The Evolution of Microbial Life

Prokaryotes and Protista

An artist's rendition of Earth about 3 billion years ago.
MAJOR EPISODES IN THE HISTORY OF LIFE

• Earth was formed about 4.6 billion years ago.

• Prokaryotes
  – Evolved by 3.5 billion years ago
  – Began oxygen production about 2.7 billion years ago
  – Lived alone for almost 2 billion years
  – Continue in great abundance today
- Single-celled **eukaryotes** first evolved about 2.1 billion years ago.
- Multicellular eukaryotes first evolved at least 1.2 billion years ago.
Paleozoic

Mesozoic

Cenozoic

Bacteria

Archaea

Plants

Fungi

Animals

Prokaryotes

Eukaryotes

Oldest eukaryotic fossils

Origin of multicellular organisms

Cambrian explosion

Oldest animal fossils

Plants and symbiotic fungi colonize land

Extinction of dinosaurs

First humans

Figure 15.1b
• All the major phyla of animals evolved by the end of the Cambrian explosion, which began about 540 million years ago and lasted about 10 million years.

• Plants and fungi
  – First colonized land about 500 million years
  – Were followed by amphibians that evolved from fish
The evolution of earth in 60 sec

Humans

Colonization of land

Animals

Multicellular eukaryotes

Single-cell eukaryotes

Atmospheric oxygen

Origin of solar system and Earth

Billions of years ago

Present

0

1

2

3

4

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Figure 15.2
Stanley Miller re-creating his 1953 experiment

Miller and Urey’s experiment

“Sea”

Cooled water containing organic molecules

“Atmosphere”

CH$_4$  NH$_3$  H$_2$

Electrode

Condenser

Cold water

Sample for chemical analysis

H$_2$O

Figure 15.4
They’re Everywhere!

• Prokaryotes
  – Are found wherever there is life
  – Far outnumber eukaryotes
  – Can cause disease
  – Can be beneficial

• Prokaryotes live deep within the Earth and in habitats too cold, too hot, too salty, too acidic, or too alkaline for any eukaryote to survive.
Bacteria

Archaea

Prokaryotes

Eukarya

Protists

Plants

Fungi

Animals

Figure 15.UN01
• Compared to eukaryotes, prokaryotes are
  – Much more abundant
  – Typically much smaller
• Prokaryotes
  – Are ecologically significant, recycling carbon and other vital chemical elements back and forth between organic matter, the soil, and atmosphere
  – Cause about half of all human diseases
  – Are more typically benign or beneficial
The Structure and Function of Prokaryotes

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

  Most prokaryotes are
  - Unicellular
  - Very small

- **Some prokaryotes**
  - Form true colonies
  - Show specialization of cells
  - Are very large
The Two Main Branches of Prokaryotic Evolution: Bacteria and Archaea

- By comparing diverse prokaryotes at the molecular level, biologists have identified two major branches of prokaryotic evolution:
  - Bacteria
  - Archaea (more closely related to eukaryotes)
Some archaea are “extremophiles.”

- Halophiles thrive in salty environments.
- Thermophiles inhabit very hot water.
- Methanogens inhabit the bottoms of lakes and swamps and aid digestion in cattle and deer.
Bacteria That Cause Disease

• Bacteria and other organisms that cause disease are called pathogens.

• Most pathogenic bacteria produce poisons.
  – **Exotoxins** are poisonous proteins secreted by bacterial cells.
  – **Endotoxins** are not cell secretions but instead chemical components of the outer membrane of certain bacteria.
• Lyme disease is
  – Caused by bacteria carried by ticks
  – Treated with antibiotics, if detected early
Spirochete that causes Lyme disease
Bioterrorism

- Humans have a long and ugly history of using organisms as weapons.
  - During the Middle Ages, armies hurled the bodies of plague victims into enemy ranks.
  - Early conquerors, settlers, and warring armies in South and North America gave native peoples items purposely contaminated with infectious bacteria.
  - In 1984, members of a cult in Oregon contaminated restaurant salad bars with *Salmonella* bacteria.
  - In the fall of 2001, five Americans died from the disease anthrax in a presumed terrorist attack.
PROTISTS

• Protists
  – Are eukaryotic
  – Evolved from prokaryotic ancestors
  – Are ancestral to all other eukaryotes, which are
    – Plants
    – Fungi
    – Animals
The Diversity of Protists

• Protists can be
  – Unicellular
  – Multicellular

• More than any other group, protists vary in
  – Structure
  – Function

• Protists are not one distinct group but instead represent all the eukaryotes that are not plants, animals, or fungi.
• The classification of protists remains a work in progress.

• The four major categories of protists, grouped by lifestyle, are
  – Protozoans
  – Slime molds
  – Unicellular algae
  – Seaweeds
Protozoans

- Protists that live primarily by ingesting food are called protozoans.

- Protozoans with flagella are called flagellates and are typically free-living, but sometimes are nasty parasites.
A flagellate: *Giardia*
Another flagellate: trypanosomes
• **Amoebas** are characterized by
  
  – Great flexibility in their body shape
  
  – The absence of permanent organelles for locomotion

• Most species move and feed by means of **pseudopodia** (singular, *pseudopodium*), temporary extensions of the cell.
• **Apicomplexans** are
  
  – Named for a structure at their apex (tip) that is specialized for penetrating host cells and tissues
  
  – All parasitic, such as *Plasmodium*, which causes malaria
• Ciliates
  
  – Are mostly free-living (nonparasitic), such as the freshwater ciliate *Paramecium*
  
  – Use structures called cilia to move and feed
Slime Molds

- Slime molds resemble fungi in appearance and lifestyle, but the similarities are due to convergence, and slime molds are not at all closely related to fungi.

- The two main groups of these protists are
  - Plasmodial slime molds
  - Cellular slime molds

A plasmodial slime mold
• Plasmodial slime molds
  – Can be large
  – Are decomposers on forest floors
  – Are named for the feeding stage in their life cycle, an amoeboid mass called a plasmodium
• **Cellular slime molds** have an interesting and complex life cycle that changes between a

  – Feeding stage of solitary amoeboid cells
  – Sluglike colony that moves and functions as a single unit
  – Stalklike reproductive structure
Unicellular and Colonial Algae

• Algae are
  – Photosynthetic protists
  – Found in **plankton**, the communities of mostly microscopic organisms that drift or swim weakly in aquatic environments

• Unicellular algae include
  – **Diatoms**, which have glassy cell walls containing silica
  – **Dinoflagellates**, with two beating flagella and external plates made of cellulose
(a) A dinoflagellate, with its wall of protective plates

(b) A sample of diverse diatoms, which have glossy walls

(c) *Chlamydomonas*, a unicellular green alga with a pair of flagella

(d) *Volvox*, a colonial green alga
Seaweeds

- Are only similar to plants because of convergent evolution
- Are large, multicellular marine algae
- Grow on or near rocky shores
- Are often edible
Seaweeds

- Seaweeds are classified into three different groups, based partly on the types of pigments present in their chloroplasts:
  - Green algae
  - Red algae
  - Brown algae (including kelp)