Chapter 17
History of Life

What You'll Learn

You will examine how rocks and fossils provide evidence of changes in Earth's organisms.

You will correlate the geologic time scale with biological events.

You will sequence the steps by which small molecules may have produced living cells.

Section Objectives:

- Identify the different types of fossils and how they are formed
- Summarize the major events of the geologic time scale.

Early History of Earth

- What was early Earth like? Some scientists suggest that it was probably very hot. The energy from colliding meteorites could have heated its surface, while both the compression of minerals and the decay of radioactive materials heated its interior.

Early History of Earth

- Volcanoes might have frequently spewed lava and gases, relieving some of the pressure in Earth's hot interior. These gases helped form Earth's early atmosphere.

Early History of Earth

- About 4.4 billion years ago, Earth might have cooled enough for the water in its atmosphere to condense. This might have led to millions of years of rainstorms with lightning—enough rain to fill depressions that became Earth's oceans.

History in Rocks

- There is no direct evidence of the earliest years of Earth's history. The oldest rocks that have been found on Earth formed about 3.9 billion years ago.
- Although rocks cannot provide information about Earth's infancy, they are an important source of information about the diversity of life that has existed on the planet.

Fossils-Clues to the past

- About 95 percent of the species that have existed are extinct—they no longer live on Earth.
- Among other techniques, scientists study fossils to learn about ancient species.

Fossils-Clues to the past

Types of Fossils

Fossils Types	Formation
Trace fossils	A trace fossil is any indirect evidence left by an animal and may include a footprint, a trail, or a burrow.
Casts	When minerals in rocks fill a space left by a decayed organism, they make a replica, or cast, of the organism.
Molds	A mold forms when an organism is buried in sediment and then decays, leaving an empty space.
Petrified/ Permineralized fossils	Petrified-minerals sometimes penetrate and replace the hard parts of an organism. Permineralized-void spaces in original organism infilled by minerals.
Amber-Preserved or frozen fossils	At times, an entire organism was quickly trapped in ice or tree sap that hardened into amber.

- A fossil is evidence of an organism that lived long ago that is preserved in Earth's rocks.

Paleontologists-Detectives to the past

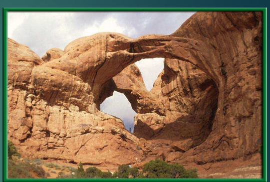
- Paleontologists, scientists who study ancient life, are like detectives who use fossils to understand events that happened long ago.
- They use fossils to determine the kinds of organisms that lived during the past and sometimes to learn about their behavior.

Paleontologists-Detectives to the past

- Paleontologists also study fossils to gain knowledge about ancient climate and geography.
- By studying the condition, position, and location of rocks and fossils, geologists and paleontologists can make deductions about the geography of past environments.

Fossil formation

- For fossils to form, organisms usually have to be buried in mud, sand, or clay soon after they die.



- Most fossils are found in sedimentary rocks. These rocks form at relatively low temperatures and pressures that may prevent damage to the organism.

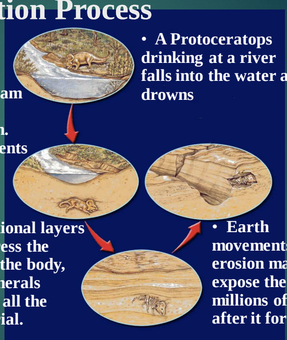
Fossil formation

- Fossils are not usually found in other types of rock because of the ways those rocks form. For example, the conditions under which metamorphic rocks form often destroy any fossils that were in the original sedimentary rock.

The Fossilization Process

- Few organisms become fossilized because, without burial, bacteria and fungi immediately decompose their dead bodies. Occasionally, however, organisms do become fossils in a process that usually takes many years.

The Fossilization Process



Relative dating

- Scientists use a variety of methods to determine the age of fossils. One method is a technique called relative dating.
- If the rock layers have not been disturbed, the layers at the surface must be younger than the deeper layers.

Relative dating

- The fossils in the top layer must also be younger than those in deeper layers.
- Using this principle, scientists can determine relative age and the order of appearance of the species that are preserved as fossils in the layers.

Radiometric dating

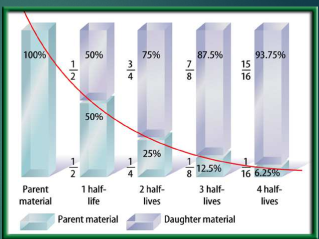
- To find the specific ages of rocks, scientists use radiometric dating techniques utilizing the radioactive isotopes in rocks.
- Recall that radioactive isotopes are atoms with unstable nuclei that break down, or decay, over time, giving off radiation.
- A radioactive isotope forms a new isotope after it decays.

Radiometric dating

- Because every radioactive isotope has a characteristic decay rate, scientists use the rate of decay as a type of clock.
- The decay rate of a radioactive isotope is called its half-life.

Radiometric dating

- Scientists try to determine the approximate ages of rocks by comparing the amount of a radioactive isotope and the new isotope into which it decays.



Radiometric dating

- Scientists use potassium-40, a radioactive isotope that decays to argon-40, to date rocks containing potassium bearing minerals.
- Based on chemical analysis, chemists have determined that potassium-40 decays to half its original amount in 1.3 billion years.

Radiometric dating

- Scientists use carbon-14 to date fossils less than 70 000 years old.
- Again, based on chemical analysis, they know that carbon-14 decays to half its original amount in 5730 years.

Radiometric dating

- Scientists always analyze many samples of a rock using as many methods as possible to obtain consistent values for the rock's age.
- Errors can occur if the rock has been heated, causing some of the radioactive isotopes to be lost or gained.

A Trip Through Geologic Time

- By examining sequences containing sedimentary rock and fossils and dating some or the igneous or metamorphic rocks that are found in the sequences, scientists have put together a chronology, or calendar, of Earth's history.
- This chronology, called the geologic time scale, is based on evidence from Earth's rocks and fossils.

The geologic time scale

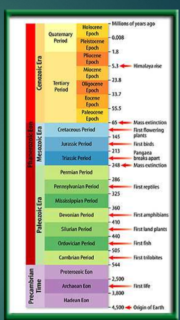
- Rather than being based on months or even years, the geologic time scale is divided into four large sections, the Precambrian (pree KAM bree un) Era, the Paleozoic (pay lee uh ZOH ihk) Era, the Mesozoic (me zuh ZOH ihk) Era, and the Cenozoic (se nuh ZOH ihk) Era.

The geologic time scale

- An era is a large division in the scale and represents a very long period of time.
- Each era is subdivided into periods.

The geologic time scale

- The divisions in the geologic time scale are distinguished by the organisms that lived during that time interval.



The geologic time scale

- The fossil record indicates that there were several episodes of mass extinction that fall between time divisions.
- A mass extinction is an event that occurs when many organisms disappear from the fossil record almost at once.
- The geologic time scale begins with the formation of Earth about 4.6 billion years ago.

Life during the Precambrian

- The oldest fossils are found in Precambrian rocks that are about 3.4 billion years old.
- Scientists found these fossils, in rocks found in the deserts of western Australia.
- The fossils resemble the forms of modern species of photosynthetic cyanobacteria.

Life during the Precambrian

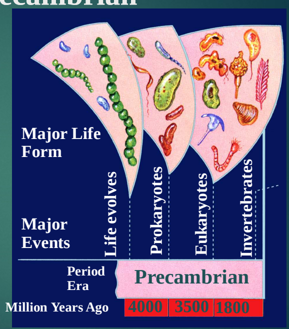
- Scientists have also found dome-shaped structures called stromatolites (stroh MAT ul ites) in Australia and on other continents.
- Stromatolites still form today in Australia from mats of cyanobacteria. Thus, the stromatolites are evidence of the existence of photosynthetic organisms on Earth during the Precambrian.

Life during the Precambrian

- The Precambrian accounts for about 87 percent of Earth's history.
- At the beginning of the Precambrian, unicellular prokarotes—cells that do not have a membrane-bound nucleus—appear to have been the only life forms on Earth.

Life during the Precambrian

- About 1.8 billion years ago, the fossil record shows that more complex eukaryotic organisms, living things with membrane-bound nuclei in their cells, appeared.



Life during the Precambrian

- By the end of the Precambrian, about 543 million years ago, multicellular eukaryotes, such as sponges and jelly-fishes, diversified and filled the oceans.

Diversity during the Paleozoic

- In the Paleozoic Era, which lasted until 248 million years ago, many more types of animals and plants were present on Earth, and some were preserved in the fossil record.
- During the Cambrian Period, the oceans teemed with many types of animals, including worms, sea stars, and unusual arthropods.

Diversity during the Paleozoic

- During the first half of the Paleozoic, fishes, the oldest animals with backbones, appeared in Earth's waters.
- There is also fossil evidence of ferns and early seed plants existing on land about 400 million years ago.
- Around the middle of the Paleozoic, four-legged animals such as amphibians appeared on Earth.

Diversity during the Paleozoic

- During the last half of the era, the fossil record shows that reptiles appeared and began to flourish on land.

Diversity during the Paleozoic

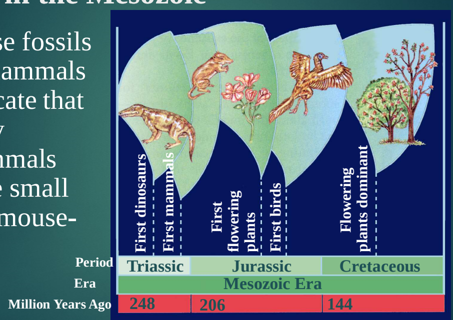
- The largest mass extinction recorded in the fossil record marked the end of the Paleozoic.
- About 90 percent of Earth’s marine species and 70 percent of the land species disappeared at this time.

Life in the Mesozoic

- The Mesozoic Era began about 248 million years ago.
- The Mesozoic Era is divided into three periods.
- Fossils from the Triassic Period, the oldest period, show that mammals appeared on Earth at this time.

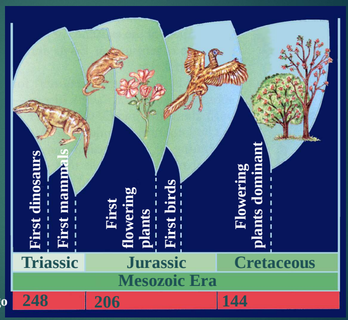
Life in the Mesozoic

- These fossils of mammals indicate that early mammals were small and mouse-like.



Life in the Mesozoic

- The middle of the Mesozoic, called the Jurassic Period, began about 206 million years ago.



Life in the Mesozoic

- Recent fossil discoveries support the idea that modern birds evolved from one of the groups of dinosaurs toward the end of this period.

A mass extinction

- The last period in the Mesozoic, the Cretaceous, began about 144 million years ago.
- During this period, many new types of mammals appeared and flowering plants flourished on Earth.

A mass extinction

- The mass extinction of the dinosaurs marked the end of the Cretaceous Period about 65 million years ago.
- Some scientists propose that a large meteorite collision caused this mass extinction.

Changes during the Mesozoic

- The theory of continental drift, suggests that Earth's continents have moved during Earth's history and are still moving today at a rate of about six centimeters per year.

Changes during the Mesozoic

Click image to view movie.

Changes during the Mesozoic

- Early in the Mesozoic, the continents were merged into one large landmass. During the era, this super-continent broke up and the pieces drifted apart.

Changes during the Mesozoic

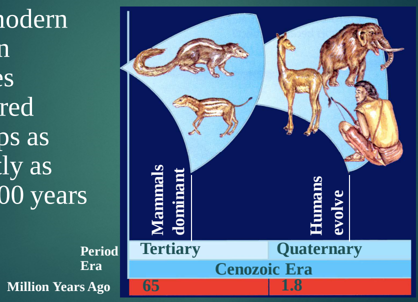
- The theory for how the continents move is called plate tectonics.
- According to this idea, Earth's surface consists of several rigid plates that drift on top of a plastic, partially molten layer of rock.
- These plates are continually moving- spreading apart, sliding by, or pushing against each other. The movements affect organisms.

The Cenozoic Era

- The Cenozoic began about 65 million years ago.
- It is the era in which you now live. Mammals began to flourish during the early part of this era.
- Primates first appeared approximately 75 million years ago and have diversified greatly.

The Cenozoic Era

- The modern human species appeared perhaps as recently as 200,000 years ago.



Section Objectives:

- Analyze early experiments that support the concept of biogenesis.
- Review, analyze, and critique modern theories of the origin of life.
- Relate hypotheses about the origin of cells to the environmental conditions of early Earth.

Origins: The Early Idea

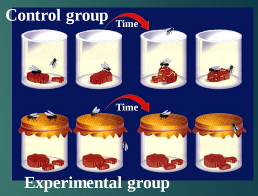
- In the past, the ideas that decaying meat produced maggots, mud produced fishes, and grain produced mice were reasonable explanations for what people observed occurring in their environment.
- Such observations led people to believe in spontaneous generation—the idea that nonliving material can produce life.

Spontaneous generation is disproved

- In 1668, an Italian physician, Francesco Redi, disproved a commonly held belief at the time—the idea that decaying meat produced maggots, which are immature flies.

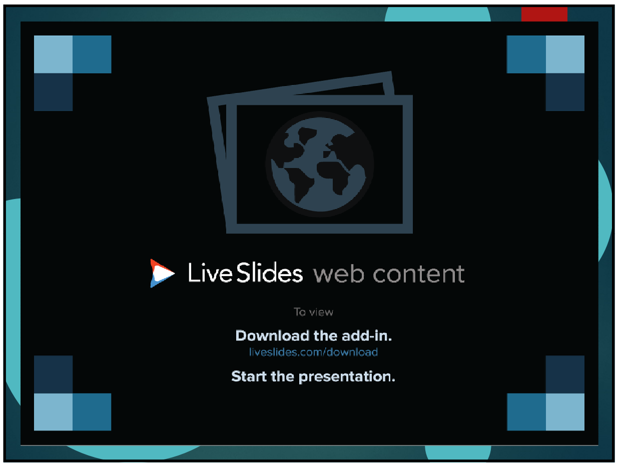
Spontaneous generation is disproved

- Redi's well-designed, controlled experiment successfully convinced many scientists that maggots, and probably most large organisms, did not arise by spontaneous generation.



Spontaneous generation is disproved

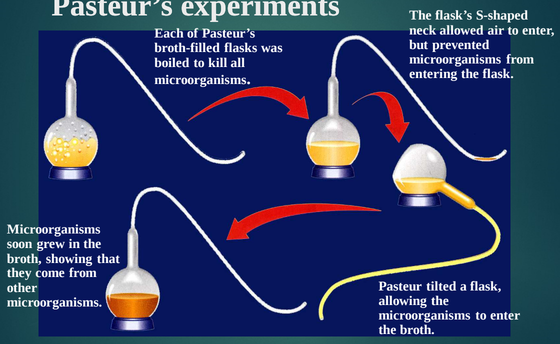
- However, during Redi's time, scientists began to use the latest tool in biology—the microscope.
- Although Redi had disproved the spontaneous generation of large organisms, many scientists thought that microorganisms were so numerous and widespread that they must arise spontaneously-probably from a vital force in the air.



Pasteur's experiments

- In the mid-1800s, Louis Pasteur designed an experiment that disproved the spontaneous generation of microorganisms.
- Pasteur set up an experiment in which air, but no microorganisms, was allowed to contact a broth that contained nutrients.

Pasteur's experiments



Pasteur's experiments

- Pasteur's experiment showed that microorganisms do not simply arise in broth, even in the presence of air.
- From that time on, biogenesis (bi oh JEN uh sus), the idea that living organisms come only from other living organisms, became a cornerstone of biology.

Origins: The Modern Ideas

- No one has yet proven scientifically how life on Earth began.
- However, scientists have developed theories about the origin of life on Earth from testing scientific hypotheses about conditions on early Earth.

Simple organic molecules formed

- Scientists hypothesize that two developments must have preceded the appearance of life on Earth.
- First, simple organic molecules, or molecules that contain carbon, must have formed.
- Then these molecules must have become organized into complex organic molecules such as proteins, carbohydrates, and nucleic acids that are essential to life.

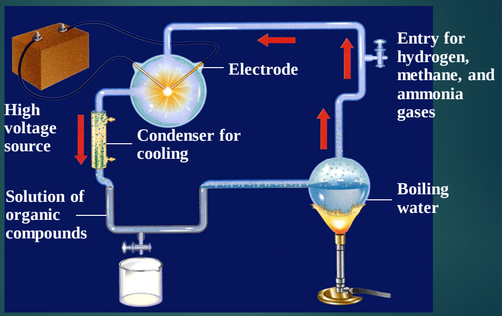
Simple organic molecules formed

- In the 1930s, a Russian scientist, Alexander Oparin, hypothesized that life began in the oceans that formed on early Earth.
- He suggested that energy from the sun, lightning, and Earth's heat triggered chemical reactions to produce small organic molecules from the substances present in the atmosphere.

Simple organic molecules formed

- Then, rain probably washed the molecules into the oceans to form what is often called a primordial soup.
- In 1953, two American scientists, Stanley Miller and Harold Urey, tested Oparin's hypothesis by simulating the conditions of early Earth in the laboratory.

Simple organic molecules formed



The formation of protocells

- The next step in the origin of life, as proposed by some scientists, was the formation of complex organic compounds.
- In the 1950s, various experiments were performed and showed that if the amino acids are heated without oxygen, they link and form complex molecules called proteins.
- A similar process produces ATP and nucleic acids from small molecules.

The formation of protocells

- The work of American biochemist Sidney Fox in 1992 showed how the first cells may have occurred.
- Fox produced protocells by heating solutions of amino acids.
- A protocell is a large, ordered structure, enclosed by a membrane, that carries out some life activities, such as growth and division.

The Evolution of Cells

- Fossils indicate that by about 3.4 billion years ago, photosynthetic prokaryotic cells existed on Earth.
- But these were probably not the earliest cells.

The first true cells

- The first forms of life may have been prokaryotic forms that evolved from a protocell.
- Because Earth's atmosphere lacked oxygen, scientists have proposed that these organisms were most likely anaerobic.

The first true cells

- For food, the first prokaryotes probably used some of the organic molecules that were abundant in Earth's early oceans.
- Over time, these heterotrophs would have used up the food supply.

The first true cells

- However, organisms that could make food had probably evolved by the time the food was gone.
- These first autotrophs were probably similar to present-day archaebacteria.

The first true cells

- Archaebacteria (ar kee bac TEER ee uh) are prokaryotic and live in harsh environments, such as deep-sea vents and hot springs.

The first true cells

- The earliest autotrophs probably made glucose by chemosynthesis rather than by photosynthesis.
- In chemosynthesis, autotrophs release the energy of inorganic compounds, such as sulfur compounds, in their environment to make their food.

Photosynthesizing prokaryotes

- Photosynthesizing prokaryotes might have been the next type of organism to evolve.
- As the first photosynthetic organisms increased in number, the concentration of oxygen in Earth’s atmosphere began to increase.
- Organisms that could respire aerobically would have evolved and thrived.

Photosynthesizing prokaryotes

- The presence of oxygen in Earth’s atmosphere probably affected life on Earth in another important way.
- The sun’s rays would have converted much of the oxygen into ozone molecules that would then have formed a layer that contained more ozone than the rest of the atmosphere.

The endosymbiont theory

- Complex eukaryotic cells probably evolved from prokaryotic cells.
- The endosymbiont theory,proposed by American biologist Lynn Margulis in the early 1960s, explains how eukaryotic cells may have arisen.
- The endosymbiont theory proposes that eukaryotes evolved through a symbiotic relationship between ancient prokaryotes.

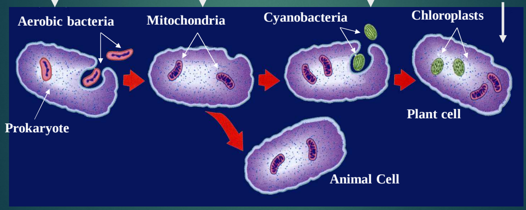
The endosymbiont theory

A prokaryote ingested some aerobic bacteria. The aerobes were protected and produced energy for the prokaryote.

Over a long time, the aerobes become mitochondria, no longer able to live on their own.

Some primitive prokaryotes also ingested cyanobacteria, which contain photosynthetic pigments.

The cyanobacteria become chloroplasts, no longer able to live on their own.



The endosymbiont theory

- New evidence from scientific research supports this theory and has shown that chloroplasts and mitochondria have their own ribosomes that are similar to the ribosomes in prokaryotes.
- In addition, both chloroplasts and mitochondria reproduce independently of the cells that contain them.

The endosymbiont theory

- The fact that some modern prokaryotes live in close association with eukaryotes also supports the theory.