

# CHAPTER 5: CELL STRUCTURE

## CHAPTER SYNOPSIS

All life is composed of cells, individually or as components of multicellular organisms. With certain exceptions, cells are very small. Substances diffuse more rapidly in a small cell, enhancing both its metabolism and its communication with other cells and with its environment. As a cell's size increases, its volume increases at a much greater rate than its surface area. A cell's survival depends on its surface, where all molecules enter and exit. If there is too little surface to support the workings of the interior, the cell will die.

Many of the structural differences between prokaryotes and eukaryotes are visible at the level of the light microscope; the presence of the nucleus in eukaryotes, for example. The nuclear material in prokaryotes is a single, circular strand of DNA, unencumbered by either proteins or a surrounding membrane and is difficult to see at the same scale. Observation with an electron microscope reveals details about the cytoskeleton and internal membrane systems of the eukaryotes, both absent in prokaryotes.

On a biochemical level, all of the reactions of a prokaryote, including those associated with ribosomes, occur openly in its cytoplasm, bounded only by invaginations of the plasma membrane. The reactions in a eukaryote are compartmentalized by the endoplasmic reticulum (ER) and by various membrane-bound organelles. Among these organelles are the nucleus, the Golgi apparatus, lysosomes, and microbodies (peroxisomes and glyoxysomes). The smooth and rough ER differ in appearance and function.

Rough endoplasmic reticulum possesses ribosomes while smooth endoplasmic reticulum lacks them. Various chemical products are synthesized on the rough endoplasmic reticulum, channeled into the Golgi bodies, and packaged into microbodies and lysosomes. Smooth ER contains embedded enzymes and is involved in carbohydrate and lipid synthesis and detoxification.

Some eukaryotic organelles contain DNA, notable among these are the cell's powerhouses, the mitochondria and the chloroplasts, and the centrioles. The latter are found in animal and protist cells where they direct the assembly of the cytoskeletal microtubules and form the basal bodies that anchor the flagella. The cytoskeleton, composed of actin filaments, microtubules, and intermediate filaments, provides a framework to anchor the organelles and give a cell its shape. Microtubules move organelles within a cell assisted by kinesin and dynein proteins. They also provide the characteristic 9+2 arrangement of eukaryotic flagella, cilia, and centrioles. Plant cells have special adaptations that are lacking in other cells. One is their large central vacuole which serves as a storage compartment and helps increase the cell's surface-to-volume ratio. Plants cells also have strong, rigid cell walls composed of cellulose.

There is a myriad of evidence supporting the evolution of eukaryotes via endosymbiotic events. Both mitochondria and chloroplasts are endosymbionts of prokaryotic origin. Similarly, centrioles resemble spirochaete bacteria.

## CHAPTER OBJECTIVES

- ä Understand why most cells are small in size.
- ä Describe the function and the composition of the plasma membrane.
- ä Explain the principles of the cell theory.
- ä Differentiate between prokaryotes and eukaryotes.
- ä Understand the importance of the nucleus and its components.
- ä Differentiate between rough and smooth endoplasmic reticulum both in structure and function.

- ä Understand how the endoplasmic reticulum and Golgi apparatus interact with one another and know with which other organelles they are associated.
- ä Differentiate between the two energy-producing organelles of eukaryotes.
- ä Identify the three primary components of the cell's cytoskeleton and how they affect cell shape, function, and movement.
- ä Compare and contrast bacterial flagella with eukaryotic flagella and cilia.
- ä Know how plant cells are fundamentally different from other kinds of cells.
- ä Explain the endosymbiotic origin of the eukaryotic organelles.

## KEY TERMS

9+2 structure	glyoxysome	nucleosome
amyloplast	Golgi body	nucleus
basal body	Golgi apparatus	nucleoid
cell theory	gram negative	organelle
cell wall	gram positive	peroxisome
central vacuole	granum	plasma membrane
centriole	histone	plastid
centrosome	intermembrane space	polymerization
chloroplast	liposome	primary (cell) wall
chromatin	lysosome	prokaryote
chromosome	matrix	pseudopod
cilium	microbody	resolution
cisterna	microscope	ribosome
compound microscope	microtubule	rough ER
connector molecule	microtubule-organizing center	scanning electron microscope
crista	microvillus	secondary (cell) wall
cytoplasm	middle lamella	signal sequence
cytoskeleton	mitochondrion	smooth ER
endomembrane system	motor molecule	surface area-to-volume ratio
endoplasmic reticulum (ER)	nuclear envelope	thylakoid
endosymbiosis	nuclear pore	transmission electron microscope
eukaryote	nucleolus	vesicle
flagellum		

## CHAPTER OUTLINE

### 5.0 Introduction

#### I. CELLS MAKE UP ALL ORGANISMS

A. Some Are Small and Single Celled

fig 5.1

B. Others Are Composed of Multitudes of Cells

### 5.1 All organisms are composed of cells

#### I. CELLS

A. The Plasma Membrane Surrounds the Cell

1. Phospholipid bilayer contains embedded proteins

a. Appear as two dark lines separated by lighter area

b. Appearance due to arrangement of phospholipid molecules

fig 3.18

c. Major proteins have large hydrophobic domains

2. Proteins enable cell to interact with environment
  - a. Transport proteins facilitate passage across membrane
  - b. Receptors induce cell changes with contact by molecules
  - c. Markers provide cell identity
  
- B. The Central Portion of the Cell Contains the Genetic Material
  1. Genetic material in prokaryotes
    - a. Single, circular molecule of DNA
    - b. Is concentrated in the nucleoid, not membrane bound
  2. Genetic material in eukaryotes
    - a. Contained within the nucleus
    - b. Surrounded by two membranes
  
- C. The Cytoplasm Comprises the Rest of the Cell's Interior
  1. Cytoplasm is a semifluid matrix
  2. Contains chemicals to carry out growth and reproduction
  3. Eukaryotic cells also contain membrane-bound organelles
  
- D. The Cell Theory
  1. Most cells are microscopic in size
    - a. Exceptions like *Acetabularia* may be up to 5 cm long
    - b. Typical eukaryotic cell is 10 to 100 micrometers
  2. Cells were observed with the invention of the microscope
    - a. Robert Hooke
      - 1) First observed honeycomb of empty compartments in cork in 1665
      - 2) Called compartments "cellulae" (cells)
    - b. Antonie Van Leeuwenhoek
      - 1) First observance of living cells
      - 2) Called organisms "animalcules"
    - c. Matthias Schleiden
      - 1) Observed plant tissues
      - 2) All plants aggregates of separate cells
    - d. Theodor Schwann
      - 1) Observed animal tissues
      - 2) All animals are composed of individual cells
  3. Modern principles of cell theory
    - a. All organisms composed of one or more cells
    - b. Cell is smallest living organizational unit
    - c. Cells arise only from division of other cells

fig 5.2

## II. CELLS ARE SMALL

- A. The Resolution Problem
  1. Human eye can't see cells because of limited resolution
  2. Resolution: Minimum distance between two points to distinguish as separate points
  3. Human eye can resolve points if 100 micrometers or more apart
  
- B. Microscopes
  1. Magnification increases resolution, objects appear larger than 100 micrometer limit
  2. Earliest microscopes used single glass lens between object and eye
  3. Modern microscopes are compound microscopes
    - a. Use two magnifying and multiple correcting lenses
    - b. Best resolution distinguishes objects 200 nanometers apart

fig 5.3a

## C. Increasing Resolution

1. Light microscope resolution limited by size of wavelengths of light
2. Wavelength of electrons shorter than light by 1,000 fold
3. Transmission electron microscope
  - a. Electrons transmitted through slice of object
  - b. Can resolve objects only 0.2 nanometers apart fig 5.3b
4. Scanning electron microscope
  - a. Electrons directed to surface of object, bounce back
  - b. Shows a three-dimensional image of the object fig 5.3c

## D. Why Aren't Cells Larger?

1. Limitation of communication
2. Limitations of molecular diffusion
  - a. Faster passage through small cells
  - b. More efficient communication
3. Limitations of surface-to-volume ratio fig 5.4
  - a. With increase in size, greater increase in volume than surface area
  - b. Interaction with outside occurs only at surface
  - c. Insufficient exchange of materials at plasma membrane for survival
  - d. Small cells have more surface per unit of volume than large cells
4. Large cells overcome problem with special adaptations
  - a. More than one nucleus
  - b. Actively move material within cell
  - c. Shape is long and thin

## 5.2 Eukaryotes are far more complex than bacterial cells

## I. BACTERIA ARE SIMPLE CELLS

## A. Prokaryotes Are the Simplest Cellular Organisms

1. Similar organization, small size fig 5.5
  - a. Surrounded by membrane, encased in rigid cell wall
  - b. No internal compartments
2. Important in economy of living organisms
  - a. Photosynthesize, degrade, and recycle
  - b. Cause disease, produce industrial chemicals

## B. Strong Cell Walls

1. Peptidoglycan carbohydrate matrix cross linked with peptide units
2. Gram positive, thick cell wall, retains primary stain
3. Gram negative, thinner cell wall, releases primary stain
4. Polysaccharide layer may surround cell wall

## C. Rotating Flagella

1. Long, threadlike structures that protrude from cell surface
2. Used in locomotion and feeding
3. May be one or more per cell, help characterize species
4. Cell movement results from screw-like rotation fig 5.6

## D. Simple Interior Organization

1. Lack internal compartmentalization
  - a. Contain ribosomes, but lack membrane-bound organelles
  - b. No true nucleus or internal support structures
  - c. Cell strength due to rigid cell wall fig 5.5

2. Plasma membrane carries out functions of organelles in eukaryotes
    - a. Associated with cell division
    - b. Location of bacterial photosynthetic pigments
  3. Reactions not separated, cell is a single metabolic unit
- fig 5.7

II. EUKARYOTIC CELLS HAVE COMPLEX INTERIORS

- A. Eukaryotes Are More Complex Than Prokaryotes fig 5.8,9

B. Hallmark Is Compartmentalization

1. Possess internal membrane-bound organelles
  - a. Central vacuole in plants stores proteins, pigment, wastes
  - b. Vesicles in animals store and transport many materials
  - c. Nucleus contains chromosomes made of DNA and proteins
2. Cytoskeleton is an internal scaffold of proteins
3. Cell walls: Cellulose/chitin fibers embedded in polysaccharides, proteins

5.3 Take a tour of a eukaryotic cell

I. THE NUCLEUS: INFORMATION CENTER FOR THE CELL

A. Largest Organelle in Most Cells, Readily Visible

1. Spherical appearance, centrally located fig 5.10
2. Positioned by filaments
3. Repository of all genetic information
4. Usually singular, lacking in mature red blood cells
5. Dark-staining nucleolus visible in cells synthesizing RNA

B. The Nuclear Envelope: Getting In and Out fig 5.10

1. Double layer of membranes
2. Outer continuous with cytoplasm's internal endoplasmic reticulum
3. Membranes pinched together at nuclear pores
  - a. Embedded with proteins, serve as molecular channels
  - b. Restrict passage of molecules to proteins and RNA

C. The Chromosomes: Packaging the DNA

1. DNA contains hereditary information specifying structure and function
2. Divided into linear chromosomes
  - a. Uncoiled as chromatin except when cell is dividing
  - b. Uncoiling permits proteins to access DNA to direct cell activities
3. Associated with histone proteins
  - a. Enables condensation during cell division
  - b. Aggregations called nucleosomes fig 5.11
4. Fully condensed chromosomes appear as dark-staining rods fig 5.12
5. Uncoiling permits RNA polymerase to access DNA
  - a. Makes RNA copies of the DNA
  - b. RNA directs synthesis of proteins

II. THE ENDOPLASMIC RETICULUM: COMPARTMENTALIZING THE CELL

A. General Characteristics

1. Membranes and organelles embedded within matrix tbl 5.1
2. Thin membranes not visible in light microscope
3. Endomembrane system divides interior into compartments

- a. Channels the passage of molecules through cell
    - b. Provides surface for protein and lipid synthesis
  - 4. Largest membrane called endoplasmic reticulum, abbreviated ER
    - a. Lipid bilayer with embedded proteins
    - b. Creates channels and interconnections between folds fig 5.13
  - 5. Has 2 primary compartments
    - a. Cisternal space: Inner region of ER
    - b. Cytosol: Region exterior to cisternal space
- B. Rough ER: Manufacturing Proteins for Export
- 1. Ribosomes assist manufacture of proteins
    - a. Aggregates of protein and RNA
    - b. Translate RNA copies of genes into proteins
    - c. Look rough through an electron microscope, like surface of sandpaper fig 5.13
  - 2. Proteins used in cell or may be exported
    - a. Contain signal sequences
    - b. Initial translation by free ribosome
    - c. Signal sequence attaches recognition factor
    - d. Aggregation travels to ER docking site
    - e. Protein directed to Golgi apparatus fig 5.14
- C. Smooth ER: Organizing Internal Activities
- 1. Possess few bound ribosomes
  - 2. Contain embedded enzymes
  - 3. Catalyze synthesis of many carbohydrates and lipids
  - 4. Associated with detoxification in liver
  - 5. Vesicles may form at plasma membrane
    - a. Bud inward in endocytosis
    - b. May move into cytoplasm and fuse with smooth ER
    - c. May form secondary lysosomes or other interior vesicles

### III. THE GOLGI APPARATUS: DELIVERY SYSTEM OF THE CELL

- A. Golgi Bodies fig 5.15
- 1. Individual, flattened stacks of membranes
  - 2. Abundant in glandular secretory cells
  - 3. Collectively called the Golgi apparatus
- B. Functions of Golgi Apparatus fig 5.16
- 1. Collection, packaging, distribution of molecules
  - 2. Golgi body has front and back ends
    - a. Materials from ER move to *cis* face, front or receiving end
    - b. Molecules pass through to back or *trans* face
    - c. Discharged into secretory vesicles
  - 3. Manufactured products of ER transported into it
    - a. Bind to polysaccharides forming glycoproteins and glycolipids
    - b. Molecules collect at flattened, stacked folds of membranous cisternae
  - 4. Liposomes are synthetically manufactured vesicles
    - a. Contain variety of beneficial substances
    - b. Injected into body, provide effective delivery to cells

IV. VESICLES: ENZYME STOREHOUSES

A. Lysosomes: Intracellular Digestion Centers

1. Component of endomembrane system, arise from Golgi apparatus
2. Contain concentrated mix of digestive enzymes
3. Enzymes catalyze breakdown of macromolecules within cell
4. Digest worn-out cell components and recycle material into new structures
5. Alter internal pH to effect control of digestion
  - a. Primary lysosome has high pH and is inactive
  - b. Secondary lysosome has low pH and is active
6. Eliminate particles and foreign cells via phagocytosis fig 5.17
  - a. Digest pathogens engulfed by white blood cells
  - b. Release enzymes into food vesicle, degrade material inside

B. Microbodies

1. Enzyme-bearing, membrane-bound vesicles called microbodies
2. Glyoxysomes in plants convert fats to carbohydrates
3. Peroxisomes fig 5.18
  - a. Contain enzymes that catalyze removal of electrons and hydrogen atoms
  - b. Need to be contained or would interfere with many metabolic activities
  - c. Catalase breaks toxic hydrogen peroxide into water and oxygen

V. RIBOSOMES: SITES OF PROTEIN SYNTHESIS

A. Proteins Are Synthesized in Cytoplasm Not Nucleus

1. Read mRNA copy of DNA gene to direct synthesis of protein
2. Ribosomes composed of ribosomal RNA (rRNA) and proteins fig 5.19
  - a. Composed of two subunits
  - b. Subunits combine only when attached to messenger RNA
  - c. Ribosomes in bacterial are smaller than ones in eukaryotes
3. Greater number of ribosomes in metabolically active tissues
  - a. Cytoplasmic proteins made by free ribosomes
  - b. Rough ER ribosomes produce proteins used on membranes or to be exported

B. The Nucleolus Manufactures Ribosomal Subunits

1. DNA coding for ribosomal RNA (rRNA) clustered to maximize synthesis
  - a. Large numbers of ribosomes synthesized rapidly
  - b. Cell can then make large amounts of protein
2. Dark-staining nucleolus visible in cells assembling ribosomes fig 5.20
  - a. Location of ribosome synthesis
  - b. Present when chromosomes are uncoiled and invisible

VI. ORGANELLES THAT CONTAIN DNA

A. Mitochondria: The Cell's Chemical Furnaces fig 5.21

1. Tubular or sausage-shaped organelles bounded by double membrane
2. Occur in all eukaryotes
3. Outer membrane is smooth
4. Inner membrane is folded into contiguous layers called cristae
  - a. Divides into inner matrix and outer compartment or intermembrane space
  - b. Associated with proteins of oxidative metabolism
5. Possesses own genome
  - a. Genes direct production of own RNA and ribosomal components
  - b. Genes for oxidative metabolism are in nucleus

6. Capable of replication
    - a. Distributed between halves of dividing cells
    - b. Replenish numbers by simple fission division
    - c. Components for division are governed by genes in nucleus
    - d. Not completely autonomous, cannot be cultured separately
- B. Chloroplasts: Where Photosynthesis Takes Place
1. Occur in plants and other photosynthetic organisms
  2. Confer advantage to cells: Can make own food
  3. Contain chlorophyll, give plants green color
  4. Bounded by double membrane fig 5.22
    - a. Internal membranes form disk-shaped thylakoids
    - b. Photosynthetic pigments on thylakoid surface
    - c. Stack of thylakoids called granum
    - d. Surrounded by stroma, a fluid matrix
  5. Possess own genome
    - a. Genes for chloroplast components located in nucleus
    - b. RNA and protein components for photosynthesis on chloroplast DNA
  6. Leucoplasts are plant organelles without pigments
    - a. Internal structure less complex
    - b. Specialized amyloplasts store starch
  7. Chloroplast, leukoplast, amyloplast collectively called plastids
  8. Plastids arise from division of other plastids
- C. Centrioles: Microtubular Assembly Centers
1. Barrel-shaped organelles present in animal and protist cells
  2. Occur in pairs at right angles near nuclear envelope, forms the centrosome fig 5.23
  3. Some contain DNA involved in producing their structural proteins
  4. Associated with assembly and organization of microtubules
    - a. Influence cell shape, move chromosomes
    - b. Produce functional internal structure of flagella and cilia
    - c. Example of microtubule-organizing centers (MTOCs)
  5. Absent in plant and fungal cells
- VII. THE CYTOSKELETON: INTERIOR FRAMEWORK OF THE CELL
- A. Network of Protein Fibers fig 5.24
1. Supports shape of cell, anchor organelles to fixed location
  2. Formed by polymerization of identical protein subunits
  3. Also disassembled subunit by subunit
- B. Three Types of Cytoskeleton Fibers
1. Actin filaments fig 5.25a
    - a. Fibers composed of two chains like two intertwined strands of pearls
    - b. Actin proteins are the pearl molecules
    - c. Form spontaneously
    - d. Cell controls polymerization via other proteins
    - e. Responsible for cellular movements, formation of cellular extensions
  2. Microtubules fig 5.25b
    - a. Spontaneously form hollow tubes of 13 protein protofilaments
    - b. Alpha and beta tubulin subunits polymerize to form protofilaments
    - c. Form from MTOC nucleation centers



- d. In constant flux, polymerizing and depolymerizing
  - 1) Stabilized when guanine triphosphate (GTP) binds to ends
  - 2) "+" end is away from the nucleating center
  - 3) "-" end is toward the nucleating center
- e. Help move materials within the cell itself
  - 1) Kinesin protein moves organelles to "+" end (periphery)
  - 2) Dynein protein moves organelles to "-" end (center)
- 3. Intermediate filaments fig 5.25c
  - a. Fibrous proteins twined together to form overlapping tetrameres
  - b. Composed of various subunits of intermediate size
  - c. Fibers very stable do not break down readily
  - d. Vimentin subunits make filaments that provide structural stability
  - e. Other examples: Keratin and neurofilaments

### VIII. CELL MOVEMENT

- A. Cell Movement Associated with Cytoskeletal Fibers
  - 1. Cell motion tied to movement of actin filaments, microtubules or both
  - 2. Intermediate fibers prevent excessive stretching
  - 3. Actin filaments also important in determining cell shape
  - 4. Rapid production of microvilli changes cell shape quickly fig 5.26
- B. Some Cells Crawl
  - 1. May have implications in healing and slowing spread of cancer
  - 2. Movement of white blood cells is good example
  - 3. Results in regional changes in gel-sol state
    - a. Periphery is usually more rigid (gel)
    - b. Interior is usually very fluid (sol)
  - 4. Formation of pseudopods to move cell
  - 5. Cell motion tied to movement of actin filaments and/or microtubules
- C. Moving Material Within the Cell
  - 1. Orchestrate activities to affect cell processes
    - a. Movement of replicated chromosomes
    - b. Division of animal cells
    - c. Contraction of muscle cells
  - 2. Provide scaffold for anchoring cell enzymes
    - a. Metabolic enzymes and ribosomes bind to actin filaments
    - b. Organize metabolic activities of cell by relocating elements
- D. Intracellular Molecular Motors
  - 1. ER transport too slow for movement over long distances
  - 2. Rapid transport via microtubular apparatus requires 4 components
    - a. Vesicle or organelle to be transported
    - b. Motor molecule provides energy-driven motion
    - c. Connector molecule connects vesicle of motor molecule
    - d. Microtubules that serve as tracks on which vesicle travels
  - 3. Example: Kinectin system
    - a. Kinectin is found in the endoplasmic reticulum
    - b. Binds ER vesicles to kinesin motor proteins
    - c. Kinesin uses ATP to power movement toward cell periphery
    - d. Drags vesicle with it

4. Another or a modified protein directs movement in the opposite direction
    - a. Binds to dynein
    - b. Moves vesicle toward center of cell
  5. Destination of vesicle and contents related to protein in vesicle's membrane
- E. Swimming with Flagella and Cilia
1. Eukaryote and bacteria flagella are completely different in structure
  2. Eukaryote 9+2 structure of microtubules fig 5.27
    - a. Undulating movement results from sliding of filaments
    - b. Projection enclosed by cell membrane
    - c. Derived from basal body below cell membrane
  3. Cilia also show 9+2 arrangement fig 5.1
    - a. Numerous, short projections called cilia
    - b. Have functions other than locomotion
      - 1) Pass fluids over tissue surface
      - 2) Bend in response to sound waves

#### IX. SPECIAL THINGS ABOUT PLANT CELLS

- A. Vacuoles: A Central Storage Compartment fig 5.28
1. Centrally located, appear to be empty
  2. Contain water, sugars, ions, pigments
  3. Help to increase surface-to-volume ration, apply pressure to cell membrane
- B. Cell Walls: Protection and Support
1. Are chemically and structurally different from bacterial cell walls
    - a. May also be present in fungi and protists
    - b. Composed of polysaccharide cellulose fibers
  2. Primary walls laid down during growth of cell
  3. Middle lamella glues plant cells together fig 5.29
  4. Secondary walls may be deposited inside primary walls

#### 5.4 Symbiosis played a key role in the origin of some eukaryotic organelles

##### I. ENDOSYMBIOSIS

- A. Eukaryotes Have Radically Different Cell Structure
1. Possess organelles that resemble bacteria, endosymbiont theory
  2. Endosymbiosis of different species of prokaryotes fig 5.30
  3. Mitochondria are like bacteria that carry out oxidative metabolism
  4. Chloroplasts are like photosynthetic bacteria
- B. Evidence Supporting Theory
1. Mitochondria and chloroplasts surrounded by double membrane
  2. Mitochondria and bacteria have similar size
  3. Mitochondrial ribosomes resemble bacterial ribosomes
  4. Mitochondria and chloroplast DNA circular like bacteria
  5. Mitochondria divide by simple fission
- C. Comparison of Features of Modern Cells tbl 5.2

## INSTRUCTIONAL STRATEGY

## PRESENTATION ASSISTANCE:

There is a lot of unfamiliar vocabulary in this chapter. Etymology of new words may be helpful.

Introduce the plasma membrane carefully. The next two chapters delve into its importance within and between cells.

Most students are familiar with simple cell theory. It may be appropriate to discuss Redi's and Pasteur's experiments refuting spontaneous generation at this point, when discussing cells originating from other cells. Students have some difficulty with the differences between prokaryotes and eukaryotes, therefore stress nuclear organization and membrane compartmentalization as definitive characteristics.

Many texts don't present much in the way of why cells are the size they are. This is an important concept elaborated on later in this text, in relation to why most animals and some plants have specific size limitations.

## VISUAL RESOURCES:

A large, clear plastic bag is a reasonable facsimile of a cell's plasma membrane. A prokaryote can be represented by a bag with various objects inside to represent their metabolic processes. A large bag with the objects inside of smaller bags represents a eukaryote and its compartmentalizing membrane-bound organelles. One could further place the bag in a box to represent the cell wall of a plant.

Fisher educational division sells a superb yet simple model of a lipid bilayer (and it is inexpensive). A saturated salt solution is the cell interior, mineral oil the exterior (the oil floats on

One may want to discuss cell fractionation and gradient centrifugation in relationship to isolating the various cell parts so they can be studied. A short description of various kinds of microscopes (especially the rationale behind why electron microscopes resolve much smaller structures) might be helpful, although this is frequently discussed in the laboratory setting. To a great extent, much of the material in this chapter is supported by laboratory activities where the students can observe many of the larger structures first-hand.

Most students mistakenly associate chloroplasts with plants and mitochondria with only animals. Stress that mitochondria are present in virtually all eukaryotes. Remember that these two organelles will be visited again when cell metabolism is discussed. Students may as well learn their structure now as opposed to later when they will be attempting to understand the biochemistry too.

the salt solution). Styrofoam balls are one side of the membrane (they float on the oil), plastic balls are the other side (they stay at the salt/oil interface). Plastic rods or straws into the balls serve as the lipid tails.

Electron micrographs are a must for this material. They can be difficult for students to interpret, therefore accompanying line drawings that simplify the micrograph are beneficial. Or use markers to outline and/or colorize particular structures on either photographs or transparencies.