chapter 14 The History of Life

section 2 The Origin of Life

MAIN Idea

Evidence indicates that a sequence of chemical events preceded the origin of life on Earth.

What You'll Learn

- differences between spontaneous generation and biogenesis
- events that might have led to cellular life
- the endosymbiont theory

Before You Read

You want to make a sandwich but find mold growing on the bread. You don't recall seeing mold on the bread yesterday. On the lines below, explain how you think the mold got there. Then read about early ideas about the origins of life.

Mark the Text

Identify Scientists

As you read this section, underline the name of each scientist introduced. Highlight the sentences that explain each person's contribution to understanding the history of life.

Read to Learn

Origins: Early Ideas

There have been many ideas about how life began. Many of these ideas came from people observing the world around them. It was once thought that mice could be created by placing damp hay and corn in a dark corner. This idea that life arises from nonlife is **spontaneous generation**. Spontaneous generation is possibly the oldest idea about the origin of life.

How was spontaneous generation tested?

In 1668, an Italian scientist named Francesco Redi tested the idea that flies arose spontaneously from rotting meat. He hypothesized that flies, not meat, produced other flies. Redi placed rotting meat in flasks that were opened and in flasks that were covered. Redi observed that maggots, the larvae of flies, appeared only in the flasks that were open to flies. The closed flasks did not have flies or maggots.

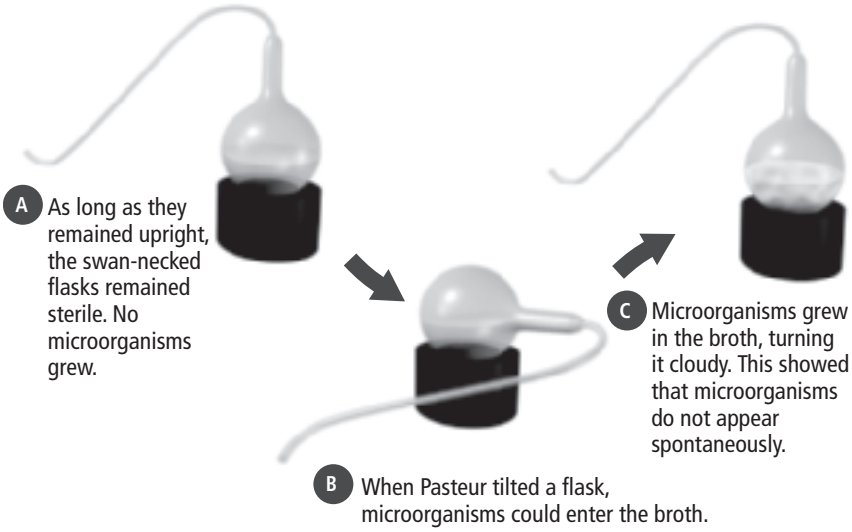
Despite Redi's experiment, people still believed in spontaneous generation. The microscope was beginning to be used during Redi's time. People knew that organisms too small to be seen were everywhere. Some people thought these microbes must arise spontaneously even if flies do not.

Reading Check

1. **Explain** What new device fueled people's belief in spontaneous generation?

What idea replaced spontaneous generation?

In the mid-1800s, Louis Pasteur designed an experiment, as shown in the figure below, to show that the theory of biogenesis was true even for microorganisms. The **theory of biogenesis** (bi oh JEN uh sus) is the idea that living organisms come from other living organisms. Only air was able to enter one flask containing a sterile nutrient broth. Both air and microorganisms were able to enter a second flask containing the sterile nutrient broth. Microorganisms were able to grow in the second flask but not the first flask. After Pasteur's experiment, people rejected spontaneous generation and embraced the theory of biogenesis.



Origins: Modern Ideas

Most biologists agree that life originated through a series of chemical events. During these events, complex organic molecules were made from simpler ones. Eventually, simple metabolic pathways developed. These pathways enabled molecules to be broken down. These pathways might have led to the origin of life.

How did early organic molecules form?

In the 1920s, Russian scientist Alexander Oparin suggested the primordial soup hypothesis explained the origin of life. He thought that if Earth's early atmosphere had a mix of certain gases, organic molecules could have been made from simple reactions involving those gases in the early oceans. UV light from the Sun and lightning might have provided the energy for the reactions. Oparin thought that these organic molecules would eventually lead to life.

Picture This

2. Describe What did Pasteur do that allowed microorganisms to enter the flask?

Reading Check

3. Determine Does biogenesis explain the origin of life?

How was Oparin's hypothesis tested?

In 1953, American scientists Stanley Miller and Harold Urey conducted an experiment showing that simple organic molecules could be made from inorganic compounds. Miller and Urey built a glass apparatus to simulate early Earth conditions. They filled the apparatus with water and gases that they thought had made up the early atmosphere. They boiled the mixture, shined UV light on it to simulate sunshine, and charged it with electricity to simulate lightning. The resulting mixture contained amino acids. Amino acids are the building blocks of proteins.

Reading Check

4. Identify Why did Miller and Urey shine UV light on their apparatus?

Later, other scientists found that hydrogen cyanide could be formed from simpler molecules. Hydrogen cyanide can react with itself to eventually form adenine, one of the nucleotides in the genetic code.

Many other experiments have been carried out under a wide variety of conditions similar to those of early Earth. The final products have been amino acids, sugars, and nucleotides. The experiments showed that reactions for the origin of life were possible on early Earth.

What other hypotheses have been proposed?

Some scientists hypothesize that Earth's surface, with its high UV levels and meteorite strikes, was too destructive to have provided a safe place for life. Some scientists suggest that the organic reactions occurred in hydrothermal volcanic vents of the deep sea, where sulfur is the base of a unique food chain. Still others think meteorites might have brought the first organic molecules to Earth.

How were the first proteins made?

Proteins are chains of amino acids. The Miller-Urey experiment shows that amino acids could form on early Earth. Amino acids can bond to one another, but they can separate just as easily. Proteins might have formed when an amino acid stuck to a particle of clay. Clay would have been a common sediment in early oceans. Clay could have provided a framework for protein assembly.

Reading Check

5. Explain What ocean sediment might have helped protein chains to form?

What was the first genetic code?

Another requirement for life is a genetic code—a coding system for making proteins. Many biologists think RNA was life's first coding system. RNA systems are capable of evolution by natural selection.

How do some RNA molecules behave?

Some types of RNA can behave like enzymes. These RNA molecules could have carried out some early life processes. Some scientists think clay particles could have been a template for RNA replication and that the resulting molecules developed a replication mechanism.

How did the first cells arise?

Another important step in the evolution of cells is the formation of membranes. Scientists have tested ways to enclose molecules in membranes that allow metabolic and reproductive pathways to develop. However, scientists might never know the exact steps that led to cell formation.

Reading Check

6. State What functions must a membrane allow?

_____

_____

Cellular Evolution

Although scientists don't know what the earliest cells were like, chemicals found in rocks suggest life was present 3.8 billion years ago even though no fossils remain. Scientists recently discovered what appear to be fossilized microbes in volcanic rock that is 3.5 billion years old. This suggests that cellular activity had become established. It also suggests that early life might have been linked to volcanic environments.

Scientists think the first cells were prokaryotes, which lack a defined nucleus and most other organelles. Many scientists think prokaryotes called archaea (ar KEE uh) are the closest relatives of Earth's first cells. These microbes live in extreme environments such as hot springs and volcanic vents in the deep sea. These environments are similar to those of early Earth.

When did photosynthetic organisms appear?

Archaea are autotrophs that get their energy from inorganic compounds such as sulfur. Archaea also do not make oxygen.

Scientists think oxygen was not present in Earth's early atmosphere until about 1.8 billion years ago. Any oxygen that appeared earlier probably bonded with free iron ions. Scientists hypothesize that eventually early Earth's free iron bonded with oxygen and oxygen accumulated in the environment.

Scientists think that cyanobacteria, prokaryotes that could perform photosynthesis, evolved about 3.5 billion years ago. These organisms released oxygen into the atmosphere and eventually produced enough oxygen to support ozone layer formation. The ozone layer provided a shield from the Sun's damaging ultraviolet radiation and made conditions right for eukaryotes to develop.

Reading Check

7. Sequence What came first: photosynthetic organisms or eukaryotic cells?

_____

_____

When did eukaryotic cells evolve?

Eukaryotic cells appeared about 1.8 billion years ago. They are larger than prokaryotes and have complex internal membranes, which enclose many organelles including the nucleus.

What is the endosymbiont theory?

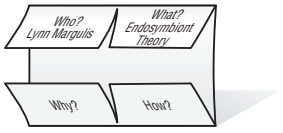
American biologist Lynn Margulis proposed the **endosymbiont theory** which states that ancestors of eukaryotic cells lived together in association with prokaryotic cells. In some cases, prokaryotes might even have lived inside eukaryotes. Prokaryotes might have entered eukaryotes as undigested prey, or they might have been internal parasites. Eventually, the relationship benefitted both cells and the prokaryotes became organelles inside the eukaryotic cells, as shown in the figure below.

Evidence suggests that mitochondria and chloroplasts formed by endosymbiosis. Mitochondria and chloroplasts contain their own DNA arranged in circular patterns like the DNA of prokaryotes. Mitochondria and chloroplasts have ribosomes that are more similar to the ribosomes in prokaryotes than to those in eukaryotes. Like prokaryotic cells, mitochondria and chloroplasts reproduce by fission independent from the rest of the cell.

Scientists do not know the early steps that led to life or to its evolution. Scientists continue to test theories and evaluate new evidence as they seek answers to understand what led to life on Earth.

FOLDABLES™

Take Notes Make a four-door Foldable, as shown below. As you read, take notes and organize what you learn about the endosymbiont theory.



Picture This

8. Highlight the name of the structure that cyanobacteria became.