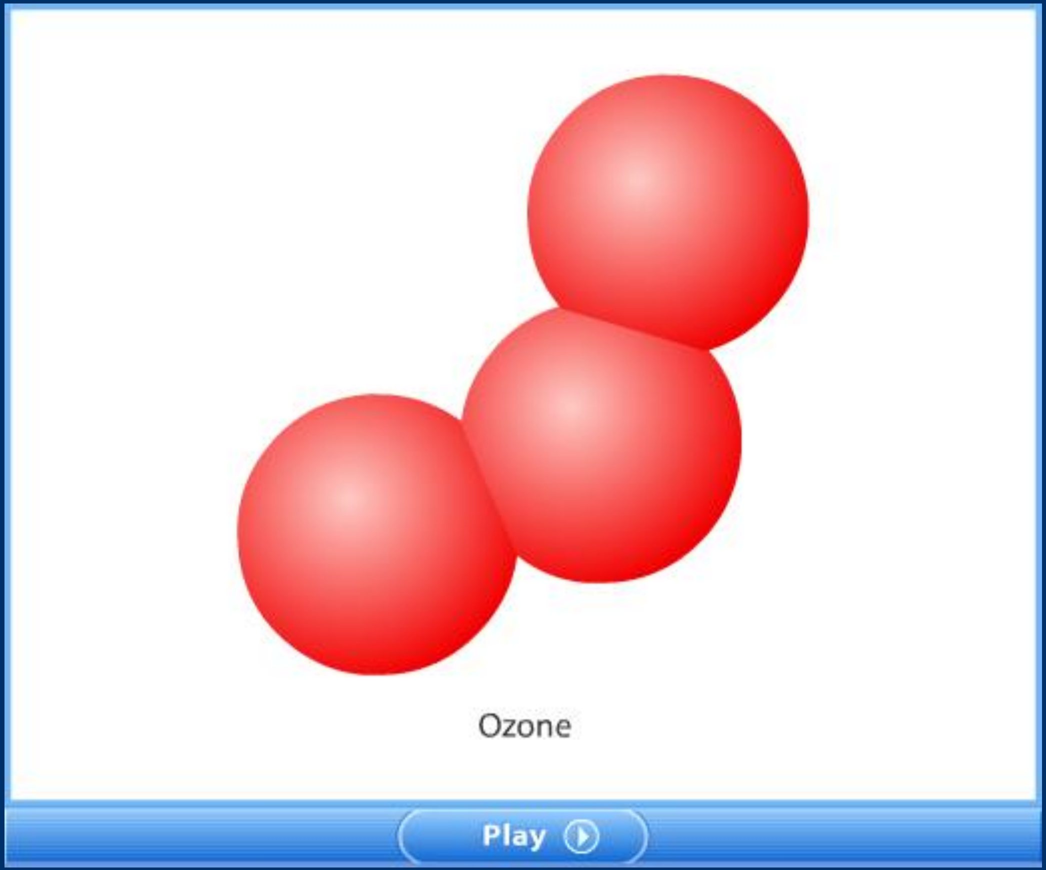
Formation of the Ozone Layer

- During the Cambrian period and for millions of years afterward, organisms did not live on the dry, rocky surface of Earth.
- About 2.5 billion years ago, photosynthesis by cyanobacteria began adding oxygen to Earth's atmosphere.
- As oxygen began to reach the upper atmosphere, the sun's rays caused some of the O_2 to chemically react and form molecules of ozone, O_3. After millions of years, enough ozone had accumulated to make the Earth's land a safe place to live.

Ozone Shields the Earth



Ozone and Ecosystems



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Plants and Fungi on Land

- The first multicellular organisms to live on land are thought to have been plants and fungi living together.
- Early plants and fungi formed biological partnerships called mycorrhizae, which enabled them to live on the harsh habitat of bare rock. **Mycorrhizae,** which exist today, are symbiotic associations between fungi and the roots of plants.
- **Mutualism** is a relationship between two species in which both species benefit.

Arthropods

- The first animals to successfully invade land from the sea were arthropods.
- An **arthropod** is a kind of animal with a hard outer skeleton, a segmented body, and paired, jointed limbs.
- Examples of arthropods include lobsters, crabs, insects, and spiders.

Characteristics of Arthropods

Vertebrates

- A **vertebrate** is an animal with a backbone—vertebrates are the animals most familiar to us.
- Humans are vertebrates, and almost all other land animals bigger than our fist are vertebrates as well.

End Of Slide

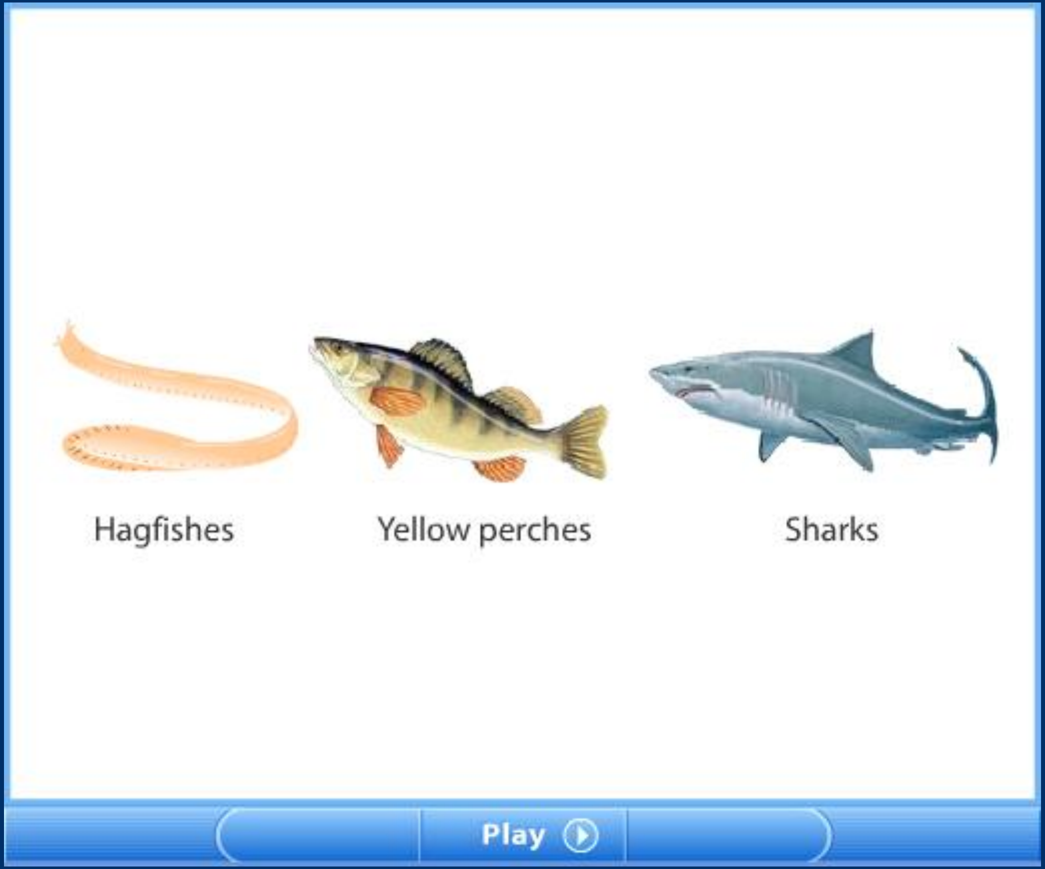
Vertebrate

Vertebrates, *continued*

Fishes

- According to the fossil record, the first vertebrates were small, jawless fishes that evolved in the oceans about 530 million years ago.
- Jawed fishes first appeared about 430 million years ago.
- Fishes are the most successful living vertebrates—they make up more than half of all modern vertebrate species.

Characteristics of Fish

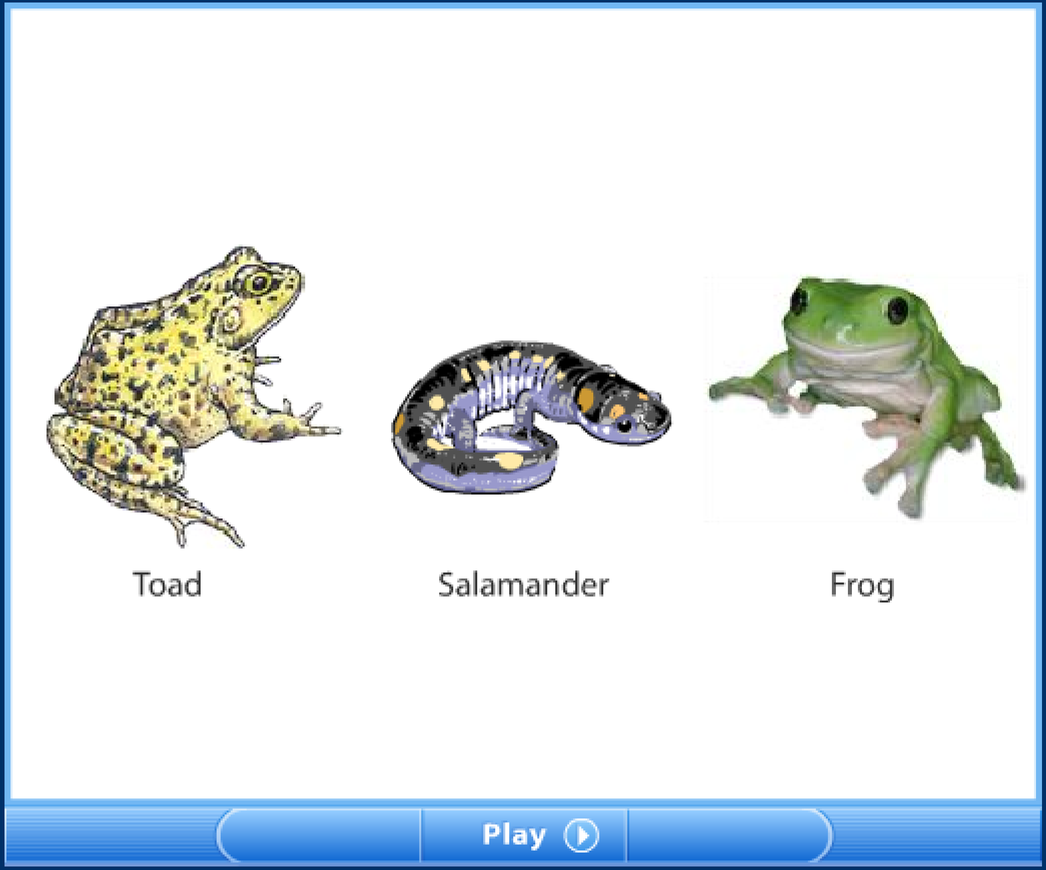


Vertebrates, *continued*

Amphibians

- The first vertebrates to inhabit the land did not come out of the sea until 370 million years ago. Those first land vertebrates were early amphibians.
- Amphibians are smooth-skinned, four-legged animals that today include frogs, toads, and salamanders.
- Amphibians had moist breathing sacs—lungs—which allowed the animals to absorb oxygen from air.

Characteristics of Amphibians



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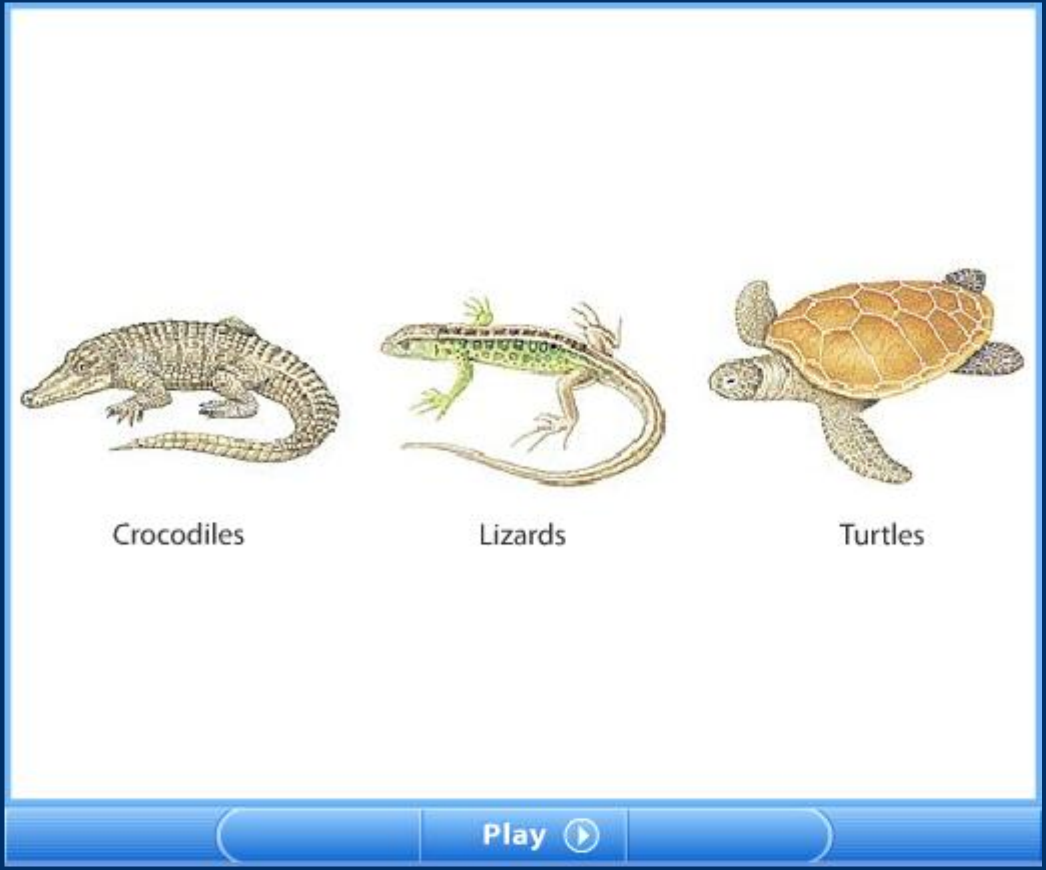
Vertebrates, *continued*

Reptiles

- Reptiles evolved from amphibian ancestors about 340 million years ago.
- Modern reptiles include snakes, lizards, turtles, and crocodiles.
- Reptiles are better suited to dry land than amphibians because reptiles' watertight skin slows the loss of moisture.

Characteristics of Reptiles



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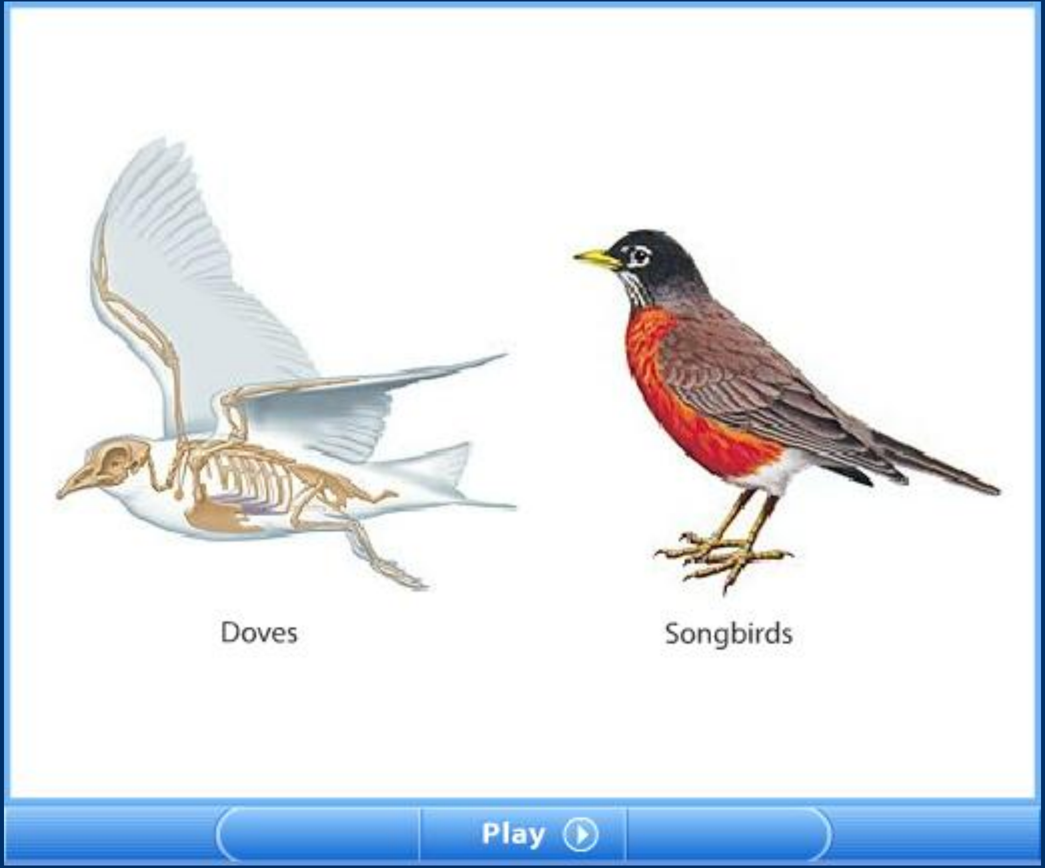
Vertebrates, *continued*

Mammals and Birds

- Birds apparently evolved from feathered dinosaurs during or after the Jurassic period.
- Therapsids, reptiles with complex teeth and legs positioned beneath their body, gave rise to mammals about the same time dinosaurs evolved, during the Triassic period.
- Sixty-five million years ago, during the fifth mass extinction, most species disappeared forever. Birds and mammals then became the dominant vertebrates on land.

Characteristics of Birds



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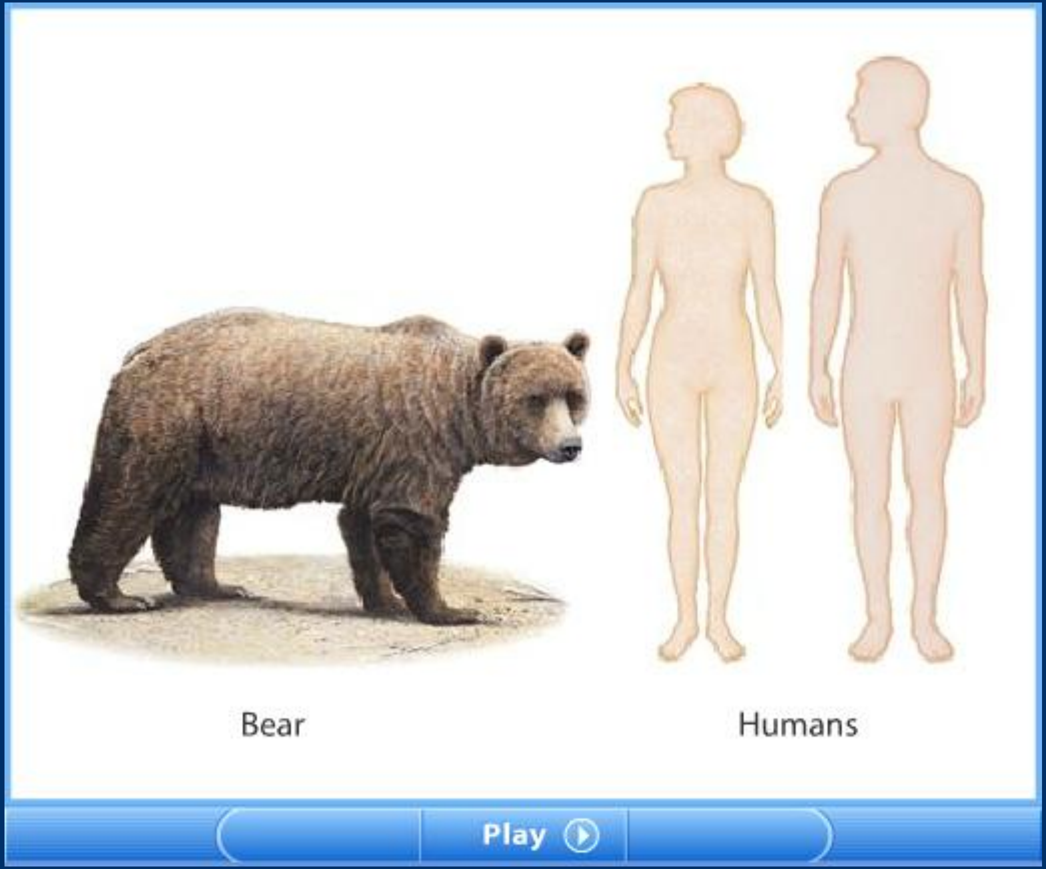
Characteristics of Mammals



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Vertebrates, *continued*

Mammals and Birds

- Both extinctions and continental drift played important roles in evolution.
- **Continental drift** is the movement of Earth's land masses over Earth's surface through geologic time.
- Continental drift resulted in the present-day position of the continents.

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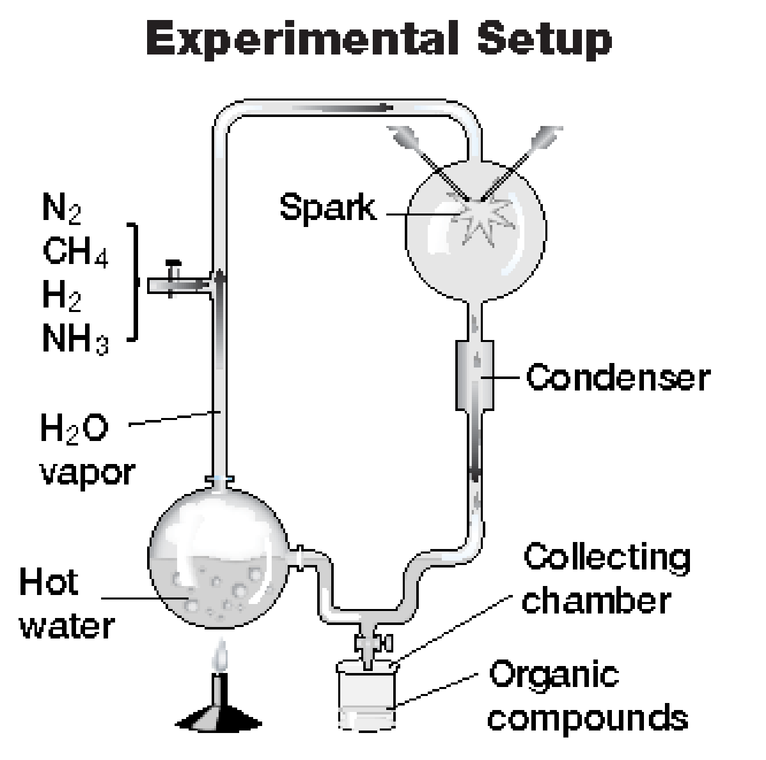
Continental Drift (Pangaea)

Multiple Choice

Use the figure below to answer questions 1–3.



Multiple Choice, *continued*

1. What event on early Earth is the spark intended to simulate?

   A. lightning
   B. A volcanic eruption
   C. An earthquake
   D. A forest fire

Multiple Choice, *continued*

1. What event on early Earth is the spark intended to simulate?

   A. lightning
   B. A volcanic eruption
   C. An earthquake
   D. A forest fire

Multiple Choice, *continued*

2. What would the collecting chamber likely contain if the spark were omitted from the experiment?

   F. Only CH_4, H_2, and NH_3
   G. Only H_2O and organic compounds
   H. N_2, CH_4, H_2, NH_3, and organic compounds
   J. H_2O, N_2, CH_4, H_2, and NH_3

Multiple Choice, *continued*

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Multiple Choice, *continued*

3. What conclusion could be drawn from the results of the experiment shown?

A. Water can be changed into organic compounds if it is heated vigorously.

B. Organic compounds can form under conditions like those in the experiment.

C. N_2 and H_2 can be converted into NH_3 when heated.

D. Earth's early atmosphere lacked N_2.

Multiple Choice, *continued*

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