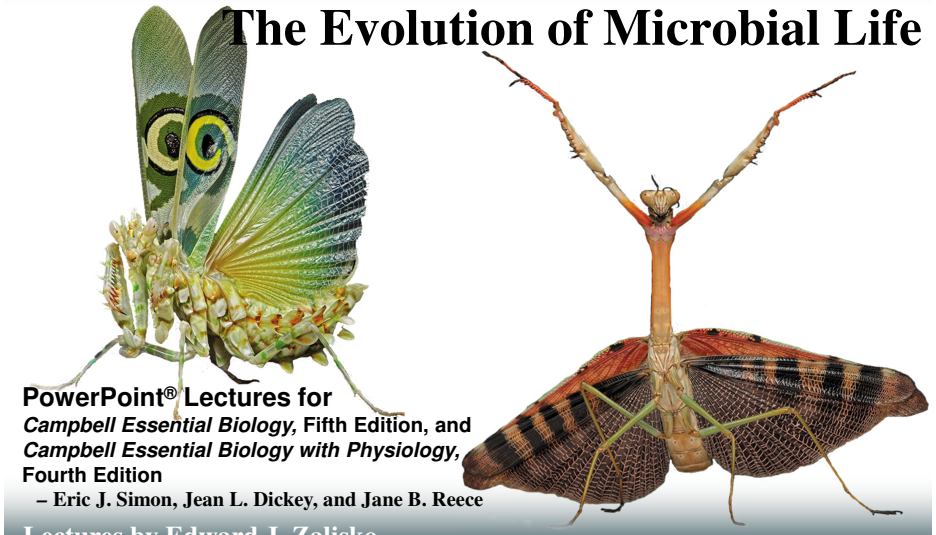
Chapter 15

The Evolution of Microbial Life



PowerPoint® Lectures for
Campbell Essential Biology, Fifth Edition, and
Campbell Essential Biology with Physiology, Fourth Edition
– Eric J. Simon, Jean L. Dickey, and Jane B. Reece

Lectures by Edward J. Zalisko

ALWAYS LEARNING

PEARSON

Chapter 15 Outline: The Evolution of Microbial Life

- Major Episodes in the History of Life
- The Origin of Life
- Prokaryotes
- Protists

Biology and Society: Has Life Been Created in the Lab?

- How did life first arise on Earth?
- To gain insight, scientists have
  - synthesized from scratch the entire genome of a small bacterium known as *Mycoplasma mycoides* and
  - transplanted the artificial genome into the cells of a closely related species called *Mycoplasma capricolum.*

Biology and Society: Has Life Been Created in the Lab?

- The newly installed genome
  - took over the recipient cells,
  - began cranking out *M. mycoides* proteins, and
  - reproduced to make more cells containing the synthetic *M. mycoides* genome.

Chapter 15 Outline: The Evolution of Microbial Life

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- **Major Episodes in the History of Life**
- The Origin of Life
- Prokaryotes
- Protists

MAJOR EPISODES IN THE HISTORY OF LIFE

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- Earth was formed about 4.6 billion years ago.
- **Prokaryotes**
  - evolved by about 3.5 billion years ago,
  - began oxygen production about 2.7 billion years ago
    - Many killed off because oxygen byproducts can be very toxic
  - lived alone for more than a billion years, and
  - continue in great abundance today.

MAJOR EPISODES IN THE HISTORY OF LIFE

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- Single-celled **eukaryotes** first evolved about 2.1 billion years ago.
- Multicellular eukaryotes first evolved at least 1.2 billion years ago.

Figure 15.1a

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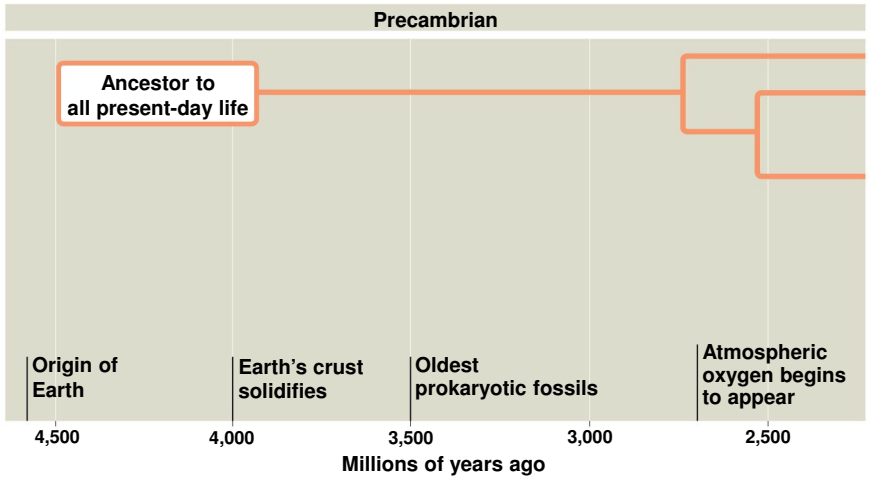


Figure 15.1b

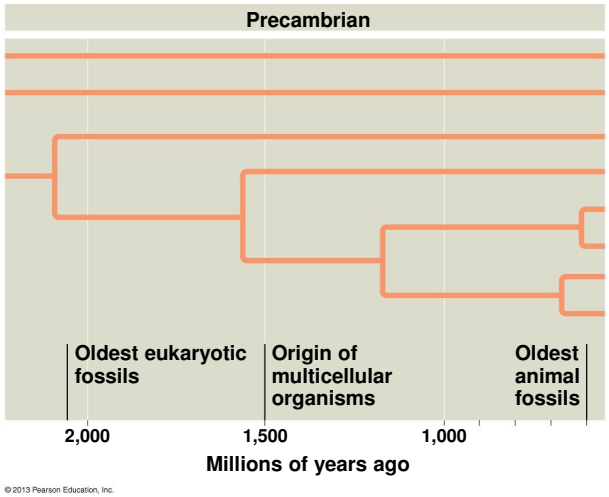
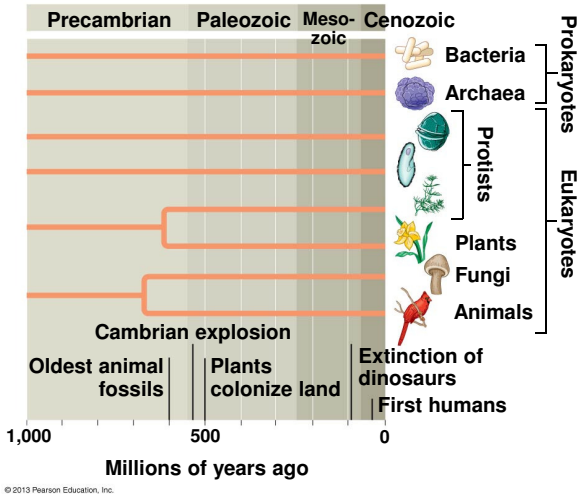


Figure 15.1c



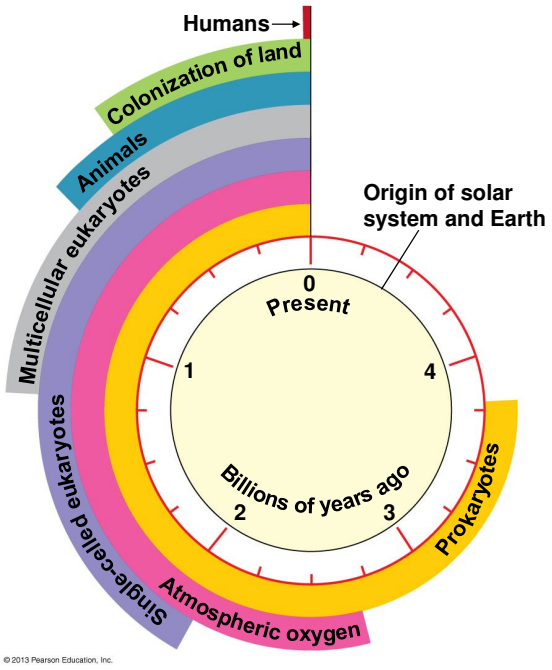
MAJOR EPISODES IN THE HISTORY OF LIFE

- 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 ago and
  - were followed by amphibians that evolved from fish.

MAJOR EPISODES IN THE HISTORY OF LIFE

- What if we use a clock analogy to tick down all of the major events in the history of life on Earth?

Figure 15.2



Chapter 15 Outline: The Evolution of Microbial Life

- Major Episodes in the History of Life
- **The Origin of Life**
  - Resolving the Biogenesis Paradox
  - A Four-Stage Hypothesis for the Origin of Life
  - From Chemical Evolution to Darwinian Evolution
- Prokaryotes
- Protists

THE ORIGIN OF LIFE

- We may never know for sure how life on Earth began.

Resolving the Biogenesis Paradox

- All life today arises by the reproduction of preexisting life, or **biogenesis**.
- If this is true, how could the first organisms arise?
- From the time of the ancient Greeks until well into the 1800s, it was commonly believed that life regularly arises from nonliving matter, an idea called **spontaneous generation**.

Resolving the Biogenesis Paradox

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- Today, most biologists think it is possible that life on early Earth evolved from simple cells produced by
  - chemical and
  - physical processes.

A Four-Stage Hypothesis for the Origin of Life

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- According to one hypothesis, the first organisms were products of chemical evolution in four stages.
  1. The abiotic synthesis of small organic molecules
  2. The joining of these molecules into macromolecules
  3. The packaging of these molecules into pre-cells
  4. The origin of self-replicating molecules that made inheritance possible

Figure 15.UN04

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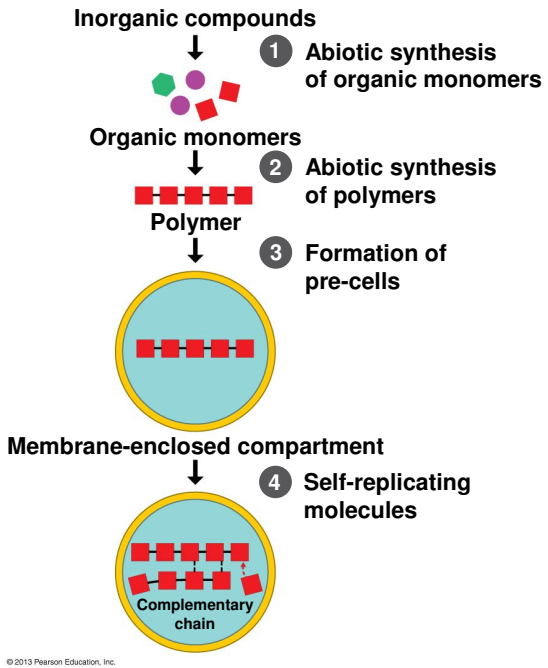

Stage 1: Abiotic Synthesis of Organic Monomers

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- The first stage in the origin of life was the first to be extensively studied in the laboratory.

The Process of Science: Can Biological Monomers Form Spontaneously?

- **Observation**: Modern biological macromolecules are all composed of elements that were present in abundance on early Earth.
- **Question**: Could biological molecules arise spontaneously under conditions like those on early Earth?

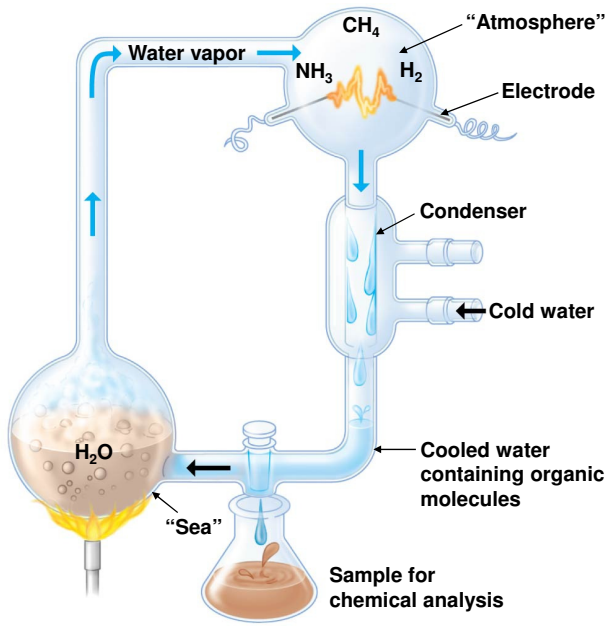
The Process of Science: Can Biological Monomers Form Spontaneously?

- **Hypothesis**: A closed system designed to simulate early Earth conditions could produce biologically important organic molecules from inorganic ingredients.
- **Prediction**: Organic molecules would form and accumulate.

The Process of Science: Can Biological Monomers Form Spontaneously?

- **Experiment**: An apparatus was built to mimic the early Earth atmosphere and included
  - hydrogen gas (H_2), methane (CH_4), ammonia (NH_3), and water vapor (H_2O),
  - sparks that were discharged into the chamber to mimic the prevalent lightning of early Earth, and
  - a condenser that cooled the atmosphere, causing water and dissolved compounds to "rain" into the miniature "sea."

Figure 15.4



Miller and Urey's experiment

The Process of Science: Can Biological Monomers Form Spontaneously?

- **Results**: After the apparatus had run for a week, an abundance of organic molecules essential for life had collected in the "sea," including amino acids, the monomers of proteins.
- These laboratory experiments
  - have been repeated and extended by other scientists and
  - support the idea that organic molecules could have arisen abiotically on early Earth.

Stage 2: Abiotic Synthesis of Polymers

- Researchers have brought about the polymerization of monomers to form polymers, such as proteins and nucleic acids, by dripping solutions of organic monomers onto
  - hot sand,
  - clay, or
  - rock.

Stage 3: Formation of Pre-Cells

- A key step in the origin of life was the isolation of a collection of abiotically created molecules within a membrane.
- Laboratory experiments demonstrate that pre-cells could have formed spontaneously from abiotically produced organic compounds.

Stage 3: Formation of Pre-Cells

- Such pre-cells produced in the laboratory display some lifelike properties. They
  - have a selectively permeable surface,
  - can grow by absorbing molecules from their surroundings, and
  - swell or shrink when placed in solutions of different salt concentrations.

Stage 4: Origin of Self-Replicating Molecules

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- Life is defined partly by the process of inheritance, which is based on self-replicating molecules.
- One hypothesis is that the first genes were short strands of RNA that replicated themselves
  - without the assistance of proteins,
  - perhaps using RNAs that can act as enzymes, called **ribozymes**.

Figure 15.5-1

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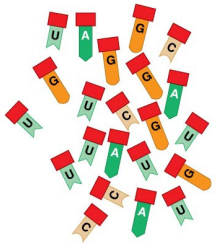

RNA monomers

Figure 15.5-2

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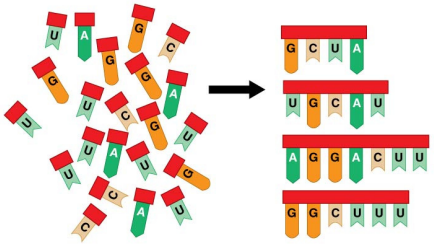

Figure 15.5-3

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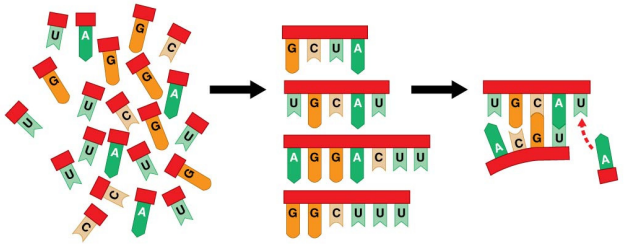


Figure 15.5-4

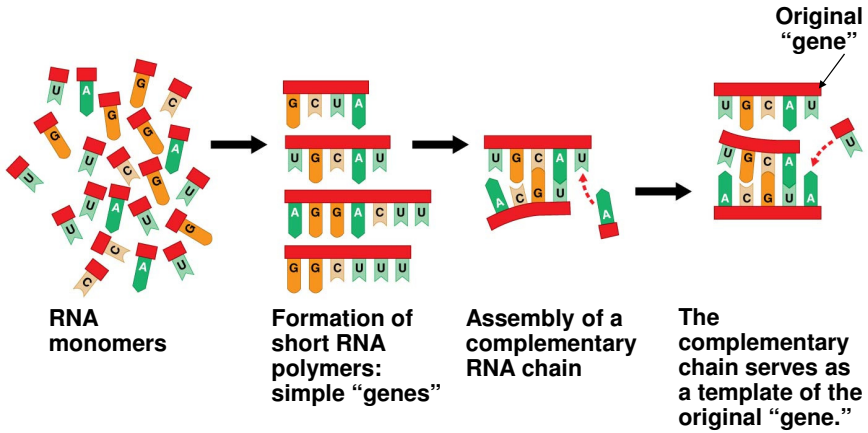
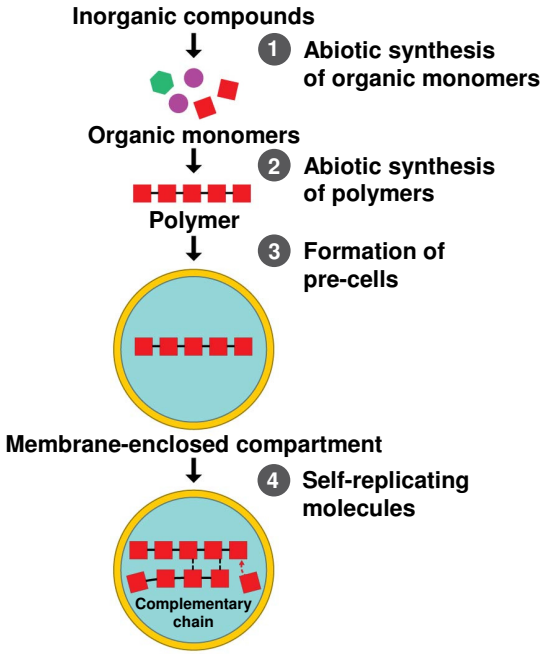


Figure 15.UN04



From Chemical Evolution to Darwinian Evolution

- Over millions of years
  - natural selection favored the most efficient pre-cells and

    …yada yada yada…
  - the first prokaryotic cells evolved!

Chapter 15 Outline: The Evolution of Microbial Life

- Major Episodes in the History of Life
- The Origin of Life
- **Prokaryotes**
  - They're Everywhere!
  - The Structure and Function of Prokaryotes
  - The Two Main Branches of Prokaryotic Evolution: Bacteria and Archaea
  - Bacteria and Disease
  - The Ecological Impact of Prokaryotes
- Protists

PROKARYOTES

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

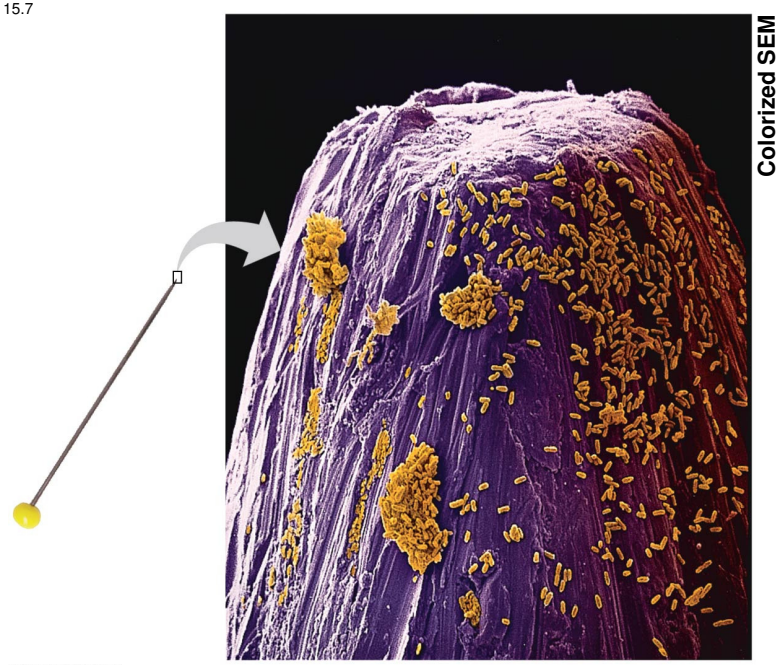
They're Everywhere!

- Prokaryotes
  - are found wherever there is life,
  - have a collective biomass that is at least ten times that of all eukaryotes,
  - thrive in habitats too cold, too hot, too salty, too acidic, or too alkaline for any eukaryote,
  - cause about half of all human diseases, and
  - are more commonly benign or beneficial.

They're Everywhere!

- Compared to eukaryotes, prokaryotes are
  - much more abundant and
  - typically much smaller.

Figure 15.7



They're Everywhere!

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- Prokaryotes living in soil and at the bottom of lakes, rivers, and oceans help to decompose dead organisms and other organic waste material, returning vital chemical elements to the environment.

The Structure and Function of Prokaryotes

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- Prokaryotic cells
  - lack a membrane-enclosed nucleus,
  - lack other membrane-enclosed organelles,
  - typically have cell walls exterior to their plasma membranes, but
  - display an enormous range of diversity.

Figure 4.4

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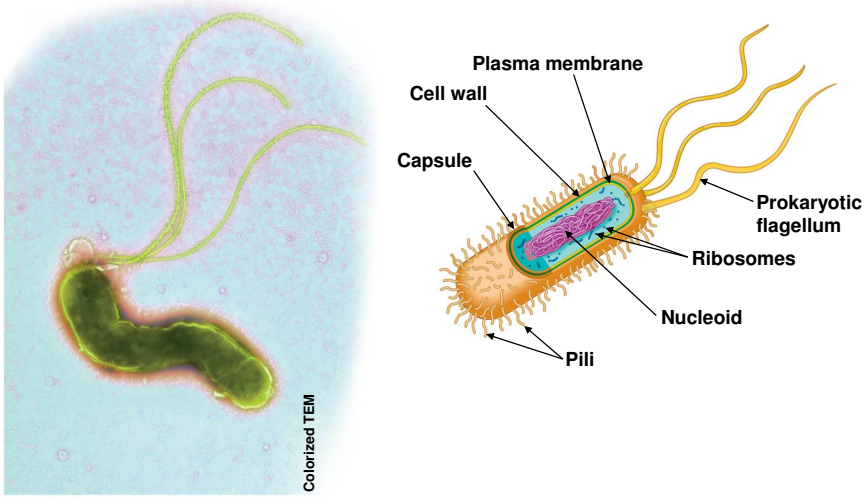

Figure 4.5

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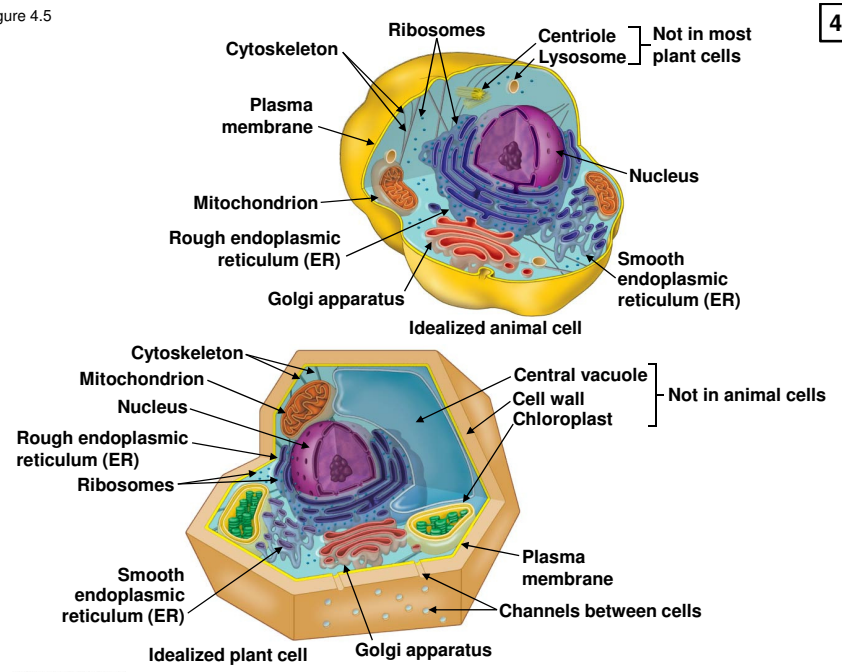


PROTISTS

- **Protists** are
  - eukaryotes that are not fungi, animals, or plants,
  - mostly unicellular, and
  - ancestral to all other eukaryotes.

The Origin of Eukaryotic Cells

- Eukaryotic cells evolved by
  - the infolding of the plasma membrane of a prokaryotic cell to form the endomembrane system and
  - a process known as **endosymbiosis**.

The Origin of Eukaryotic Cells

- **Symbiosis** is a more general association between organisms of two or more species.
- **Endosymbiosis**
  - refers to one species living inside another host species and
  - is the process by which eukaryotes gained mitochondria and chloroplasts.

Figure 15.19a

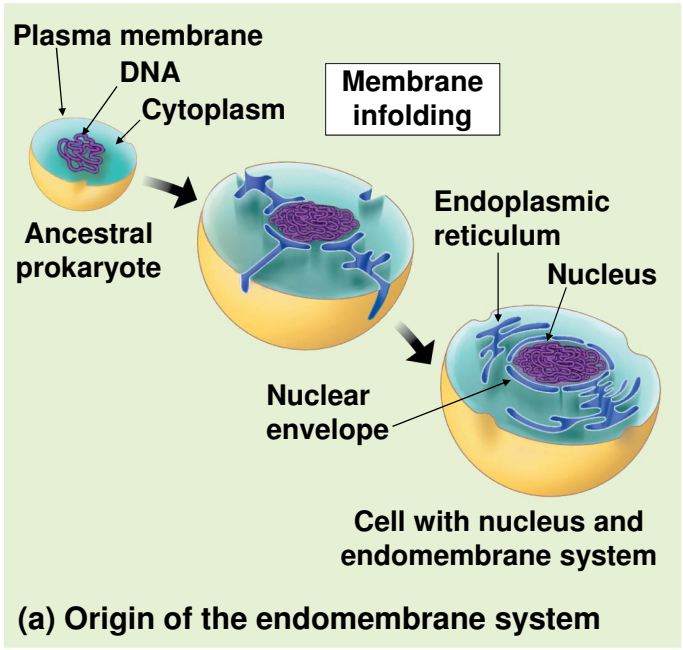
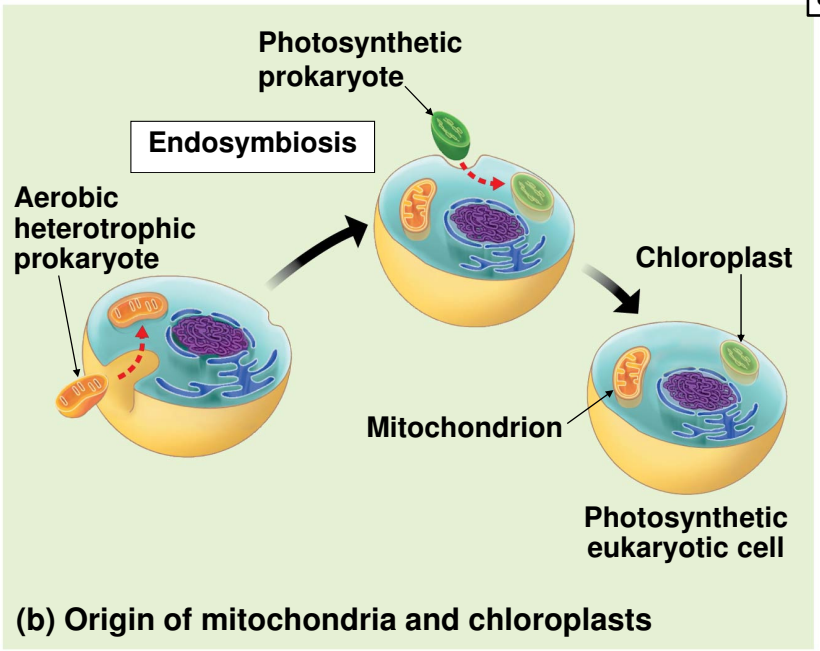


Figure 15.19b



The Diversity of Protists

- The group called protists
  - consists of multiple clades but
  - remains a convenient term to refer to eukaryotes that are not plants, animals, or fungi.

The Diversity of Protists

- Protists obtain their nutrition in a variety of ways.
  - **Algae** are autotrophs, producing their food by photosynthesis.

Evolution Connection: The Origin of Multicellular Life

- Multicellular organisms have
  - specialized cells that are dependent on each other and perform different functions, such as
    - feeding,
    - waste disposal,
    - gas exchange, and
    - protection.

Evolution Connection: The Origin of Multicellular Life

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- Colonial protists likely formed the evolutionary links between
  - unicellular and
  - multicellular organisms.
- The colonial green alga *Volvox* demonstrates one level of specialization and cooperation.

Figure 15.27-1

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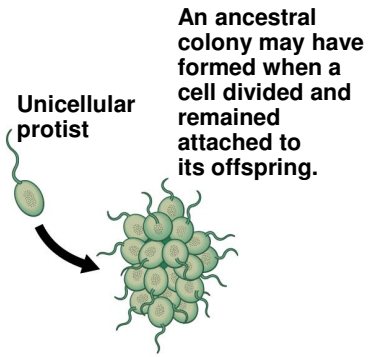

Figure 15.27-2

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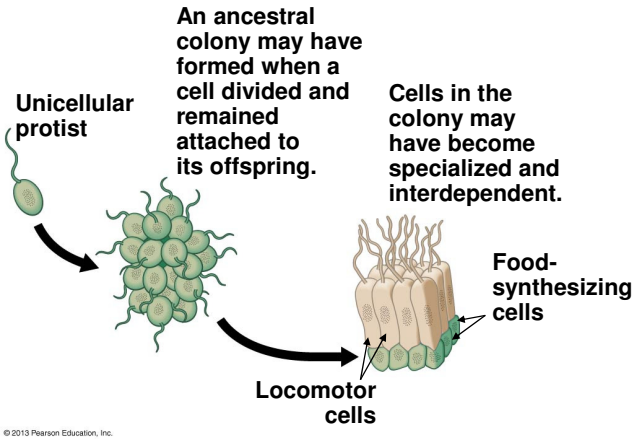

Figure 15.27-3

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