# CHAPTER 15

# The Evolution of Microbial Life

***Figures 15.1 – 15.7***

PowerPoint® Lecture Slides for
***Essential Biology, Second Edition*** & ***Essential Biology with Physiology***

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**Presentation prepared by Chris C. Romero**



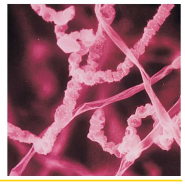
- The number of bacteria in one human's mouth is greater than the total number of people who ever lived

- Each year more than 200 million people become infected with malaria.



- Bacterial fermentation is used to produce cheese, yogurt, buttermilk, and many types of sausage

- More than half of our antibiotics come from soil bacteria of the genus *Streptomyces.*



## BIOLOGY AND SOCIETY:
## BIOTERRORISM

- During the fall of 2001, five Americans died from the disease anthrax in a presumed terrorist attack.


Figure 15.1



- Animals, plants, fungi, and viruses have all served as weapons, but the most frequently employed biowarfare agents have been bacteria
- History provides many examples of the use of biological agents as weapons
  - The practical difficulties of controlling such weapons—and a measure of ethical repugnance—led the United States to end its bioweapons program in 1969 and to destroy its products
  - Although not all signatories have honored it, 103 nations have signed the Biological Weapons Convention, pledging never to develop or store biological weapons.



- Not all bacteria are harmful to humans
  - Nearly all life on Earth depends on bacteria and other microbial life in one way or another.

## MAJOR EPISODES IN THE HISTORY OF LIFE

- Earth was born 4.5 billion years ago.



- Prokaryotes
  - Appeared about 3.5 billion years ago
- Oxygen production
  - Began about 2.5 billion years ago
- Single-celled eukaryotic organisms
  - Evolved about 1.7 billion years ago.



- Multicellular eukaryotes
  - Evolved about 1 billion years ago
- All the major phyla of animals
  - Evolved by the end of the Cambrian explosion, which began about 570 million years ago
- About 475 million years ago
  - Plants and fungi colonized land
  - Amphibians evolved from fish, and vertebrate life moved onto land.

- Some major episodes in the history of life.



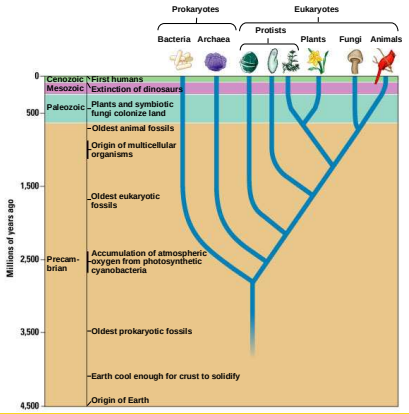



Figure 15.2



## THE ORIGIN OF LIFE

- We may never know how life began on Earth.

## Resolving the Biogenesis Paradox

- All life today arises by the reproduction of preexisting life, or biogenesis.



- Most biologists now think it is possible that chemical and physical processes on the early Earth produced simple cells.

Figure 15.3



## A Four-Stage Hypothesis for the Origin of Life

- According to one hypothetical scenario, the first organisms were products of chemical evolution in four stages.

## *Stage 1: Abiotic Synthesis of Organic Monomers*

- Stanley Miller
  - Devised an experiment that produced small organic molecules in 1953.

Figure 15.4



## *Stage 2: Abiotic Synthesis of Polymers*

- Researchers have observed polymerization of organic monomers in various situations.



## *Stage 3: Origin of Self-Replicating Molecules*

- Laboratory experiments have shown that short RNA molecules can assemble spontaneously.

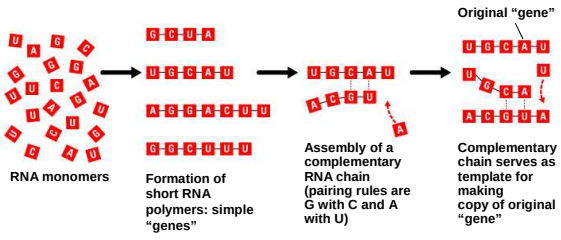
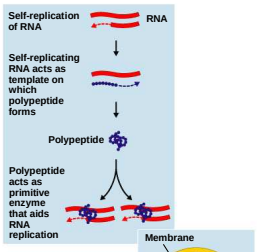



Figure 15.5

## *Stage 4: Formation of Pre-Cells*

- The properties of life emerge from an interaction of molecules organized into higher levels of order.



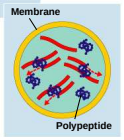




Figure 15.6



- Laboratory experiments demonstrate that pre-cells could have formed spontaneously from abiotically produced organic compounds.

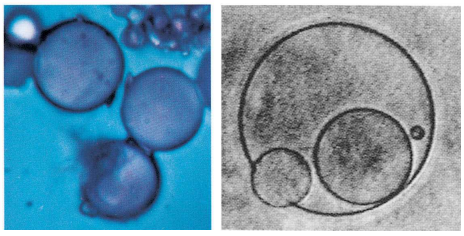


Figure 15.7



## From Chemical Evolution to Darwinian Evolution

- Over millions of years
  - Natural selection favored the most efficient pre-cells
  - The first prokaryotic cells evolved.

## Prokaryotes

- Prokaryotes
  - Lived and evolved all alone on Earth for 2 billion years.

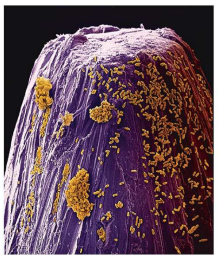


Figure 15.8



## They're Everywhere!

- Prokaryotes
  - Are found wherever there is life
  - Outnumber all eukaryotes combined
  - Can cause disease
  - Can be beneficial.



## The Two Main Branches of Prokaryotic Evolution: Bacteria and Archaea

- The majority of prokaryotes are bacteria.

- Some archaea are "extremophiles"
  - Extreme halophiles thrive in salty environments.

Figure 15.9



- Extreme thermophiles
  - Inhabit very hot water
- Methanogens
  - Inhabit the bottoms of lakes and swamps.



## The Structure, Function, and Reproduction of Prokaryotes

- Prokaryotic cells
  - Lack nuclei
  - Lack other membrane-enclosed organelles
  - Have cell walls exterior to their plasma membranes.

- Prokaryotes come in several shapes
  - Cocci
  - Bacilli
  - Spirochetes.

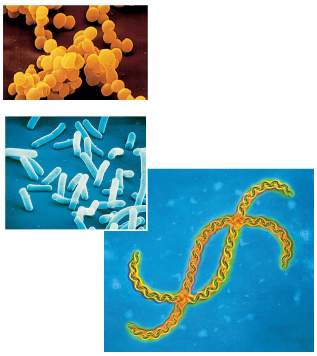


Figure 15.10



- Most prokaryotes are unicellular and very small.



- Some prokaryotes
  - Form true colonies
  - Show specialization of cells
  - Are very large.

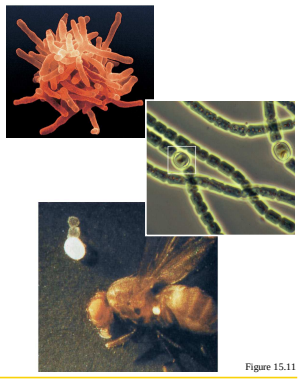


Figure 15.11

- About half of all prokaryotes are motile, using flagella.

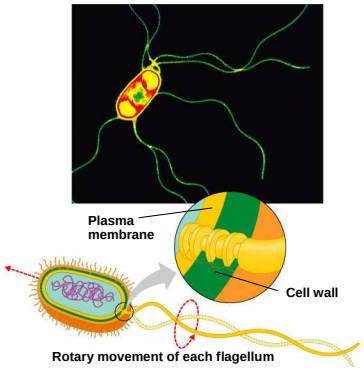



Figure 15.12



- Some prokaryotes
  - Can survive extended periods of very harsh conditions
  - Form endospores.

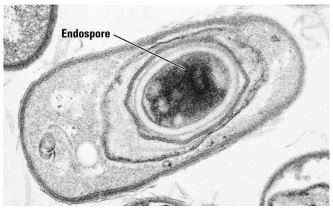



Figure 15.13



- Most prokaryotes can reproduce by binary fission at very high rates if conditions are favorable.

## The Nutritional Diversity of Prokaryotes

- Prokaryotes exhibit four major modes of nutrition.

**Table 15.1 Nutritional Classification of Organisms**

| Nutritional Type | Energy Source | Carbon Source |
|---|---|---|
| Photoautotroph (photosynthesizer) | Sunlight | $CO_2$ |
| Chemoautotroph | Inorganic chemicals | $CO_2$ |
| Photoheterotroph | Sunlight | Organic compounds |
| Chemoheterotroph | Organic compounds | Organic compounds |

Table 15.1



- Photoautotrophs
  - Are photosynthetic organisms
  - Include the cyanobacteria
- Chemoautotrophs
  - Need $CO_2$ as a carbon source
  - Extract energy from inorganic substances.



- Photoheterotrophs
  - Use light to generate ATP
  - Must obtain their carbon in organic form
- Chemoheterotrophs
  - Must consume organic molecules for both energy and carbon.

## The Ecological Impact of Prokaryotes

- Prokaryotes
  - Have a major impact on the Earth and its inhabitants.



## *Bacteria That Cause Disease*

- Pathogens
  - Are bacteria and other microorganisms that cause disease.

Figure 15.14



- Most pathogenic bacteria
  - Cause disease by producing poisons
- Exotoxins
  - Are poisonous proteins secreted by bacterial cells
- Endotoxins
  - Are chemical components of the cell walls of certain bacteria.

- The best defenses against bacterial disease are
  - Sanitation
  - Antibiotics
  - Education.



- Lyme disease
  - Is caused by bacteria carried by ticks.

Figure 15.15



## *Prokaryotes and Chemical Recycling*

- Prokaryotes play essential roles
  - In chemical cycles in the environment
  - In the breakdown of organic wastes and dead organisms.

## *Prokaryotes and Bioremediation*

- Bioremediation is the use of organisms to remove pollutants from water, air, and soil
  - A familiar example is use of prokaryotic decomposers in sewage treatment.



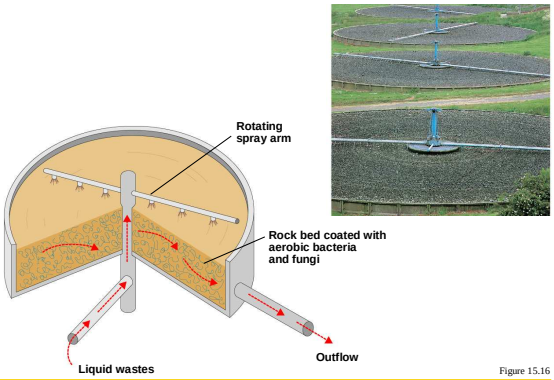



Figure 15.16



- Certain bacteria can decompose petroleum and are useful in cleaning up oil spills.

Figure 15.17

## PROTISTS

- Protists
  - Are eukaryotic
  - Evolved from prokaryotes.



## The Origin of Eukaryotic Cells

- Eukaryotic cells evolved through the combination of two processes.



- In one process, the eukaryotic cell's endomembrane system evolved from inward folds of the plasma membrane of a prokaryotic cell.

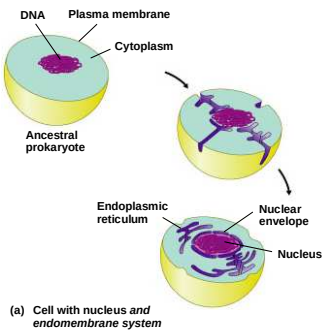
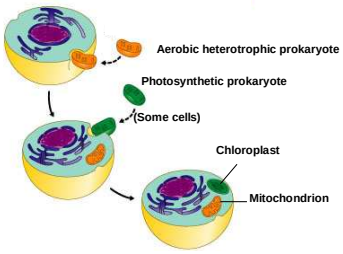



Figure 15.18a

- The second process, endosymbiosis, generated mitochondria and chloroplasts.




(b) Photosynthetic eukaryotic cell

Figure 15.18b



## The Diversity of Protists

- All protists are eukaryotes
  - Most are unicellular.



## *Protozoans*

- Protozoans
  - Live primarily by ingesting food.

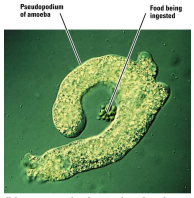
- Protozoans include
  - Flagellates, with flagella.

(a) Trypanosomes (flagellates)

Figure 15.19a

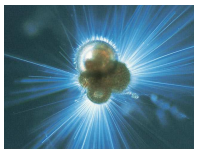


  - Amoebas, with pseudopodia




(b) An amoeba ingesting food

  - Forams.

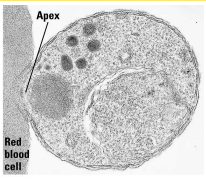


(c) A foram

Figure 15.19b, c

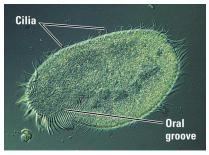


  - Apicomplexans




(d) An apicomplexan: *Plasmodium*

  - Ciliates, with cilia.




(e) *Paramecium*

Figure 15.19d, e

## *Slime Molds*

- Slime molds
  - Resemble fungi in appearance and lifestyle.



- Plasmodial slime molds
  - Can be large.

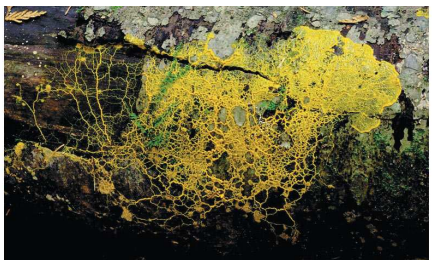


Figure 15.20



- Cellular slime molds
  - Have an interesting and complex life cycle.

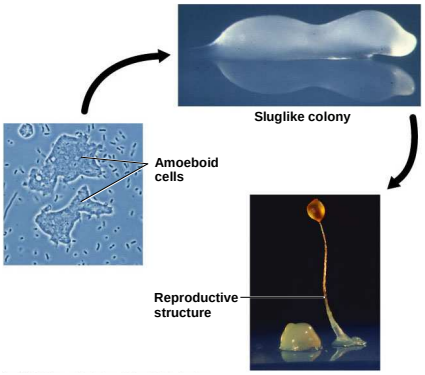



Figure 15.21



## *Unicellular Algae*

- Algae
  - Are photosynthetic protists
  - Are found in plankton.



- Unicellular algae include
  - Dinoflagellates, components of phytoplankton
  - Diatoms, which have glassy walls.

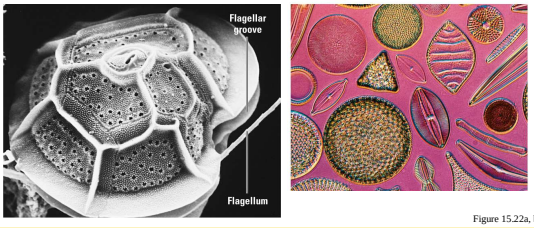



Figure 15.22a, b

– Green algae, unicellular and colonial.

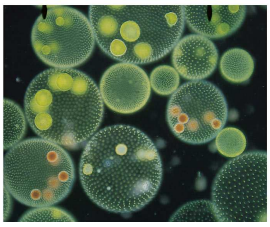


Figure 15.22c, d



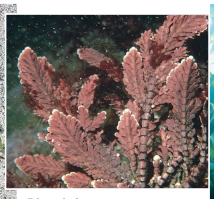
## *Seaweeds*

- Seaweeds
  - Are large, multicellular marine algae
  - Grow on rocky shores and just offshore
  - Are often edible.

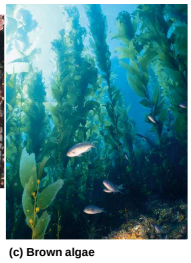


- The three major groups of seaweeds.

(a) Green algae



(b) Red algae



(c) Brown algae

Figure 15.23

## EVOLUTION CONNECTION:
## THE ORIGIN OF MULTICELLULAR LIFE

- Multicellular organisms
  - Are different from unicellular ones
  - Have specialized cells.



- The evolutionary links between unicellular and multicellular organisms were probably colonial protists.

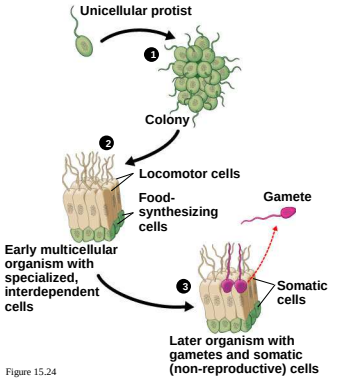



Figure 15.24



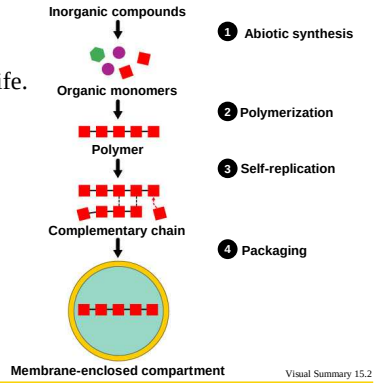
## SUMMARY OF KEY CONCEPTS

- Major Episodes in the History of Life.

| Millions of years ago | Major Episode |
|---|---|
| 475 | Plants and fungi colonize land |
| 570 | All major animal phyla established |
| 1,000 | First multicellular organisms |
| 1,700 | Oldest eukaryotic fossils |
| 2,500 | Accumulation of atmospheric $0_2$ |
| 3,500 | Oldest prokaryotic fossils |
| 4,500 | Origin of Earth |

Visual Summary 15.1

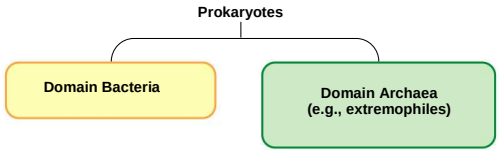
- A Four-Stage Hypothesis for the Origin of Life.




Visual Summary 15.2



- The Two Main Branches of Prokaryotic Evolution: Bacteria and Archaea.




Visual Summary 15.3



- The Nutritional Diversity of Prokaryotes.

| Nutritional Mode | Energy Source | Carbon Source |
|---|---|---|
| Photoautotroph | Sunlight | $CO_2$ |
| Chemoautotroph | Inorganic chemicals | |
| Photoheterotroph | Sunlight | Organic compounds |
| Chemoheterotroph | Organic compounds | |

Visual Summary 15.4