Chapter 4 Outline and Terms

4.1. Cells Make Up Living Things (p. 58)

A. Cell Theory

1. All organisms, both unicellular or multicellular, are made up of cells.

2. Cells are the smallest units of living matter and structural and functional units of all organisms. (Fig. 4.1)

3. Matthias Schleiden (plants) and Theodore Schwann (animals) declared all life made of cells, both in 1830s.

4. Cells are capable of self-reproduction; Rudolf Virchow declared cells come only from preexisting cells.

B. Cells Are Small

1. Cells range in size from a frog's egg (one millimeter) down to one micrometer. (Fig. 4.2)

2. Cells need surface area of plasma membrane large enough to adequately exchange materials.

3. Surface-area-to-volume ratio requires that cells be small.
   a. As cells get larger in volume, relative surface area actually decreases.
   b. Limits how large actively metabolizing cells can become.
   c. Cells needing greater surface area use modifications such as folding.

C. Microscopy of Today

1. Bright-field microscope uses light rays focused by glass lenses.

2. Transmission electron microscope (TEM) uses electrons passing through specimen; focused by magnets.
3. **Scanning electron microscope (SEM)** uses electrons scanned across metal-coated specimen.

4. **Magnification** is function of wavelengths; shorter wavelengths of electrons allow greater magnification.

5. **Resolution** is minimum distance between two objects before they are seen as one larger object.

6. **Immunofluorescence microscopy** uses fluorescent antibodies to reveal proteins in cells.

7. **Confocal microscopy** uses laser beam to focus on shallow plane; forms series of optical sections.

4.2. **Prokaryotic Cells Are Less Complex** (p. 62)

**B. Bacteria Are prokaryotic Cells**

1. Bacteria belong to the kingdom Monera. (Fig. 4.3)

2. Most are between 1-10 m in diameter, just visible with light microscopes.

3. Structures: [transp. 20]

   a. Cell wall is composed of **peptidoglycan**.

   b. Bacteria may be surrounded by a **capsule** and/or gelatinous sheath called a **slime layer**.

   c. Motile bacteria usually have **flagella**, which rotate like propellers to move through fluid medium.

   d. **Fimbriae** are short appendages that help them attach to an appropriate surface.

   e. **Plasma membrane** is the outermost membrane; regulates the entrance and exit of molecules.

   f. **Cytoplasm** consists of **cytosol**, a semifluid medium.

   g. **Ribosomes** are granular inclusions that coordinate synthesis of proteins.

   h. **Nucleoid** contains most genes in a circular DNA molecule.
i. **Plasmids** are small accessory rings of DNA aside from the nucleoid.

j. **Thylakoids** are flattened discs with light-sensitive pigment molecules.

4. Although prokaryotes are relatively simple, they are also metabolically diverse.

4.3. **Eukaryotic Cells Are More Complex** (p. 63)

A. Eukaryotic Cells (Table 4.1) (Figs. 4.4 and 4.5) [transps. 21 and 22] [micro. slides 1 and 2]

1. Include cells of organisms belonging to kingdoms other than Monera.

2. Membrane-bound nucleus houses DNA in threadlike structures called chromatin.

3. Most are between 10-100 µm in diameter, or ten to 100 times larger than prokaryotic cells.

4. Similar to prokaryotic cells, eukaryotic cells have a plasma membrane and cytoplasm including ribosomes.

5. Eukaryotic cells are more complex than prokaryotic cells, have **organelles**, including a true **nucleus**, and an organised lattice of protein filaments called the **cytoskeleton**.

B. **Nucleus Stores Genetic Information**

1. Stores genetic information determining structure/function of cells by regulating sequences of amino acids.

2. Structures (Fig. 4.6) [transp. 23]

   a. Nucleus has a diameter of about 5 µm.

   b. **Chromatin** is a threadlike material that coils into chromosomes just before cell division occurs; contains DNA, protein, and some RNA.

   c. **Chromosomes** are rod-like structures formed during cell division; coiled or folded chromatin.
d. **Nucleoplasm** is semifluid medium of nucleus; has a different pH from cytosol.

e. **Nucleoli** are dark-staining spherical bodies in nucleus; sites where rRNA joins proteins to form ribosomes.

f. **Nuclear envelope** is a double membrane that separates nucleoplasm from cytoplasm.

g. **Nuclear pores** (100 nm) permit passage of proteins into nucleus and ribosomal subunits.

C. Ribosomes Are Sites of Protein Synthesis

1. Ribosomes of eukaryotic cells are 20 nm by 30 nm; those of prokaryotic cells are slightly smaller.

2. Ribosomes are composed of a large and a small subunit. (Fig. 4.7c) [transp. 24]

3. Each subunit has its own mix of proteins and rRNA.

4. Ribosomes coordinate assembly of amino acids into polypeptide chains (i.e., protein synthesis).

5. **Polyribosomes** are several ribosomes synthesizing same protein; may be attached to ER or may lie free.

D. The Endomembrane System is Elaborate (p. 67)

1. **Endomembrane system** is an elaborate series of intracellular membranes that compartmentalize the cell.

2. Endoplasmic reticulum

   a. **Endoplasmic Reticulum (ER)** is system of membranous channels continuous with outer membrane of the nuclear envelope.

   b. **Rough ER** is studded with ribosomes; is site where proteins are synthesized and enter the ER interior for processing and modification. (Fig. 4.7) [transp. 24]

   c. **Smooth ER** is continuous with rough ER, but lacks ribosomes; site of various synthetic processes, detoxification, and storage; smooth ER forms transport vesicles.
3. Golgi Apparatus (Fig. 4.8) [transp. 24] [micro. slide 3 and 4]

   a. **Golgi apparatus** is named for Camillo Golgi who discovered it in cells in 1898.

   b. Golgi apparatus consists of a stack of 3-20 slightly curved saccules.

   c. Golgi apparatus receives protein-filled vesicles that bud from the ER.

   d. Vesicle fuses with membrane of Golgi apparatus or moves to outer face after proteins repackaged.

   e. Vesicles formed from membrane of outer face of the Golgi apparatus then move to different locations in cell; at plasma membrane, they discharge their contents as **secretions**.

4. Lysosomes (Fig. 4.8) [transp. 25]

   a. **Lysosomes** are membrane-bound vesicles produced by Golgi apparatus that contain digestive enzymes.

   b. Macromolecules enter a cell by vesicle formation; lysosomes can fuse with vesicles and digest contents.

   c. White blood cells that engulf bacteria use lysosomes to digest bacteria.

   d. Autodigestion occurs when lysosomes digest parts of cells; important during development (e.g., tadpole tail absorption, degeneration of webbing between human fingers).

   e. Missing or inactive lysosomal enzymes cause serious childhood diseases.

   f. **Microbodies** are membrane-bounded vesicles that contain specific enzymes.

      1) Peroxisomes are abundant in liver; form hydrogen peroxide that is broken down to water by catalase.

      2) Peroxisomes also occur in leaves where they give off CO₂ that can be used in photosynthesis and in germinating seeds where they convert oils into sugars used as nutrients by growing plant.
5. Vacuoles

- A **vacuole** is a large membranous sac; vesicles are smaller than vacuoles.
- More prominent plant cell vacuoles (usually one or two) are water filled and give support to cell.
- Plant vacuoles store water, sugars, salts, pigments and toxic substances to protect plant from herbivores.
- Vacuoles in protozoa include digestive vacuoles and water-regulating contractile vacuoles.

E. Energy-Related Organelles

1. **Chloroplasts** are membranous organelles that serve as sites of photosynthesis. (Fig. 4.10) [micro. slide 6]
   - Photosynthesis is process by which solar energy is converted to the chemical energy of carbohydrates: light energy + carbon dioxide + water → carbohydrate + oxygen.
   - Only plants, algae, and cyanobacteria are capable of carrying on photosynthesis.
   - Chloroplasts are about 4-6 µm in diameter and 1-5 µm in length.
   - Chloroplasts are a type of organelle called a **plastid**; plastids include **amyloplasts**, which store starch, and **chromoplasts**, which contain red and orange pigments.
   - Chloroplast is bounded by a double membrane organized into flattened sacs (thylakoids) piled into stacks called grana with a fluid-filled space around thylakoids called the **stroma**.
   - Chlorophyll is located within the thylakoid membranes.
   - The stroma contains enzymes that catalyze reactions involved in synthesis of carbohydrates.
   - There are no chloroplasts in cyanobacteria; chlorophyll is bound to cytoplasmic thylakoids.

2. **Mitochondria** are membranous organelles; sites of **cellular respiration**. (Fig. 4.11) [micro. slide 7]
a. **Cellular respiration** is process where chemical energy of carbohydrates is converted to that of ATP, the carrier of energy in cells: carbohydrate + oxygen → carbon dioxide + water + energy.

b. Cell energy is provided by ATP; all organisms carry on aerobic respiration and all except bacteria have mitochondria.

c. Mitochondria are about 0.5-1.0 µm in diameter and 7 µm in length.

d. Mitochondria are bounded by a double membrane; inner membrane has folds (cristae) that project into inner space (matrix) with enzymes that break down carbohydrate-derived products; ATP production occurs at cristae.

e. Mitochondria contain ribosomes and their own DNA that specifies some proteins; other proteins are coded by nucleus DNA.

f. Mitochondria divide before cell division occurs.

F. Cytoskeleton Contains Filaments and Microtubules (Fig. 4.12)

1. **Cytoskeleton** is a network of connected filaments and tubules; extends from nucleus to plasma membrane. [trans. 26]

   a. Electron microscopy reveals organized cytosol; immunofluorescence microscopy identifies protein fibers.

   b. Elements of cytoskeleton maintain cell shape and allow it and organelles to move.

   c. Elements can disassemble and reassemble in life of a cell.

2. Actin Filaments for Structure and Movement

   a. **Actin filaments** are long, thin fibers (about 7 nm in diameter) that occur in bundles or meshlike networks.

   b. Actin filament consists of two chains of globular actin monomers twisted to form a helix.

   c. Actin filaments play a structural role, forming a dense complex web just under the plasma membrane.

   d. Actin filaments in microvilli of intestinal cells likely shorten or extend cell into intestine.
e. In plant cells, they form tracts along which chloroplasts circulate.

f. Actin filaments move by interacting with myosin: myosin combines with and splits ATP, binding to actin and changing configuration to pull actin filament forward.

h. Similar action accounts for pinching off cells during cell division and for amoeboid movement.

3. Intermediate Filaments Are Diverse [transp. 26]

a. Intermediate filaments are 8-11 nm in diameter, between actin filaments and microtubules in size.

b. They are rope-like assemblies of fibrous polypeptides.

c. Some support nuclear envelope, others support plasma membrane, form cell-to-cell junctions.

4. Microtubules Have Tubulin Subunits (Fig. 4.12d)

a. Microtubules are small hollow cylinders (25 nm in diameter and from 200 nm-25 µm in length).

b. Microtubules are composed of a globular protein tubulin; occurs as a tubulin and βtubulin.

c. Assembly brings these two together as dimers, and the dimers arrange themselves in rows.

d. Regulation of microtubule assembly is under control of a microtubule organizing center: a centrosome.

e. Microtubules radiate from centrosome, helping maintain shape of cells and acting as tracks along which organelles move.

f. Similar to actin-myosin, motor molecules kinesin and dynein are associated with microtubules.

g. Different kinds of kinesin proteins specialize to move one kind of vesicle or cell organelle.

h. Cytoplasmic dynein is similar to the molecule dynein found in flagella.
5. Centrioles (Fig. 4.13) [micro. slide 7][transp. 27]

   a. In animal cells and most protists, centrosome contains two centrioles lying at right angles to each other.

   b. **Centrioles** are short cylinders with a 9 + 0 pattern of microtubule triplets.

   c. Centrioles serve as basal bodies for cilia and flagella.

   d. Plant and fungal cells have equivalent of a centrosome but it does not contain centrioles.

6. Cilia and Flagella (Fig. 4.14) [micro. slides 9-11]

   a. **Cilia** are short, usually numerous hairlike projections that can move in an undulating fashion (e.g., *Paramecium*, lining of human upper respiratory tract).

   b. **Flagella** are longer, usually fewer, whip-like projections that move in whip-like fashion (e.g., sperm cells).

   c. Both have similar construction, but differ from prokaryotic flagella.

      1) Membrane-bounded cylinders enclose a matrix containing a cylinder of nine pairs of microtubules encircling two single microtubules (9 + 2 pattern of microtubules).

      2) Cilia and flagella move when the microtubules slide past one another. (Fig. 4.14)

      3) Cilia and flagella have basal body at base with same arrangement of microtubule triples as centrioles.

      4) Cilia and flagella grow by the addition of tubulin dimers to their tips.

4.4. How the Eukaryotic Cell Evolved (p. 76)

   A. Invagination of the plasma membrane might explain origination of nuclear envelope and organelles.

   B. Endosymbiosis hypothesis
1. Laboratory observations indicate amoeba infected with bacteria become dependent on them.

2. Proposed by Lynn Margulis: Mitochondria are aerobic heterotrophic bacteria; chloroplasts are cyanobacteria.

3. Prokaryotes enter cell; establish symbiotic relationship where they utilize oxygen and synthesize food.

4. Evidence for this hypothesis includes the following:
   
a. Mitochondria and chloroplasts are similar to bacteria in size and structure.

b. Both bounded by double membrane: outer derived from engulfing vesicle, inner from plasma membrane.

c. Mitochondria and chloroplasts contain a limited amount of genetic material and divide by splitting; their DNA is circular loop similar to bacterial DNA.

d. Although most proteins within them are produced by eukaryotic host, they have their own ribosomes to produce own proteins, and ribosomes resemble bacterial ribosomes.

e. The RNA base sequence of their ribosomes suggests a eubacteria origin.

5. Margulis also suggests eukaryotic flagella is from a spirochete prokaryote.