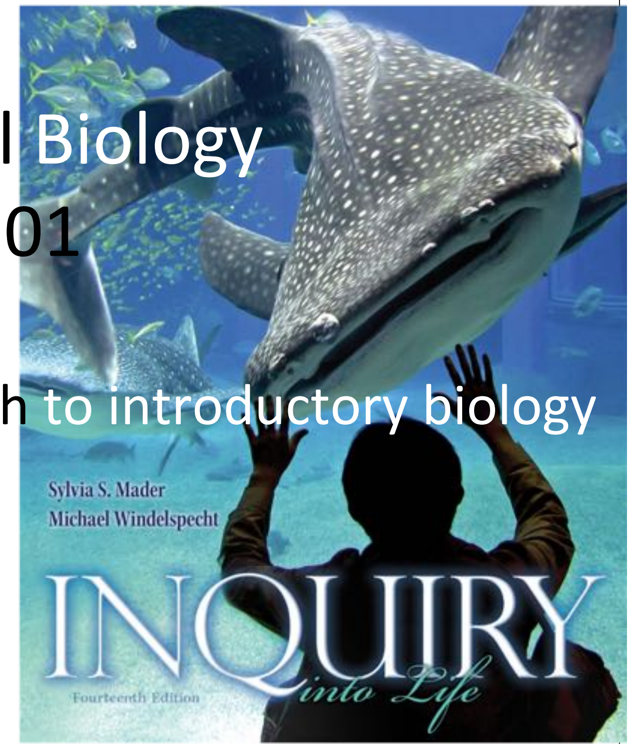
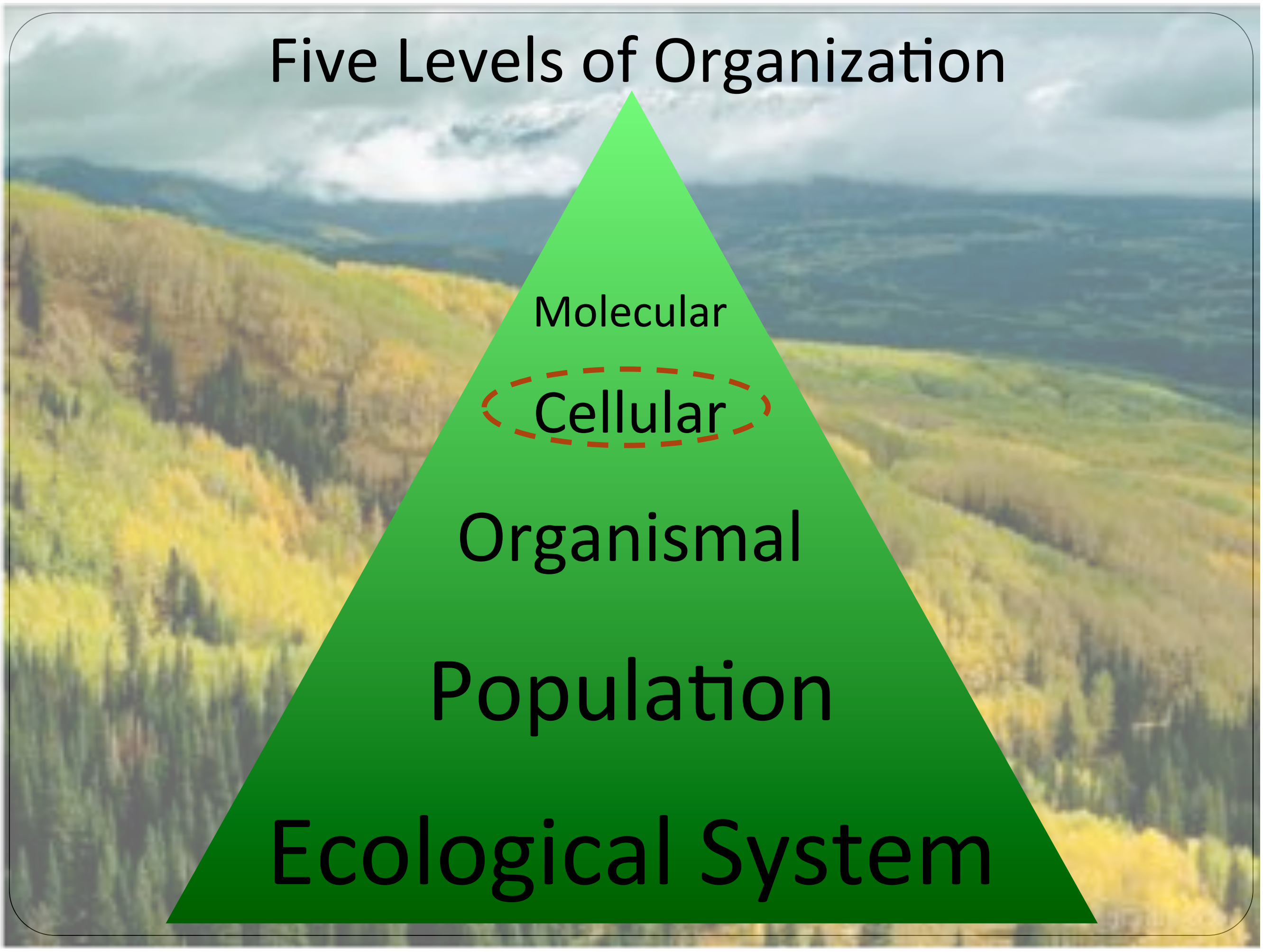
Fundamental Biology
BI 1101

an interdisciplinary approach to introductory biology

Anggraini Barlian
SITH-ITB





Ch 03: CELL (1)

Characteristics,

Structure and function

Learning Outcomes

After this chapter, students are able to:

- Describe the characteristics of cell
- Explain the basic structure and function of cell
- Distinguish the characteristics of prokaryote and eukaryote

Table 1-1 Historical Landmarks in Determining Cell Structure

1665	Hooke uses a primitive microscope to describe small pores in sections of cork that he calls **"cells."**
1674	Leeuwenhoek reports his discovery of **protozoa**. Nine years later, he sees **bacteria** for the first time.
1833	Brown publishes his microscopic observations of orchids, clearly describing the cell **nucleus**.
1838	Schleiden and Schwann propose the **cell theory**, stating that the nucleated cell is the universal building block of plant and animal tissues.
1857	Kölliker describes **mitochondria** in muscle cells.
1879	Flemming describes with great clarity **chromosome behavior during mitosis** in animal cells.
1881	Cajal and other histologists develop staining methods that reveal the structure of **nerve cells** and the organization of neural tissue.
1898	Golgi first sees, and describes, the **Golgi apparatus** by staining cells with silver nitrate.
1902	Boveri links **chromosomes and heredity** by observing chromosome behavior during sexual reproduction.
1952	Palade, Porter, and Sjöstrand develop methods of **electron microscopy** that enable many intracellular structures to be seen for the first time. In one of the first applications of these techniques, Huxley shows that muscle contains arrays of protein filaments—the first evidence of a **cytoskeleton**.
1957	Robertson describes the bilayer structure of the **cell membrane**, seen for the first time in the electron microscope.
1960	Kendrew describes the first detailed **protein structure** (sperm whale **myoglobin**) to a resolution of 0.2 nm using **X-ray crystallography**. Perutz proposes a lower-resolution structure for **hemoglobin**.
1968	Petran and collaborators make the first **confocal microscope**.
1974	Lazarides and Weber develop the use of **fluorescent antibodies** to stain the cytoskeleton.
1994	Chalfie and collaborators introduce **green fluorescent protein (GFP)** as a marker in microscopy.

3.1 The Cellular Level of Organization

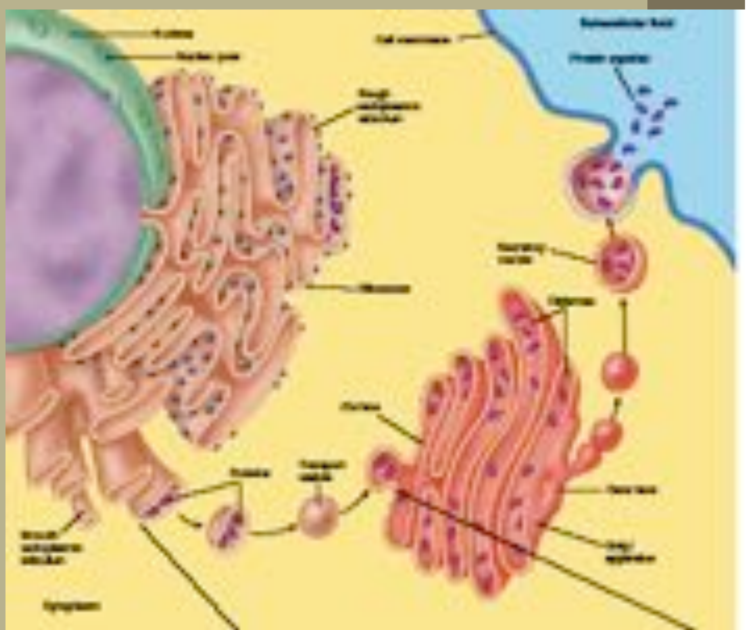
- The cell marks the boundary between the nonliving and the living.
- It is the structural and functional unit of an organism.
- It is the smallest structure capable of performing all the functions necessary for life.

The Cell Theory

- All organisms are composed of one or more cells.
- Cells are the basic living unit of structure and function in organisms.
- All cells come only from other cells.

KARAKTERISTIK DASAR SEL

- **Sel sangat kompleks namun teratur**
- **Sel memiliki program genetik dan memiliki cara untuk menggunakannya**
- **Sel mampu memperbanyak diri**
- **Sel membutuhkan, memperoleh dan menggunakan energi**
- **Sel melaksanakan berbagai reaksi kimiawi**
- **Sel terlibat dalam berbagai aktivitas mekanis**
- **Sel mampu merespon terhadap berbagai rangsang**
- **Sel mampu mengatur diri**



Cell Size

- Cell size varies, but are quite small.
- A frog's egg is about 1 millimeter (1mm) in diameter.
  - Large enough to be seen by naked eye
- Most cells are smaller than 1mm.
- Some cells are as small as 1 micrometer (1μm).

Sizes of Living Things

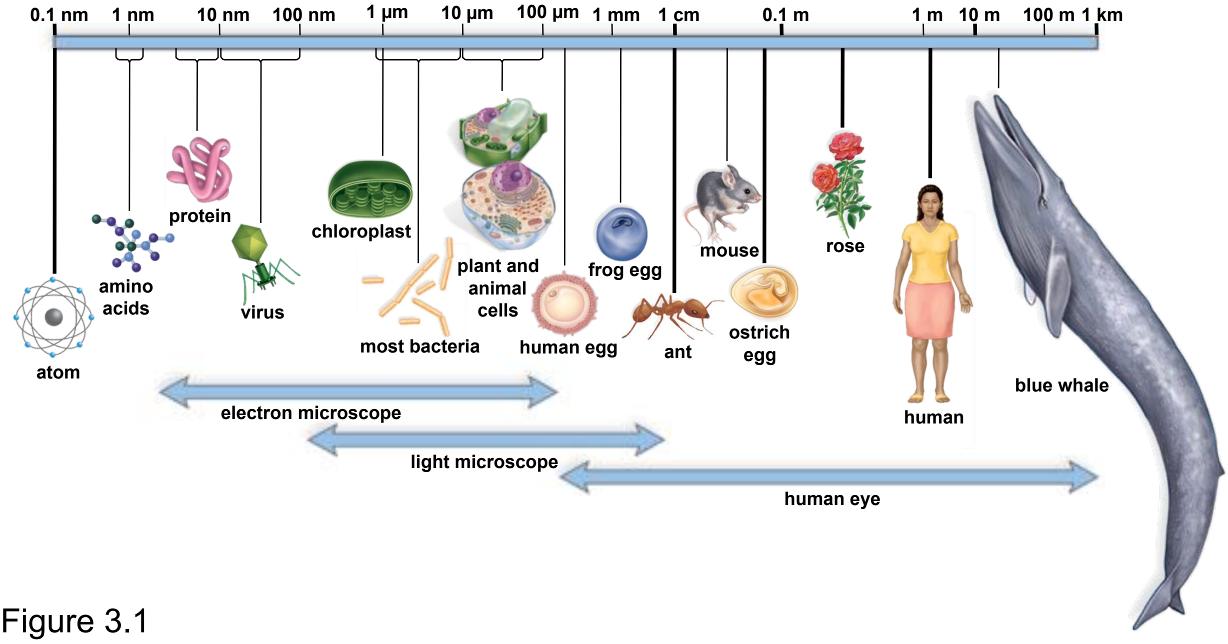


Figure 3.1

<u>Ukuran sel dan bagiannya</u>

Diagram ini memperlihatkan ukuran sel kulit manusia, dan organel serta molekulnya

Umumnya diameter sel kulit manusia adalah 20 µm

Mitochondrion : 2 µm

Ribosome : 20 nm

Molekul protein :2 nm

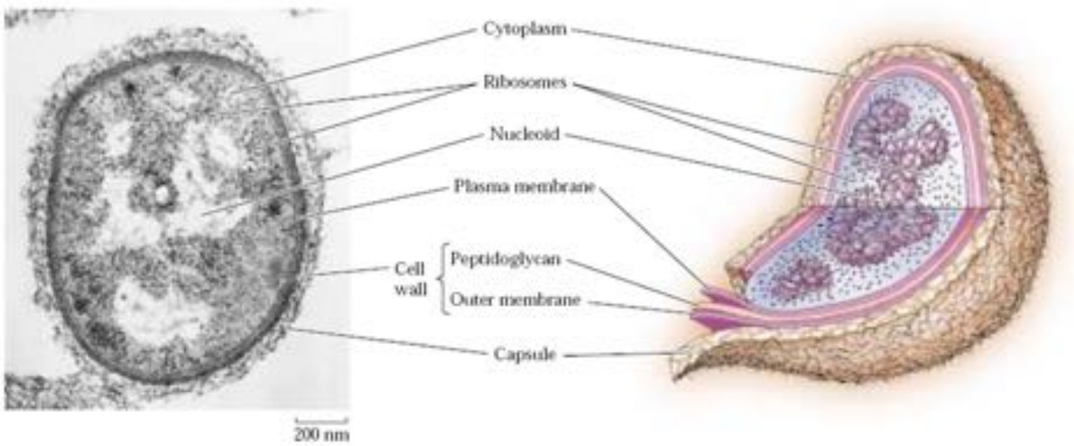
Atom :0.2 nm

3.2 Prokaryotic Cells

- Lack a membrane-bounded nucleus
  - Eukaryotic cells have a nucleus
- Comprise Domains Bacteria and Archaea
- Generally unicellular
  - May be single, strings or clusters
- Not all bacteria cause disease
  - Some are beneficial

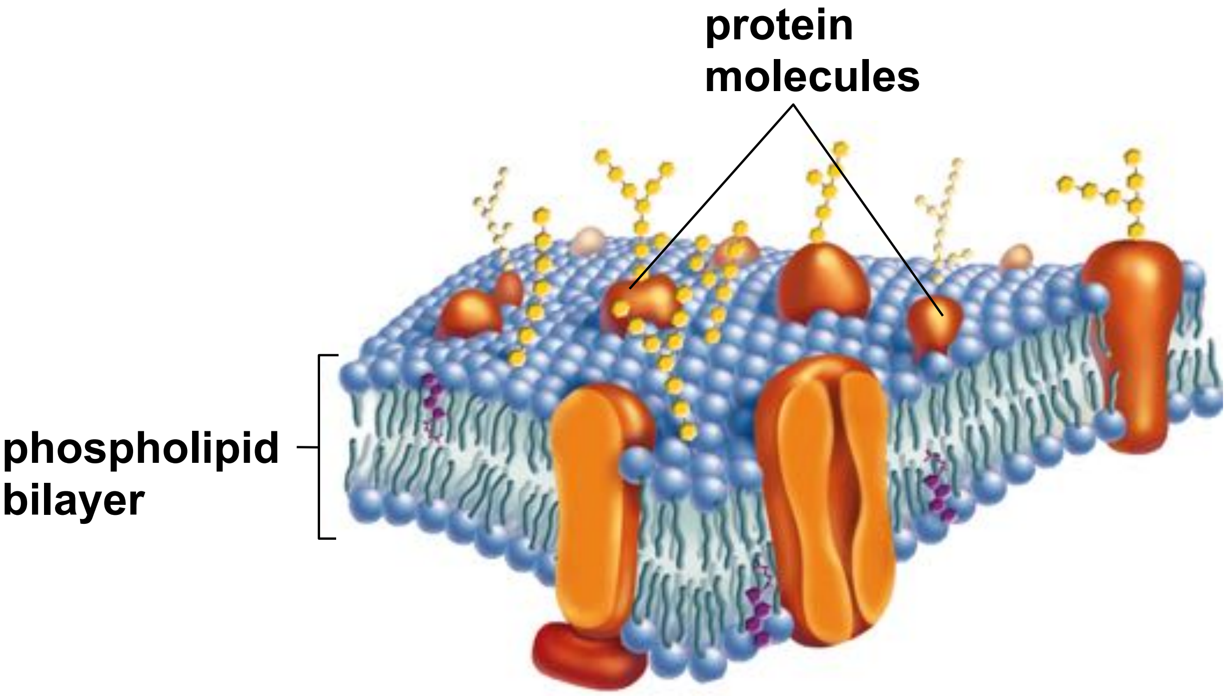
Prokaryotic Cells

- Simplest organisms
- Cytoplasm is surrounded by plasma membrane and encased in a rigid cell wall composed of peptidoglycan.
- no distinct interior compartments
- gram-positive – thick single layer wall that retains a violet dye from Gram stain procedure
- gram-negative – multilayered wall does not retain dye
- Susceptibility of bacteria to antibiotics depends on cell wall structure.



Plasma Membrane and Cytoplasm

- All cells are surrounded by a **plasma membrane.**
  - It forms a boundary that separates the contents of the cell from the surrounding environment.
  - It regulates the entrance and exit of molecules into and out of the cytoplasm.
- The semifluid medium inside of a cell is the **cytoplasm.**
  - It is composed of water, salts, and dissolved organic molecules



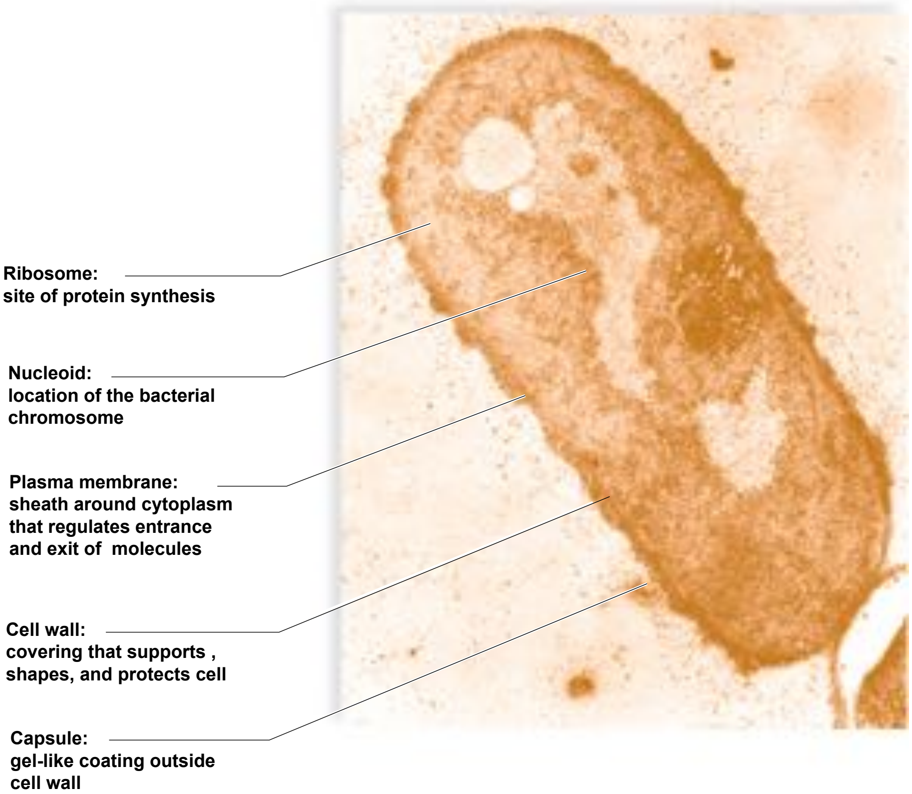
Bacterial Anatomy

- **Cell Wall**
  - Located outside of plasma membrane consisting of Peptidoglycan
- **Capsule**
  - A gelatinous sheath that surrounds the cell wall of some bacteria
- **Flagellum**
  - A long thin appendage for movement in some bacteria
- **Fimbriae**
  - Short appendages in some bacteria that help attach to appropriate surface

Bacterial Anatomy

- **Nucleoid**
  - A region of the cytoplasm where a single bacterial chromosome is located
  - Region not surrounded by a membrane
- **Ribosomes**
  - Used for protein synthesis
- **Thylakoids**
  - Membranes of flattened disks that contain light-sensitive pigments in cyanobacteria

- Prokaryotes are:
  - structurally simple;
  - metabolically diverse;
  - adapted to most types of environments.



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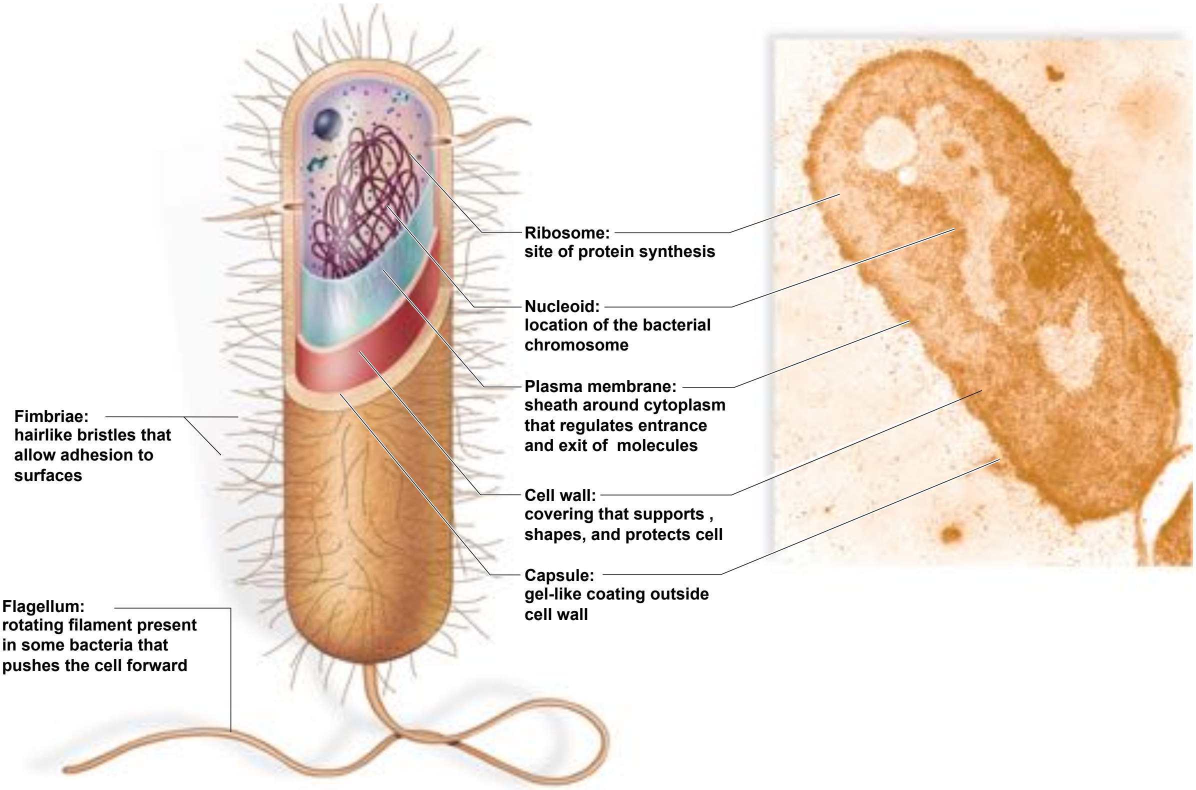

Figure 3.3

TABLE 3.1 Comparison of Major Structural Features of Archaea, Bacteria, and Eukaryotes

	Archaea	Bacteria	Eukaryotes
Cell wall	Usually present, no peptidoglycan	Usually present, with peptidoglycan	Sometimes present, no peptidoglycan
Plasma membrane	Yes	Yes	Yes
Nucleus	No	No	Yes
Membrane-bound organelles	No	No*	Yes
Ribosomes	Yes	Yes	Yes, larger than prokaryotic

* Some possess internal membranes where chemical reactions may occur.

3.3 Eukaryotic Cells

- Eukaryotic cells:
  - – are structurally complex;
  - – have a nucleus;
  - – possess membrane-bound organelles;
  - – make up animals, plants, fungi and protists.

Cell Walls

- Some eukaryotic cells have cell walls.
- Plant cells may have a primary and secondary cell wall.
  - – Cellulose and chitin make up fungi cell walls.
    - Also found in algae (protist) cell walls
  - – Lignin is found in secondary cell walls.
  - – Fungi cell walls
    - Some cellulose
    - Some chitin (also found in insect exoskeletons)

TABLE 3.2 Structures of Eukaryotic Cells

Structure	Composition	Function
Cell wall (absent in animal cells)	Contains polysacharrides	Support and protection
Plasma membrane	Phospholipid bilayer with embedded proteins	Defines cell boundary; regulates molecule passage into and out of cells
Nucleus	Nuclear envelope, nucleoplasm, chromatin, and nucleoli	Storage of genetic information; synthesis of DNA and RNA
Nucleoli	Concentrated area of chromatin, RNA, and proteins	Ribosomal subunit formation
Ribosomes	Protein and RNA in two subunits	Protein synthesis
Endoplasmic reticulum (ER)	Membranous flattened channels and tubular canals	Synthesis and/or modification of proteins and other substances, and distribution by vesicle formation
Rough ER	Network of folded membranes studded with ribosomes	Folding, modification, and transport of proteins
Smooth ER	Network of folded membranes having no ribosomes	Various; lipid synthesis in some cells

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TABLE 3.2 Structures of Eukaryotic Cells

Structure	Composition	Function
Golgi apparatus	Stack of small membranous sacs	Processing, packaging, and distribution of proteins and lipids
Lysosomes (animal cells only)	Membranous vesicle containing digestive enzymes	Intracellular digestion
Vacuoles and vesicles	Membranous sacs of various sizes	Storage of substances
Peroxisomes	Membranous vesicle containing specific enzymes	Various metabolic tasks
Mitochondria	Inner membrane (cristae) bounded by an outer membrane	Cellular respiration
Chloroplasts (primarily in plant cells)	Membranous grana bounded by two membranes	Photosynthesis
Cytoskeleton	Microtubules, intermediate filaments, actin filaments	Shape of cell and movement of its parts
Cilia and flagella (cilia are rare in plant cells)	9 + 2 pattern of microtubules	Movement of cell
Centriole (animal cells only)	9 + 0 pattern of microtubules	Formation of basal bodies

Organelles of Eukaryotic Cells

- The term **organelle** originally referred to only membranous structures.
- It now refers to any well-defined cell structure that performs a particular function(s).
- The cell is analogous to a factory where raw materials enter, whereupon different departments turn them into various products.
  - Must also get rid of wastes

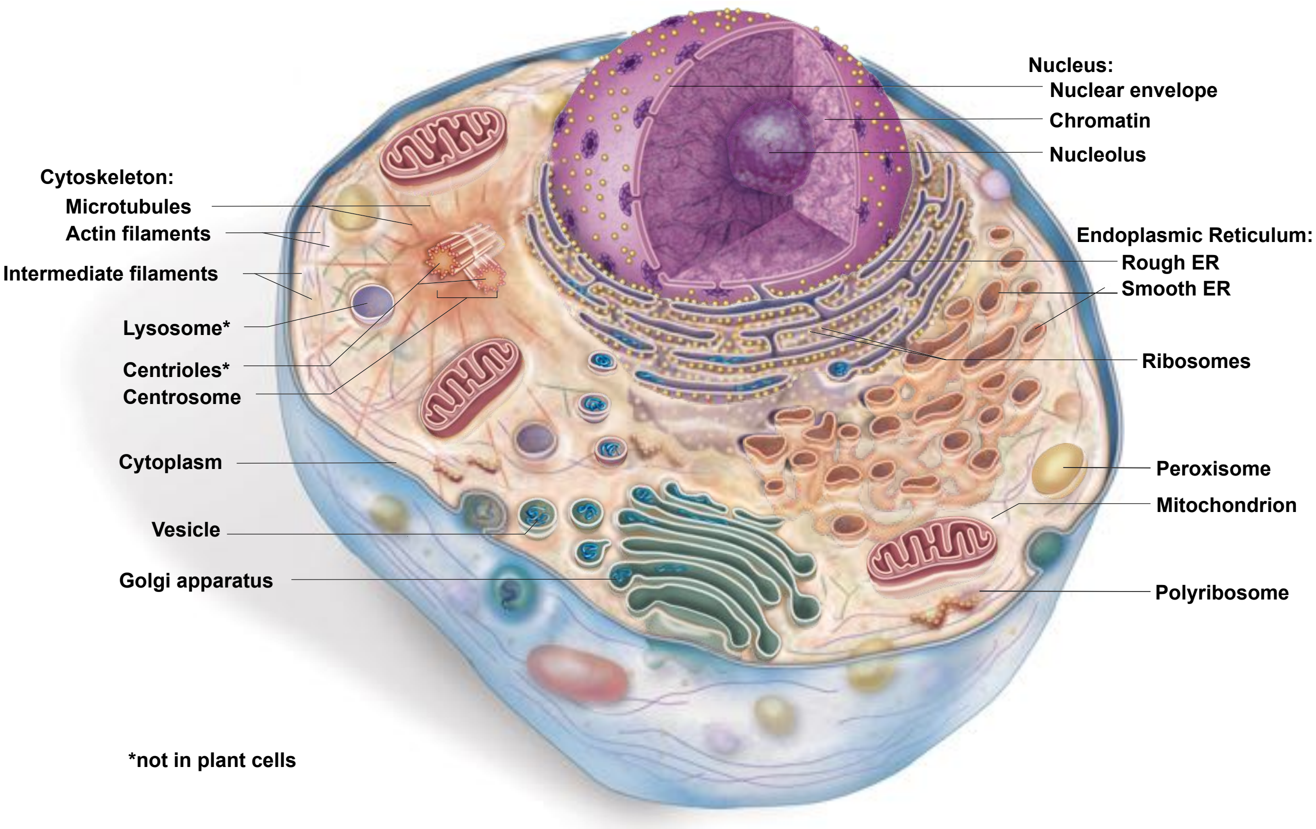


Figure 3.4

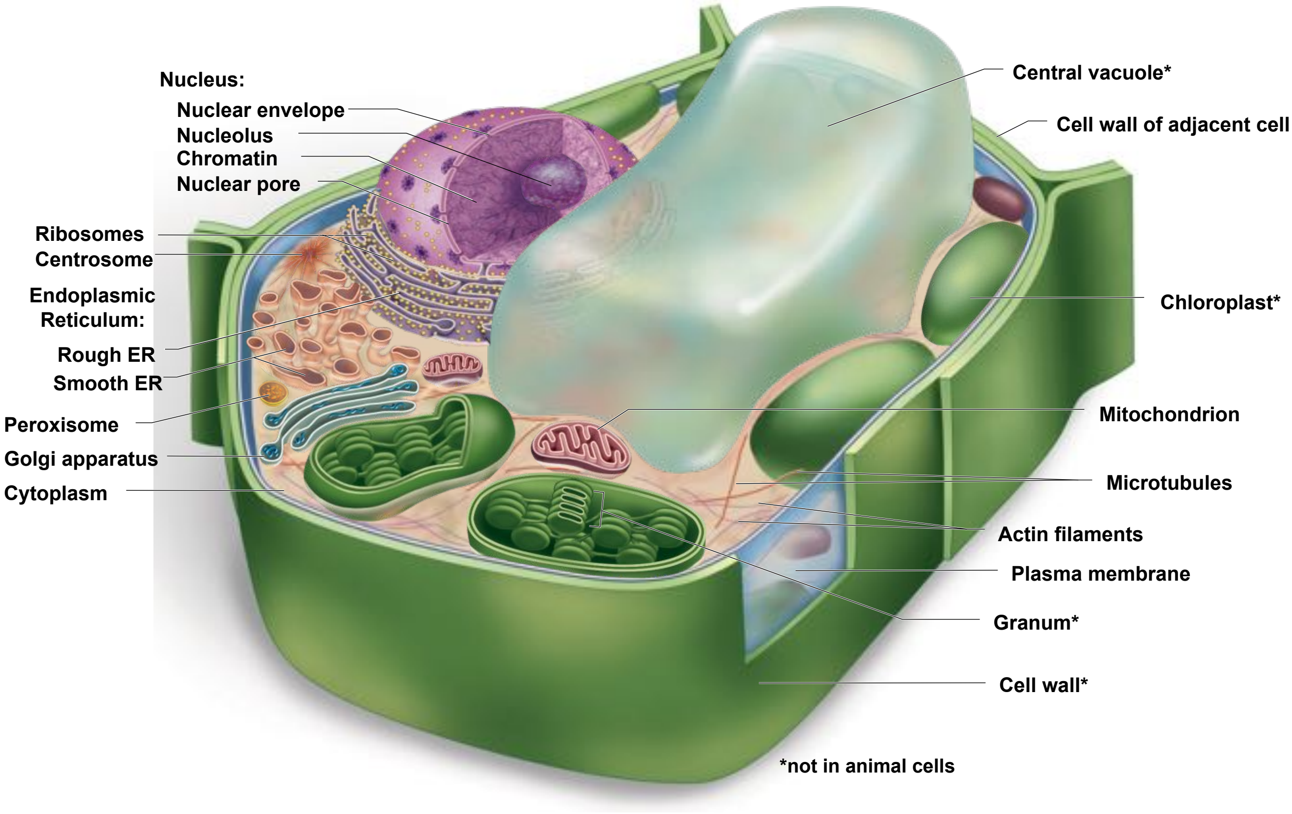


Figure 3.5

The Nucleus

- The nucleus is a prominent structure with a diameter of ~5µm.
  - Stores genetic material, **DNA**
    - Every cell in an individual contains the same DNA.
    - DNA governs the characteristics and metabolism of a cell.
  - Contains **chromatin**
    - Consists of DNA and associated proteins
    - Undergoes coiling and condenses into **chromosomes**

The Nucleus

- **Nucleoplasm**, a semifluid medium in the nucleus
- **Nucleolus**
  - Where ribosomal RNA (rRNA) is made
- **Nuclear Envelope**—a double membrane that separates the nucleus from the cytoplasm
- **Nuclear pores**—openings that permit transport of protein and ribosomal subunits

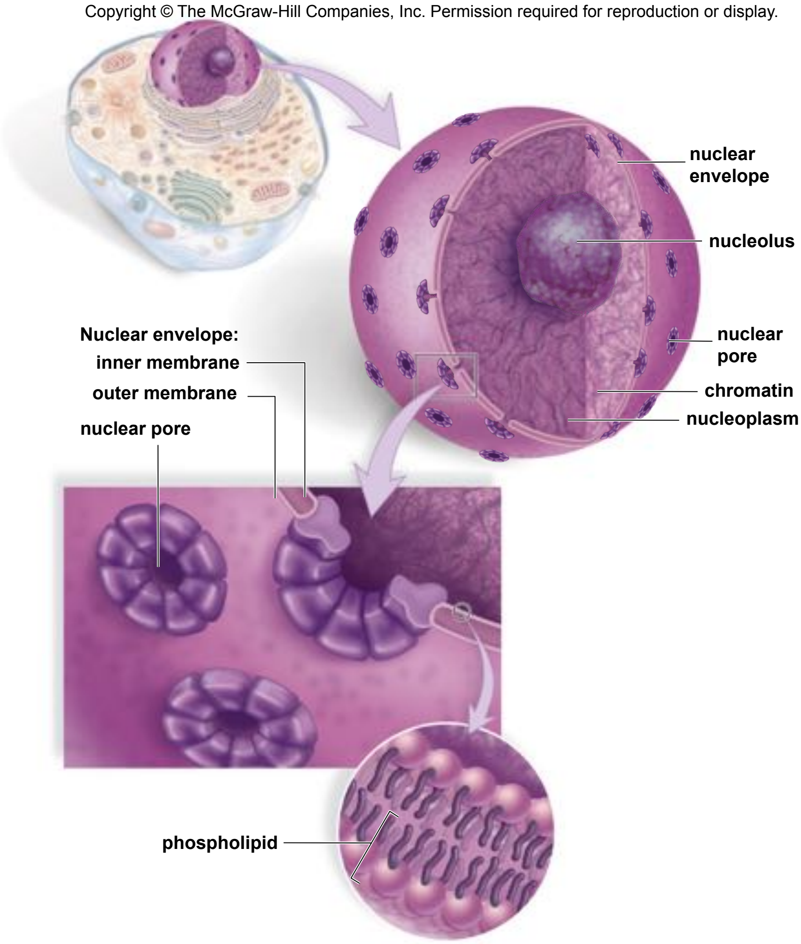


Figure 3.6

Ribosomes

- Site of protein synthesis
  - Use messenger RNA (mRNA) as template
- Composed of two subunits (large and small)
  - Subunits consist of rRNA and protein molecules
- Where found
  - In groups of **polyribosomes**, several ribosomes associated with a single mRNA
  - attached to endoplasmic reticulum
  - free in cytoplasm

Endomembrane System

- Consists of the nuclear envelope, the endoplasmic reticulum, the Golgi apparatus, and several **vesicles** (tiny membranous sacs)
- Acts as the transportation and product-processing section of the cell
- Compartmentalizes cell so that enzymatic reaction restricted to specific cell sections

Endoplasmic Reticulum

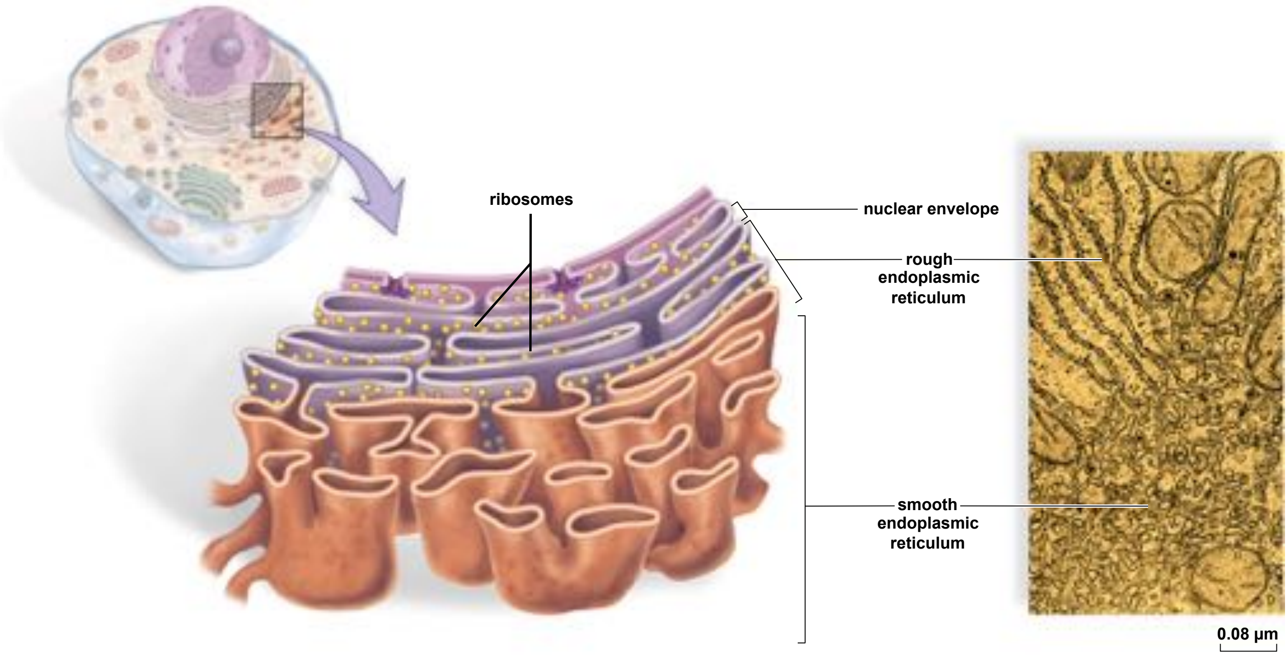


Figure 3.7

Endoplasmic Reticulum

- Rough ER
  - Studded with ribosomes
  - Processing, folding and modification of proteins
- Smooth ER
  - Has no attached ribosomes
  - Synthesizes phospholipids and steroids
  - Stores calcium ions
  - Various other functions, depending on cell type

Golgi Apparatus

- Consists of a stack of three to twenty slightly curved sacs.
- In animal cells, one side is directed toward the ER, and other side is directed toward the plasma membrane.
- Often referred to as the shipping center of the cell.
- Apparatus collects, sorts, packages, and distributes materials such as proteins and lipids.

Golgi Apparatus

- Apparatus receives proteins and also lipid-filled vesicles that bud from the ER.
- Proteins made in rough ER have tags that serve as “zip codes” to direct Golgi apparatus where to send them.
- Lipids and proteins are modified in transit through the Golgi before being repackaged into secretory vesicles
- Contents are discharged out of the cell by **secretion.**

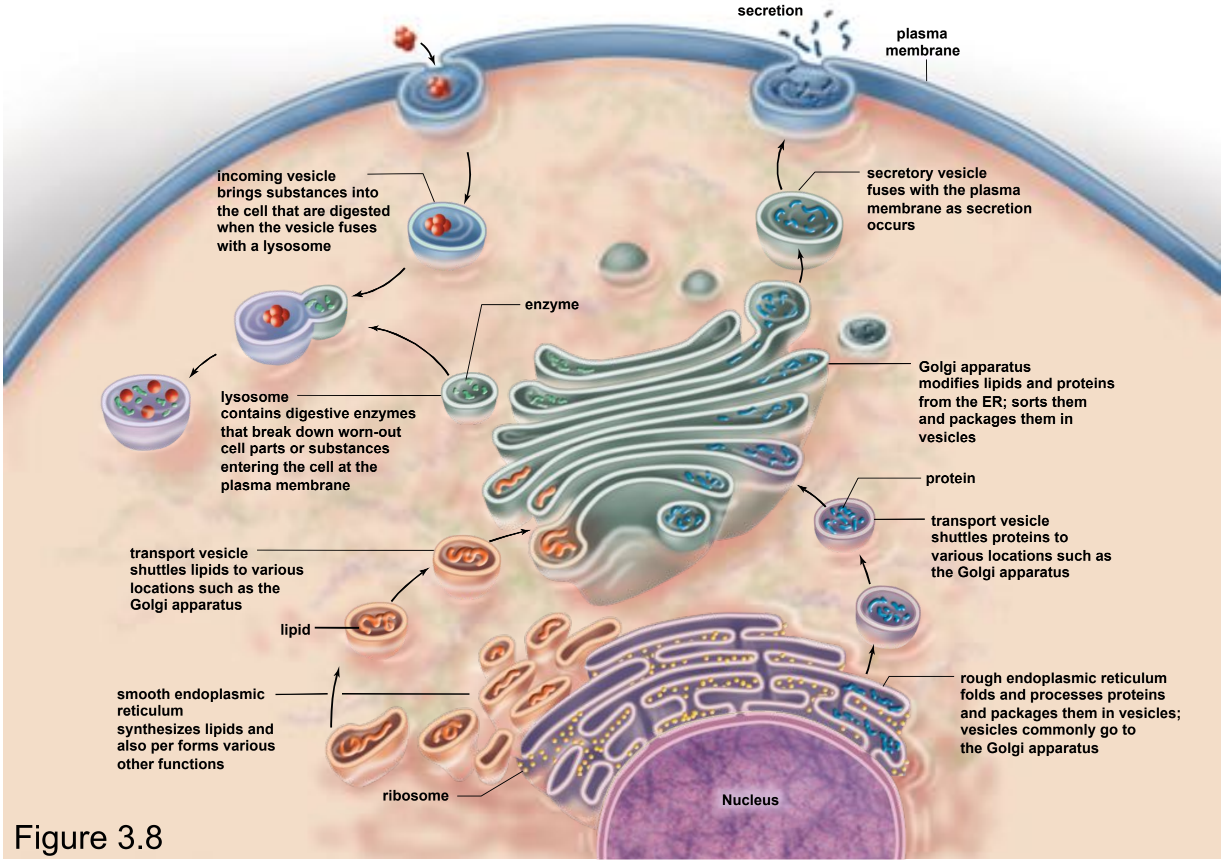


Figure 3.8

Lysosomes

- Membrane-enclosed vesicles formed by Golgi
  - Contain hydrolytic digestive enzymes
  - Act as garbage disposals of the cell
  - Break down unwanted, foreign substances or worn-out parts of cells
  - Bring macromolecules into the cell

Vacuoles

- Large membranous sacs
- Larger than vesicles
- More prominent in plants
  - Central vacuole provides added support
- Store substances
  - Water
  - Pigments
  - Toxins

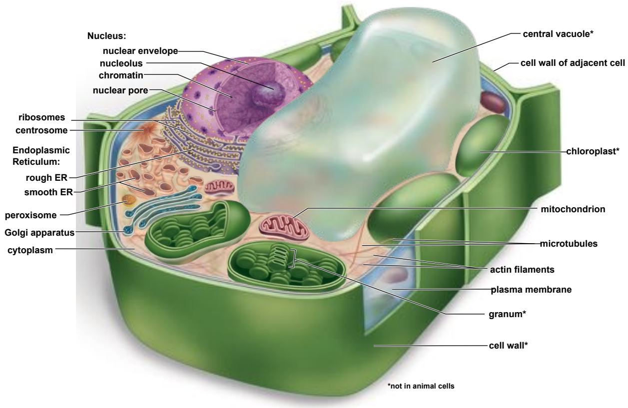


Figure 3.5

Peroxisomes

- Membrane-bound vesicles containing enzymes derived from cytoplasmic ribosomes
  - Actions of enzymes lead to hydrogen peroxide (H_2O_2)
  - H_2O_2 quickly broken down into water and oxygen by the enzyme **catalase**
  - Functions vary amongst cells
    - In liver cells, they metabolize fats or produce bile.
    - In germinating plant cells, they oxidize fatty acids.

Peroxisomes

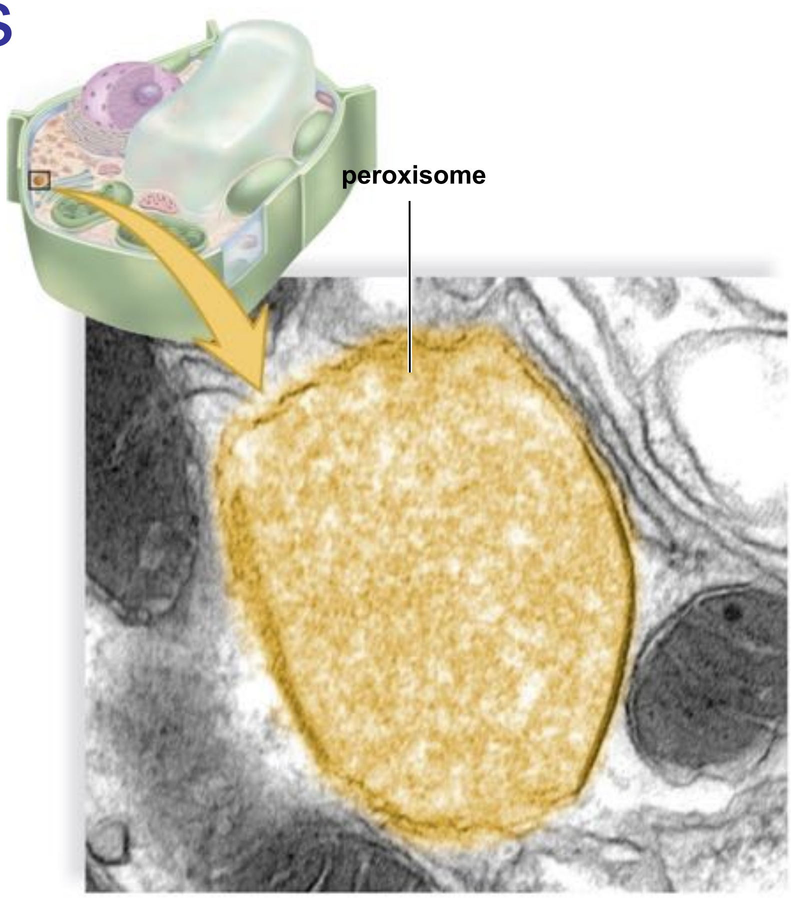


Figure 3.9

Energy-Related Organelles

- Chloroplasts and Mitochondria are organelles that specialize in converting energy into useable forms for cells.
  - **Chloroplasts** use solar energy to synthesize carbohydrates.
  - **Mitochondria** use the breakdown of carbohydrates to produce ATP.

Energy-Related Organelles

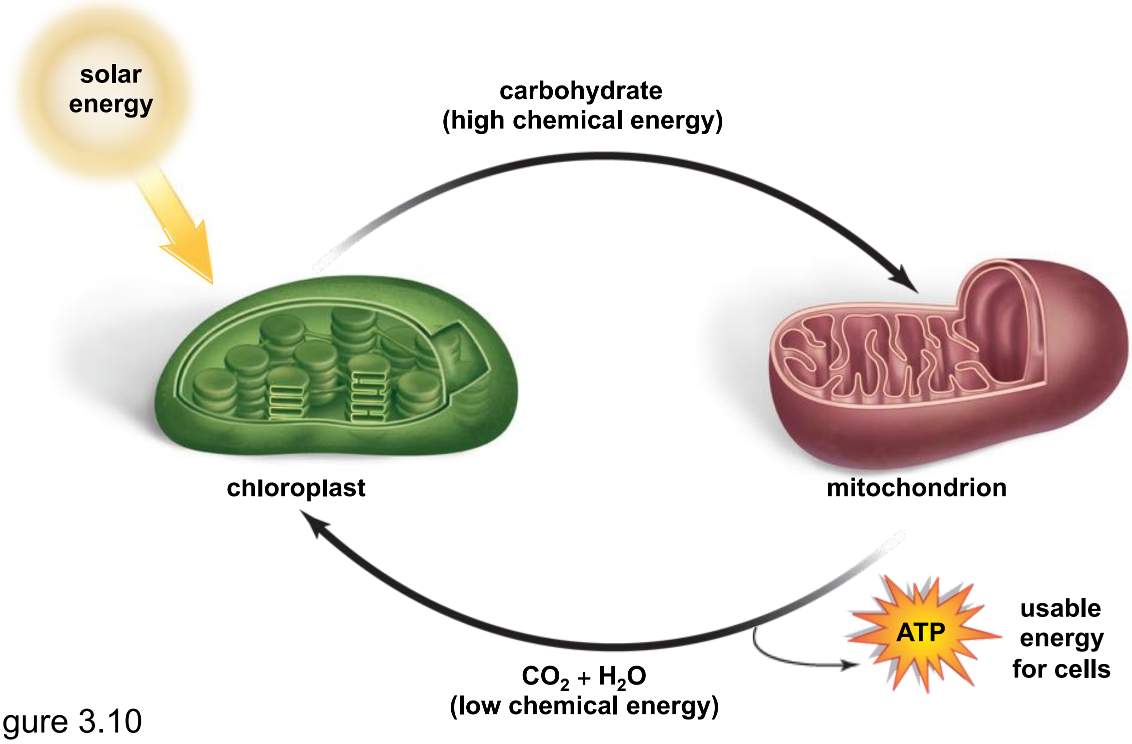


Figure 3.10

solar energy + carbon dioxide + water ⟶ carbohydrate + oxygen

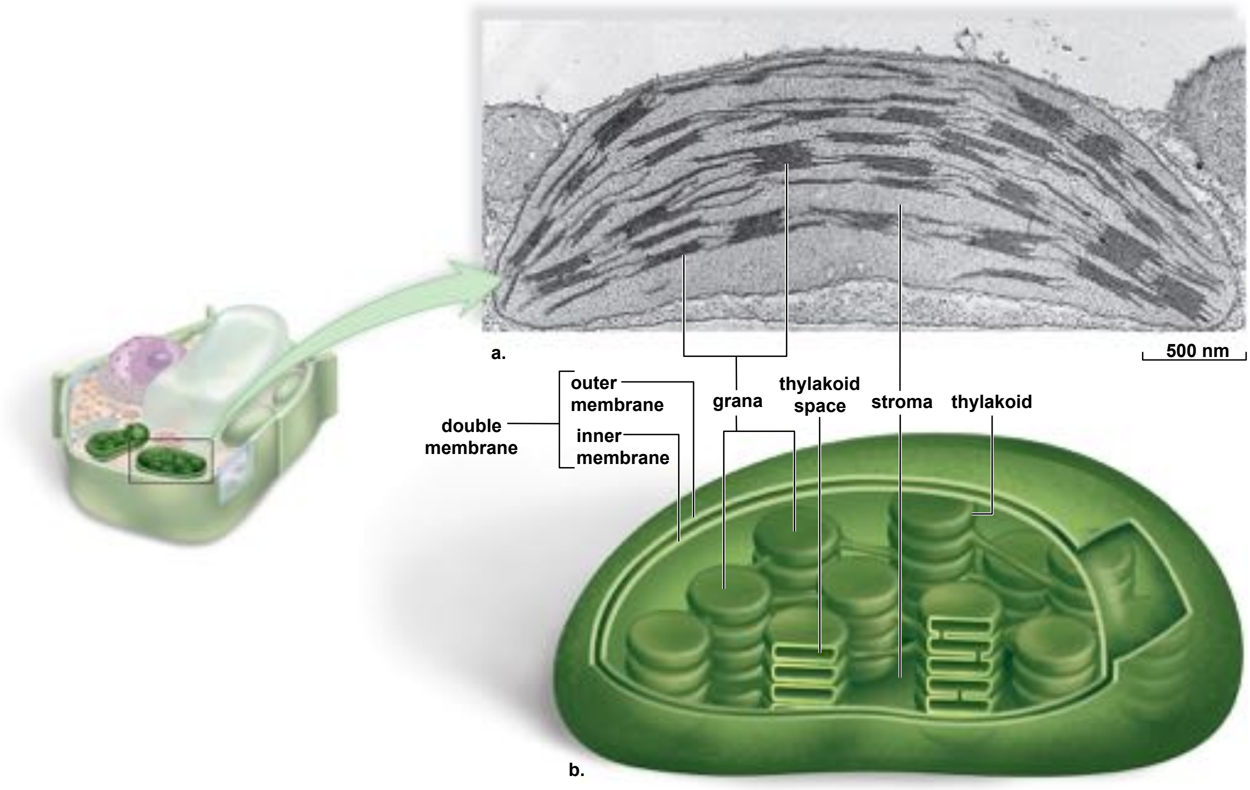
- **Photosynthesis**
  - Plants, algae, and cyanobacteria have this ability.
  - Solar energy is the ultimate source of energy for most cells.

carbohydrate + oxygen ⟶ carbon dioxide + water + energy

- **Cellular respiration**
  - All organisms convert chemical energy into ATP.
  - ATP is used for all energy-requiring processes in cells.

Chloroplasts

- Site of photosynthesis in plants and algae
- Structure:
  - Double membrane
  - Make most of their own proteins
  - **Stroma** – fluid-filled space bounded by double membranes
    - Contains single circular DNA molecule and ribosomes
  - **Grana** – stacks of thylakoids
    - Chlorophyll located in thylakoid membranes



Courtesy Herbert W. Israel, Cornell University

Figure 3.11

Mitochondria

- Found in all eukaryotic cells
  - Including plants and algae
- Site of cellular respiration
- Structure
  - Bounded by double membrane
  - **Matrix**—the inner fluid-filled space
  - **Cristae**—formed by invaginations of the inner membrane
    - Invaginations increase surface area
- Contain their own DNA

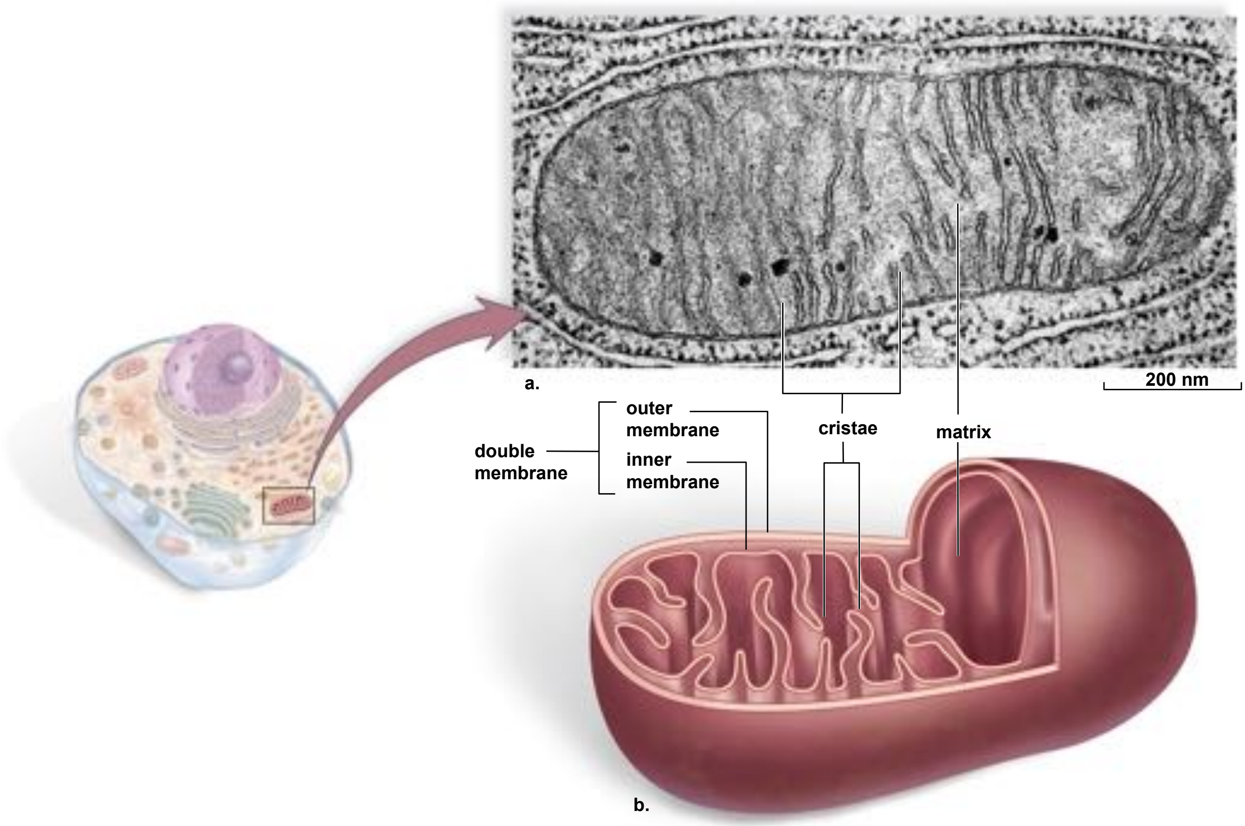


Figure 3.12

Courtesy Dr. Keith Porter

3.4 The Cytoskeleton

- Consists of three interconnecting proteins
  - Actin filaments
  - Intermediate filaments
  - Microtubules
- Maintains cell shape
- Assists in movement of cell and organelles
- Dynamic—assembled and disassembled as needed

Actin Filaments

- Two long, thin, flexible actin chains twisted in helix
- Roles
  - Provide structure as dense web under plasma membrane
  - Form projections in intestinal cells as microvilli
  - Allow for formation of pseudopods in amoeboid movement

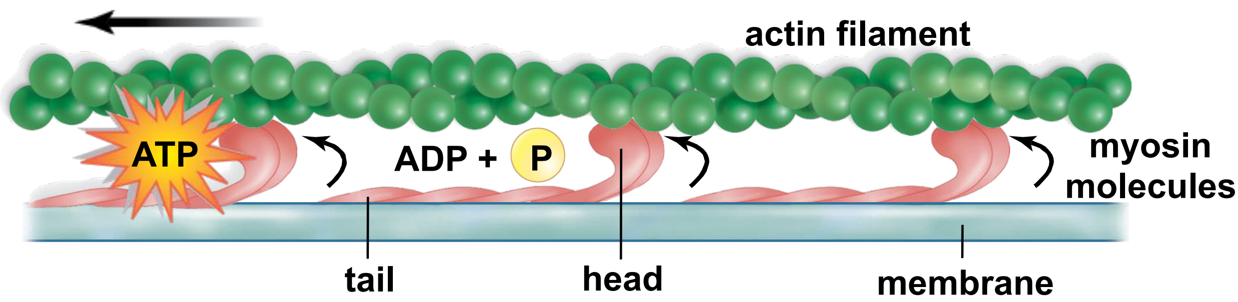
Figure 3.13

a. Actin filaments

a(actin): © M. Schliwa/Visuals Unlimited; a(Chara): © The McGraw-Hill Companies, Inc. /Dennis Strete and Darrell Vodopich, photographers

Actin Filaments

- Actin interacts with motor molecules for movement
  - Example: muscle cells
- In the presence of ATP, myosin pulls actin along



Intermediate Filaments

- Intermediate in size between actin filaments and microtubules
- Functions:
  - Support nuclear envelope
  - Help form cell-to-cell junctions, such as those holding skin cells tightly together
  - Strengthen human hair

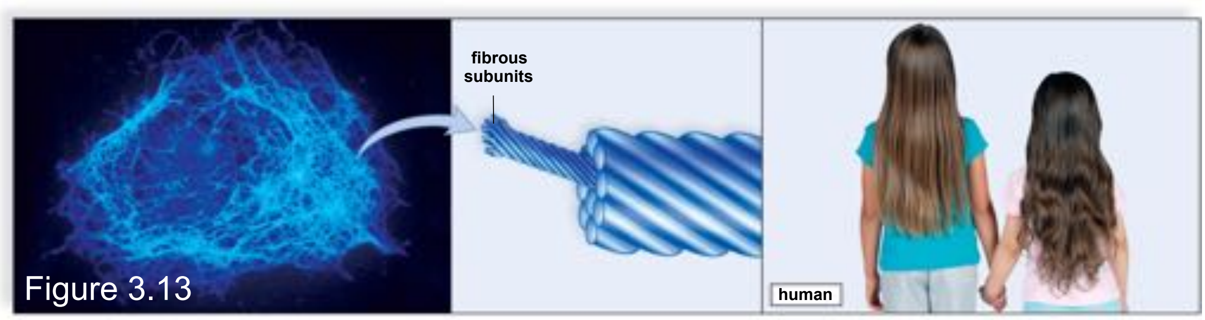


Figure 3.13

b. Intermediate filaments

Microtubules

- Hollow cylinders made of globular tubulin (α and β)
- Assembly
  - Controlled by Microtubule Organizing Center (MTOC)
  - Most important MTOC is **centrosome**

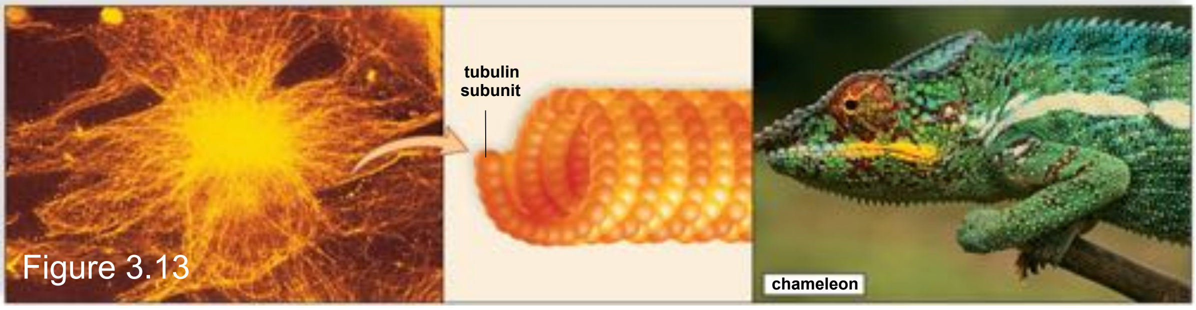


Figure 3.13

c. Microtubules

c(microtubules): © K.G. Murti/Visuals Unlimited; c(chameleon): © Photodisc/Vol. 6/Getty RF

Microtubules

- Roles
  - Help maintain cell shape
  - Interact with motor molecules kinesin and dynein to cause movement of organelles
  - Form spindle apparatus during cell division

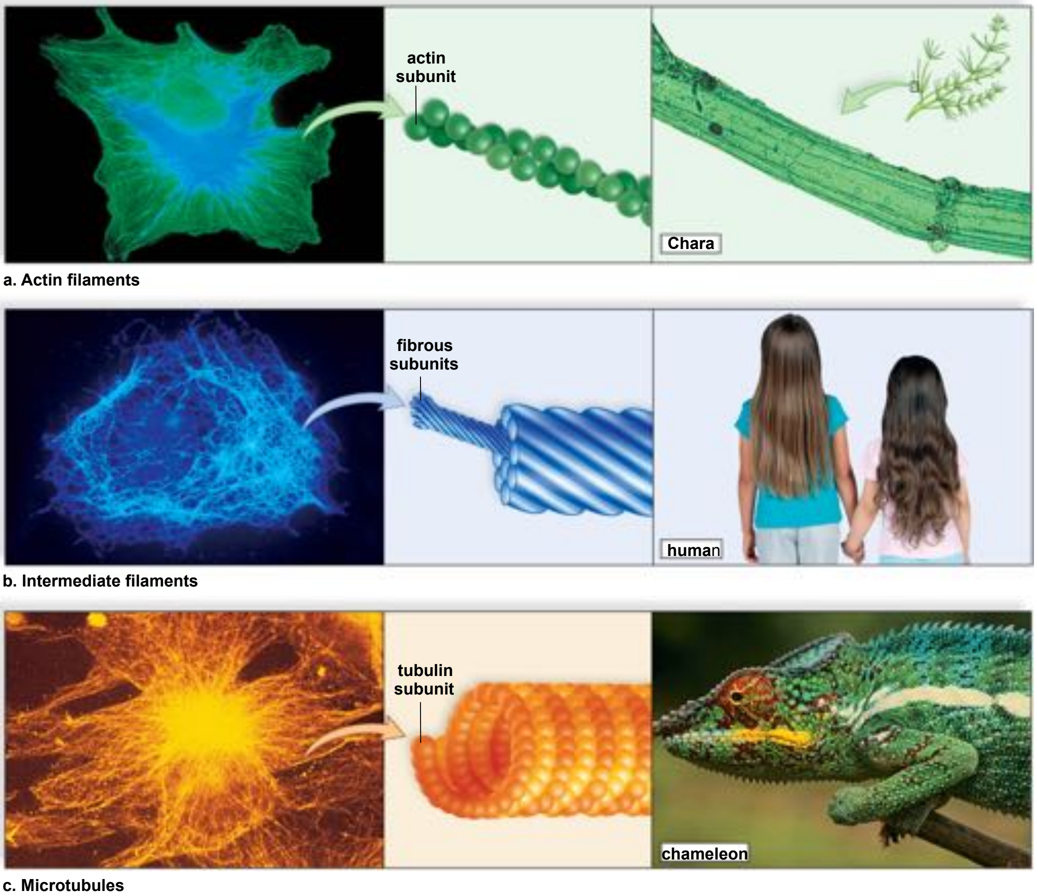


Fig 3.13

Centrioles

- Found in centrosomes of animal cells
- May be involved in microtubule assembly and disassembly
- Short cylinders with a 9 + 0 pattern of microtubule triplets

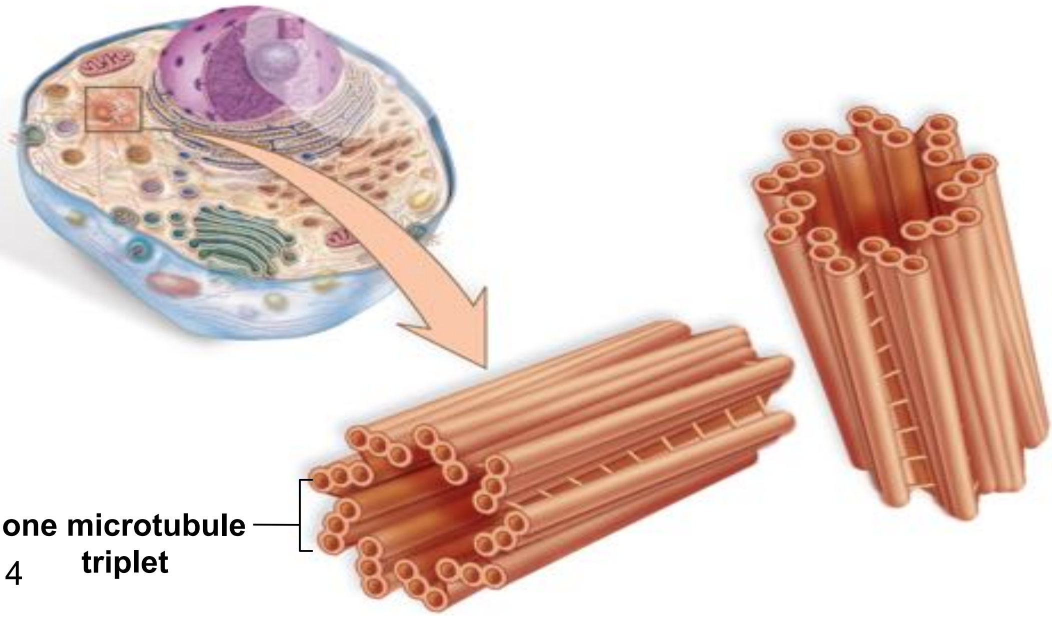


Figure 3.14

Cilia and Flagella

- Hairlike projections that aid in cell movement
  - In eukaryotes, cilia are much shorter than flagella.
  - Both are membrane-bound cylinders.
    - 9 + 2 pattern of microtubules
  - Examples
    - Paramecia move by means of cilia.
    - Cells of the upper respiratory tract use cilia to sweep debris trapped within mucus.

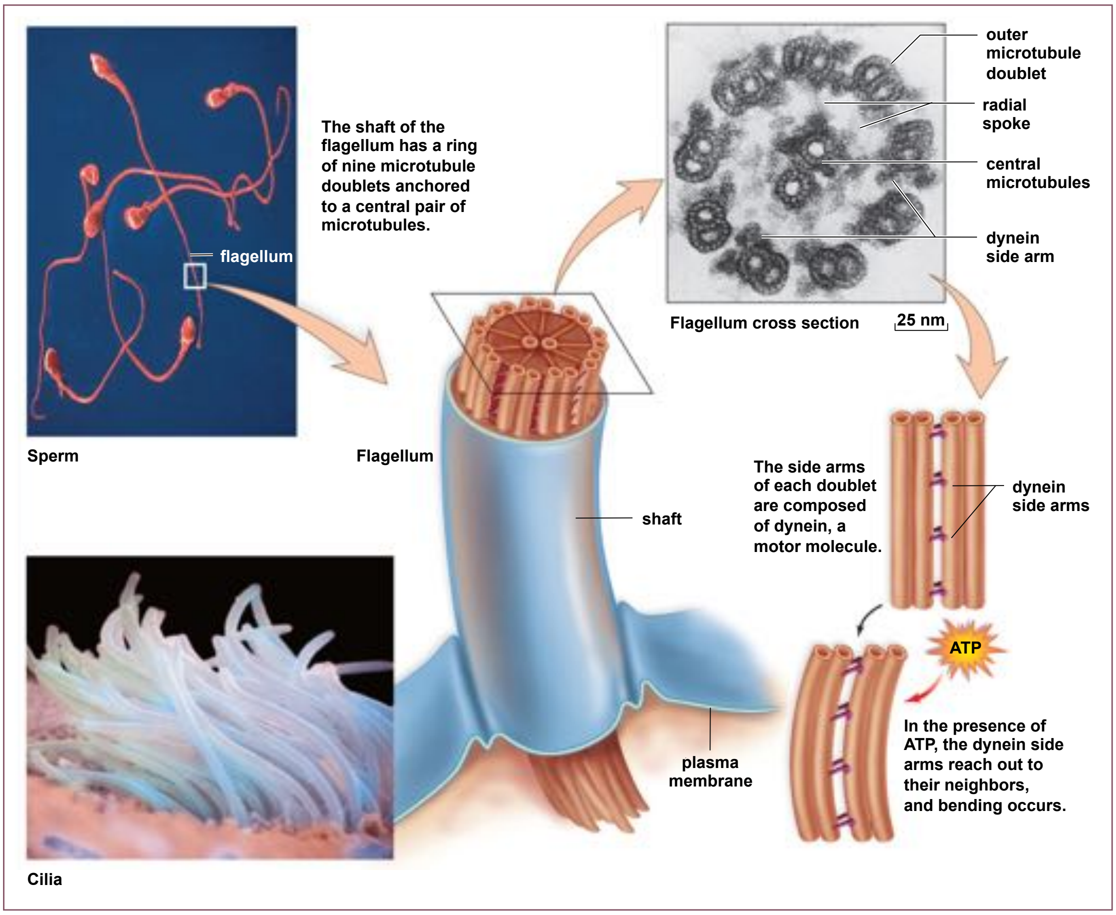


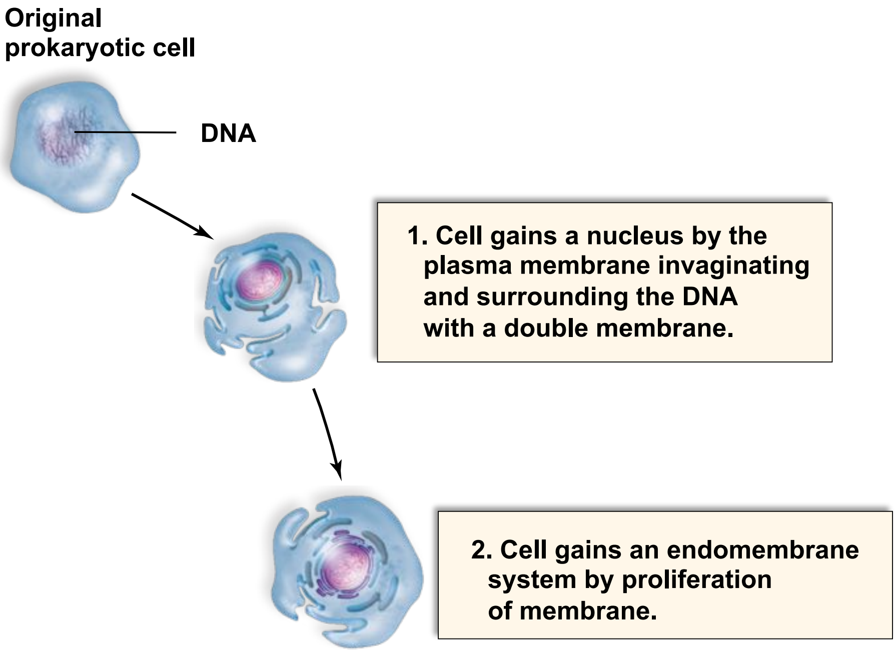
Fig 3.15

3.4 Evolution of the Eukaryotic Cell

- Fossil record suggests first cells were prokaryotes.
- Biochemical datas suggests archaea are more closely related to eukaryotes.
- Eukaryotes evolved in stages from prokaryotes.

3.4 Evolution of the Eukaryotic Cell

- **Endosymbiotic theory-**Mitochondria and chloroplasts derived from prokaryotes that were taken up by a larger cell
  - Mitochondria were originally heterotrophic bacteria
  - Chloroplasts were originally cyanobacteria
  - After entering the host cell, the bacteria begun living together cooperatively


Original
prokaryotic cell
DNA
1. Cell gains a nucleus by the plasma membrane invaginating and surrounding the DNA with a double membrane.
2. Cell gains an endomembrane system by proliferation of membrane.

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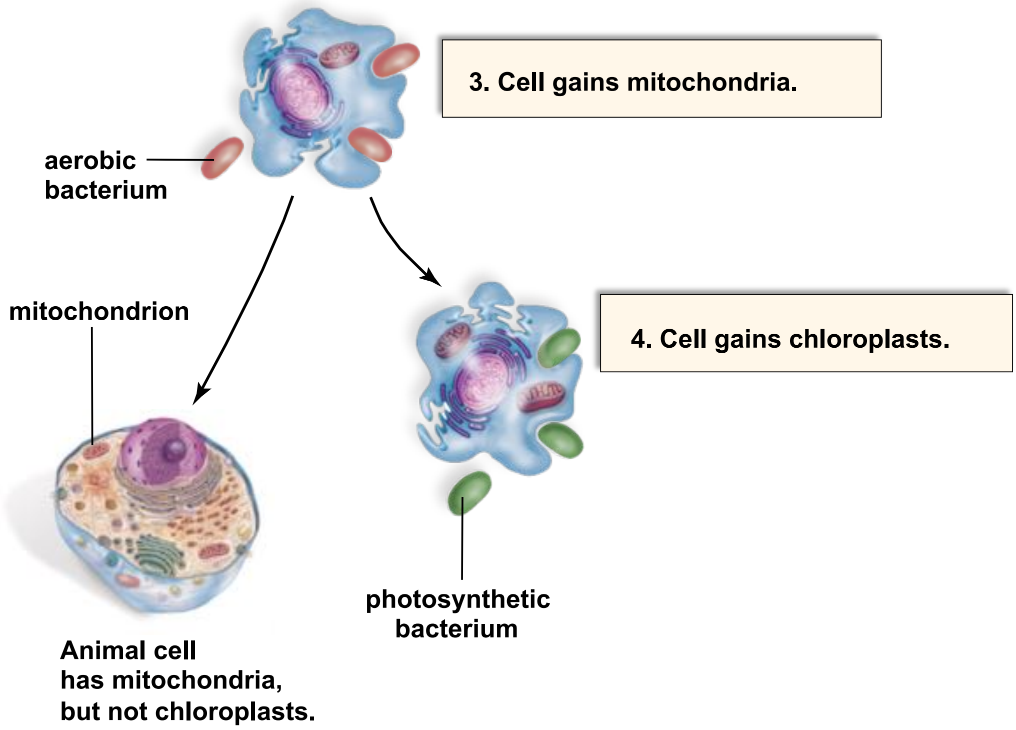
3. Cell gains mitochondria.
aerobic
bacterium
mitochondrion
4. Cell gains chloroplasts.
photosynthetic
bacterium
Animal cell
has mitochondria,
but not chloroplasts.

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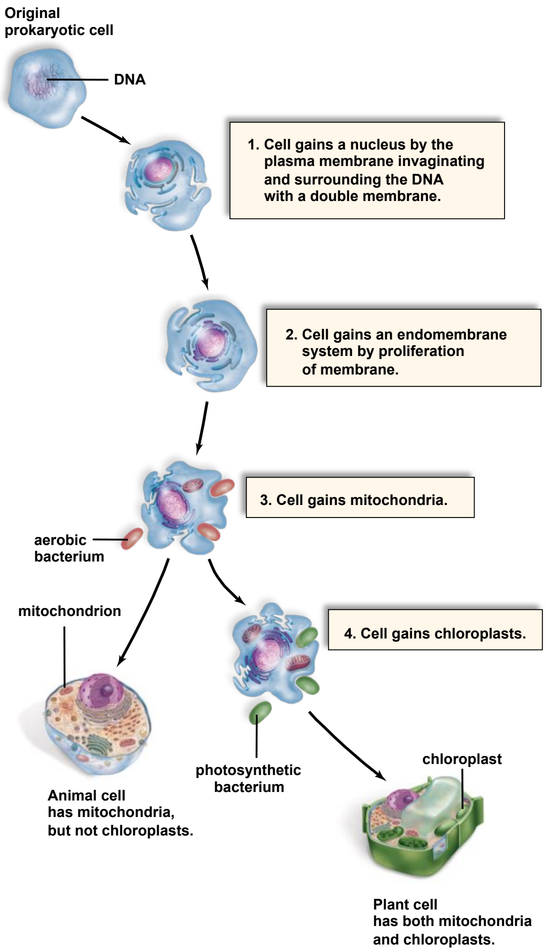


Supporting Evidence for Hypothesis

1. Both organelles are similar to bacteria in size and structure
2. Both organelles are bounded by a double membrane
    – The outer membrane may be derived from the engulfing vesicle
    – The inner one may be derived from the plasma membrane of the original prokaryote

Supporting Evidence for Hypothesis

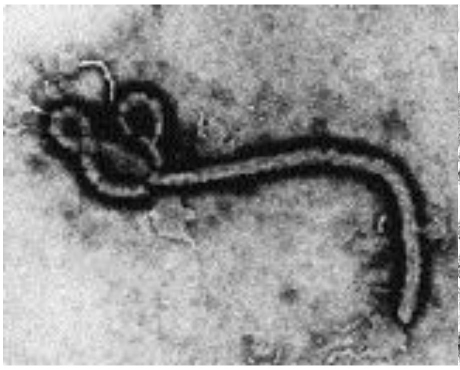
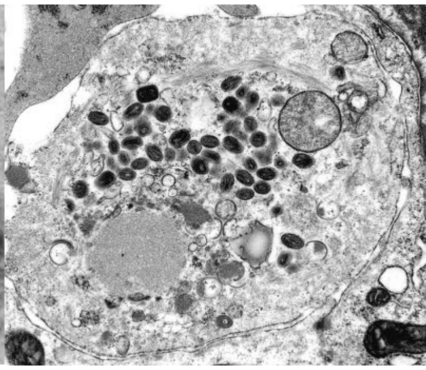
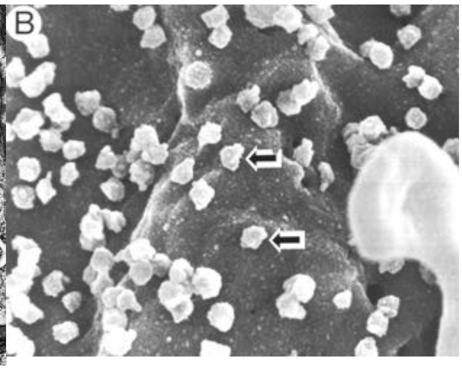
3. Both organelles contain a limited amount of genetic material and divide by splitting.
   – Their DNA is a circular loop like that of prokaryotes.
4. Although most of the proteins within these organelles are produced by the eukaryotic host, they have their own ribosomes and produce some proteins .
   – Their ribosomes resemble those of prokaryotes

Supporting Evidence for Hypotheis

5. The RNA (ribonucleic acid) base sequence of the ribosomes in chloroplasts and mitochondria also suggests a prokaryotic origin of these organelles.

Viruses

Many viruses cause disease

Ebola virus | Smallpox virus | HIV virus

Obligate cellular parasites- → can't replicate without cells

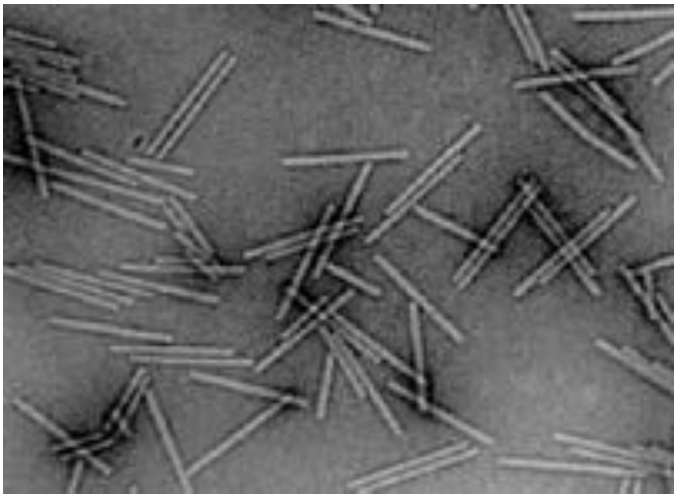
nucleic acid core (DNA or RNA) surrounded by a protein coat

take over cellular machinery to reproduce themselves and eventually kill the host cell

Viruses

bacteriophage are viruses that infect bacteria

vital to early molecular biology

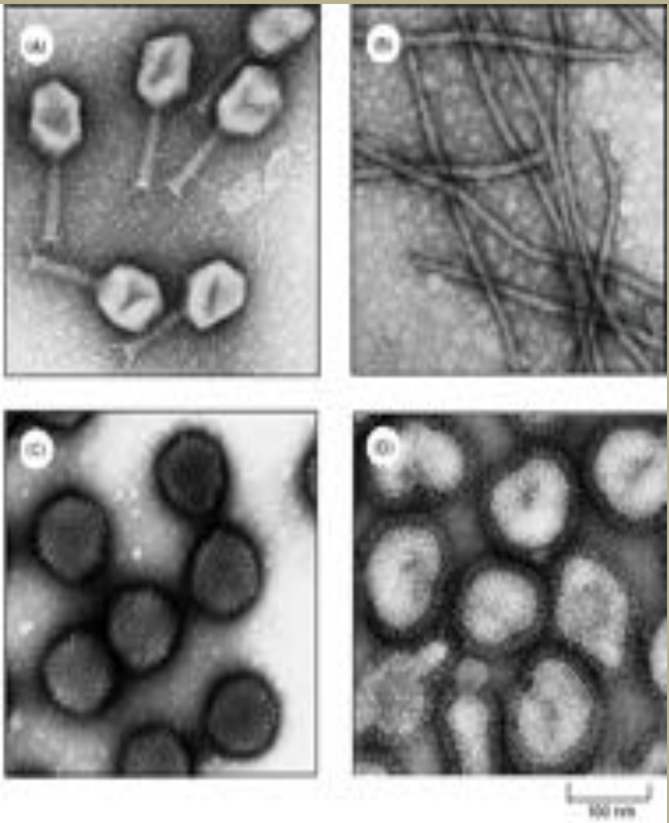


Tobacco mosaic virus infects plants

excellent model for studying life cycle

viruses can be used for genetic engineering of plants and animals

Virus



Electron micrographs dari partikel virus

(A)T4, virus (mengandung DNA) yang menginfeksi *E. coli*. DNA berada dalam kepala bacterio phage dan diinjeksikan ke dalam bacterium melalui ekor silindrisnya.

(B) *Potato virus X*, virus tumbuhan yang mengandung genome RNA.

(C) *Adenovirus*, virus yang mengandung DNA- dapat menginfeksi sel manusia.

(D) *Influenza virus*, virus yang mengandung RNA dengan kapsul protein yang diliputi pembungkus (envelope) berupa lipid-bilayer. Jarum yang menonjol keluar pembungkus envelope adalah protein virus yang tertanam dalam membran bilayer