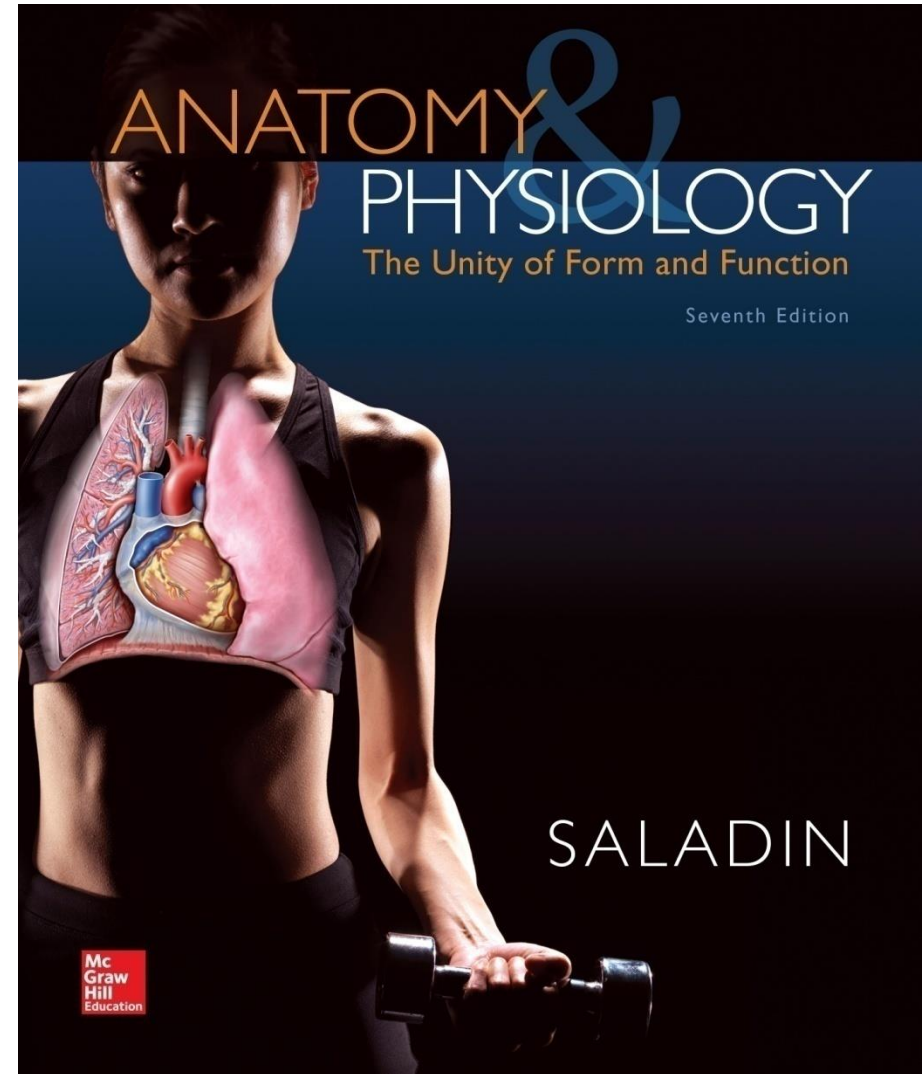


Chapter 03

Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.



Introduction

- **All organisms are composed of cells**
- **Cells are responsible for all structural and functional properties of a living organism**
- **Important for understanding**
 - Workings of human body
 - Mechanisms of disease
 - Rationale of therapy

Concepts of Cellular Structure

- **Expected Learning Outcomes**
 - Discuss the development and modern tenets of the cell theory.
 - Describe cell shapes from their descriptive terms.
 - State the size range of human cells and discuss factors that limit their size.
 - Discuss the way that developments in microscopy have changed our view of cell structure.
 - Outline the major components of a cell.

Development of the Cell Theory

- **Cytology**—scientific study of cells
 - Began when **Robert Hooke** coined the word *cellulae* to describe empty cell walls of cork in 17th century
- **Theodor Schwann** concluded, about two centuries later, that all animals are made of cells
- **Louis Pasteur** demonstrated in 1859 that “cells arise only from other cells”
 - Refuted idea of **spontaneous generation**—living things arising from nonliving matter

Development of the Cell Theory

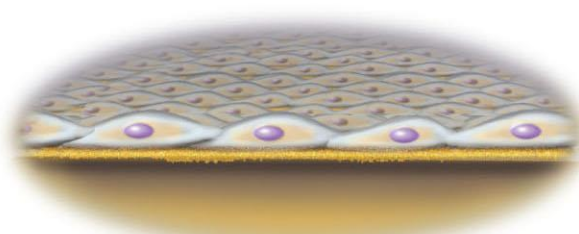
- **Cell theory**
 - All organisms composed of cells and cell products
 - Cell is the simplest structural and functional unit of life
 - An organism's structure and functions are due to activities of cells
 - Cells come only from preexisting cells
 - Cells of all species exhibit biochemical similarities

Cell Shapes and Sizes

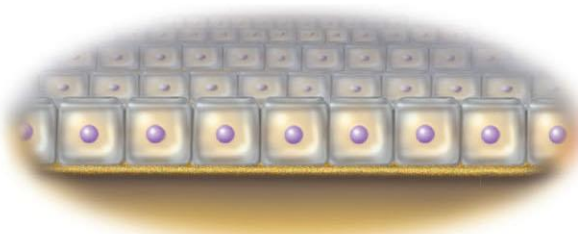
- About 200 types of cells in human body with varied shapes
- **Squamous**—thin, flat, scaly
- **Cuboidal**—squarish-looking
- **Columnar**—taller than wide
- **Polygonal**—irregularly angular shapes, multiple sides
- **Stellate**—star-like
- **Spheroid** to **ovoid**—round to oval
- **Discoid**—disc-shaped
- **Fusiform**—thick in middle, tapered toward the ends
- **Fibrous**—thread-like
- **Note: A cell's shape can appear different if viewed in a different type of section (longitudinal vs. cross section)**

Cell Shapes and Sizes

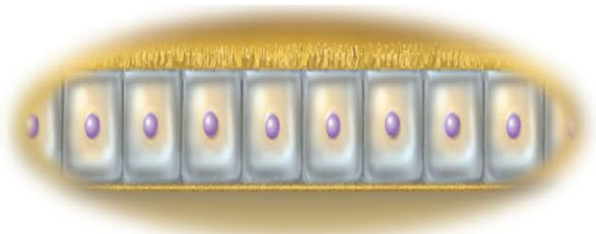
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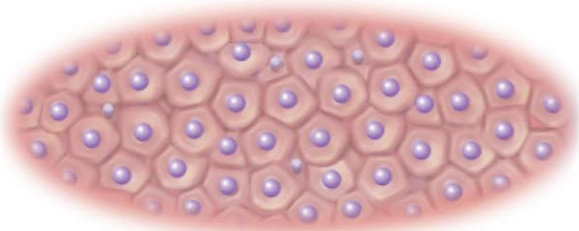
Squamous



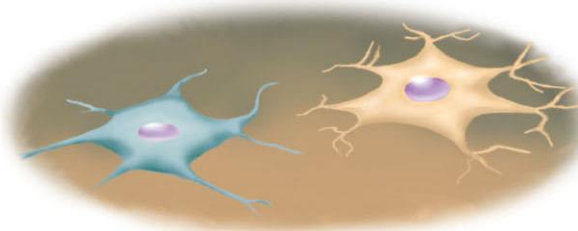
Cuboidal



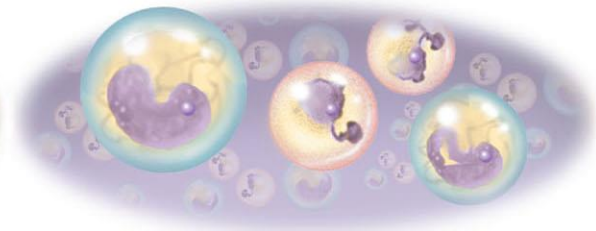
Columnar



Polygonal



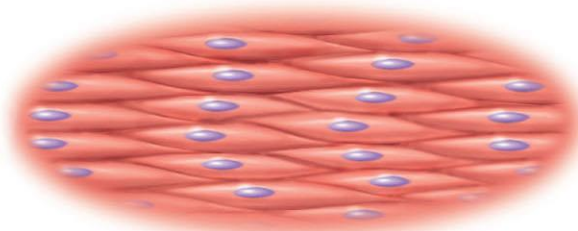
Stellate



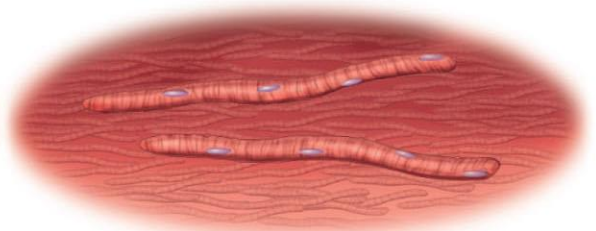
Spheroidal



Discoid



Fusiform (spindle-shaped)



Fibrous

Figure 3.1

Cell Shapes and Sizes

- **Human cell size**

- Most cells about 10–15 micrometers (μm) in diameter
 - Egg cells (very large) 100 μm diameter
 - Some nerve cells over 1 meter long
- Limit on cell size: an overly large cell cannot support itself, may rupture
 - For a given increase in diameter, volume increases more than surface area
 - Volume proportional to cube of diameter
 - Surface area proportional to square of diameter

Cell Shapes and Sizes

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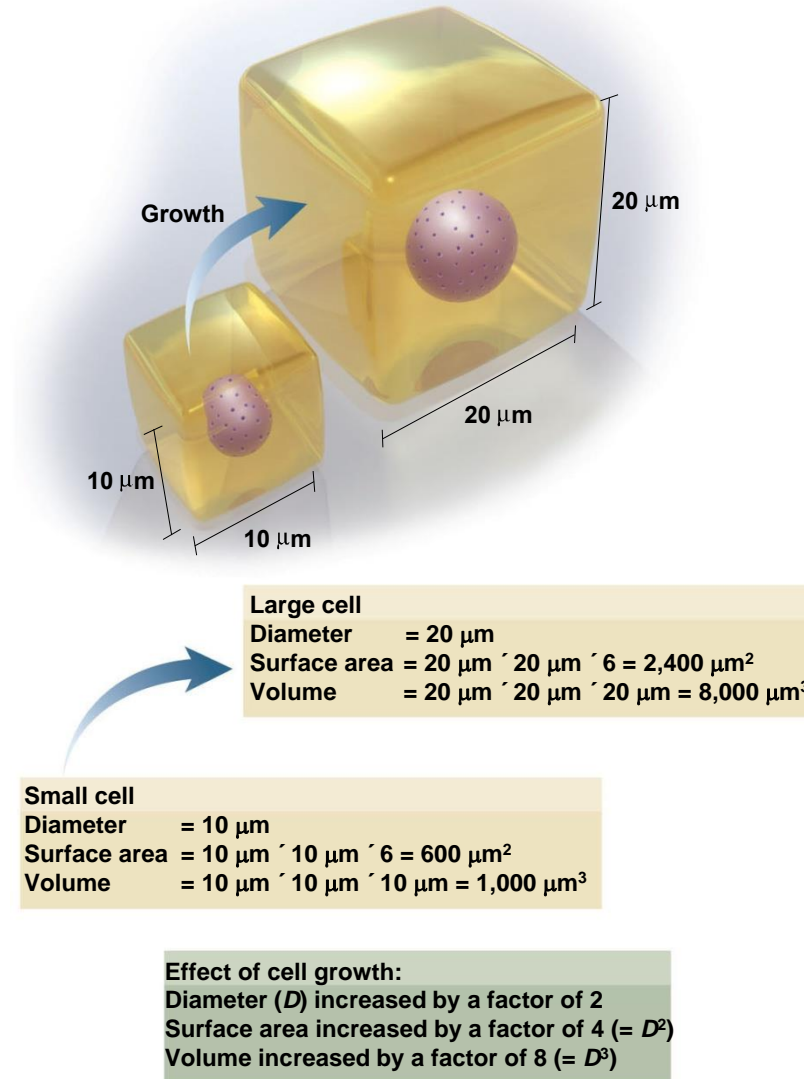
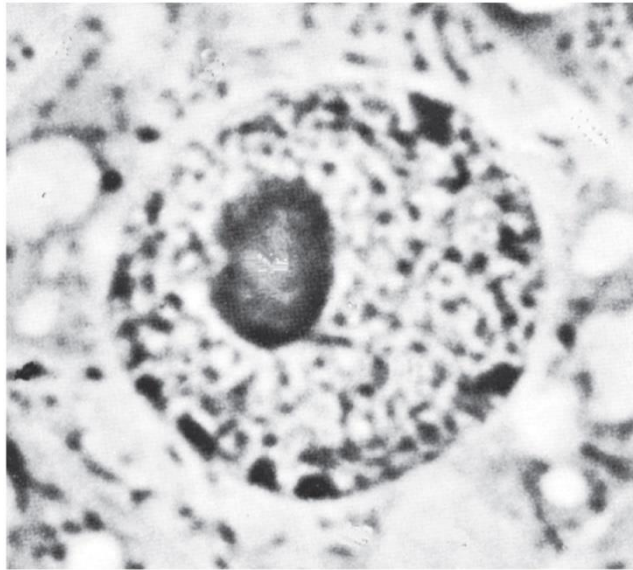


Figure 3.2

Basic Components of a Cell

- **Light microscope (LM)** revealed plasma membrane, nucleus, and cytoplasm (fluid between nucleus and surface)
- **Transmission electron microscope (TEM)** improved **resolution** (ability to reveal detail)
- **Scanning electron microscope (SEM)** improved resolution further, but only for surface features

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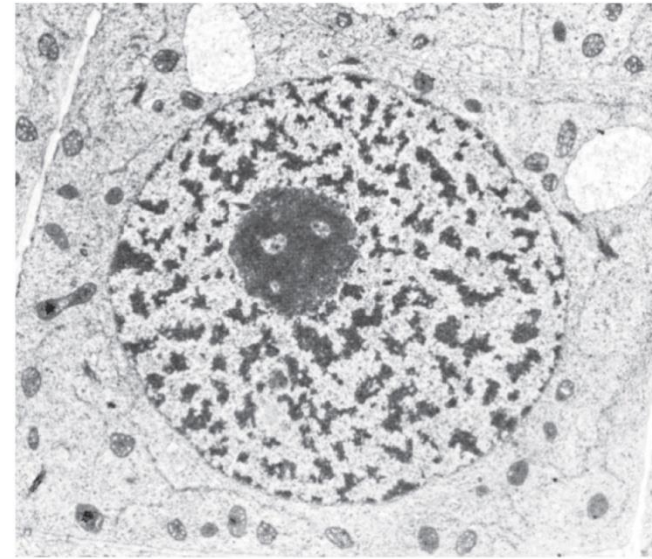


(a) Light microscope (LM)

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Figure 3.4a

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(b) Transmission electron microscope (TEM)

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Figure 3.4b

Basic Components of a Cell

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TABLE 3.1		Sizes of Biological Structures in Relation to the Resolution of the Eye, Light Microscope, and Transmission Electron Microscope
Object	Size	
Visible to the Naked Eye (Resolution 70–100 μm)		
Human egg, diameter	100 μm	
Visible with the Light Microscope (Resolution 200 nm)		
Most human cells, diameter	10–15 μm	
Cilia, length	7–10 μm	
Mitochondria, width × length	0.2 × 4 μm	
Bacteria (<i>Escherichia coli</i>), length	1–3 μm	
Microvilli, length	1–2 μm	
Lysosomes, diameter	0.5 μm = 500 nm	
Visible with the Transmission Electron Microscope (Resolution 0.5 nm)		
Nuclear pores, diameter	30–100 nm	
Centriole, diameter × length	20 × 50 nm	
Poliovirus, diameter	30 nm	
Ribosomes, diameter	15 nm	
Globular proteins, diameter	5–10 nm	
Plasma membrane, thickness	7.5 nm	
DNA molecule, diameter	2.0 nm	
Plasma membrane channels, diameter	0.8 nm	

Basic Components of a Cell

- **Plasma (cell) membrane**
 - Surrounds cell, defines boundaries
 - Made of proteins and lipids
- **Cytoplasm**
 - Organelles
 - Cytoskeleton
 - Inclusions (stored or foreign particles)
 - Cytosol (**intracellular fluid, ICF**)
- **Extracellular fluid (ECF)**
 - Fluid outside of cells
 - Includes tissue (interstitial) fluid

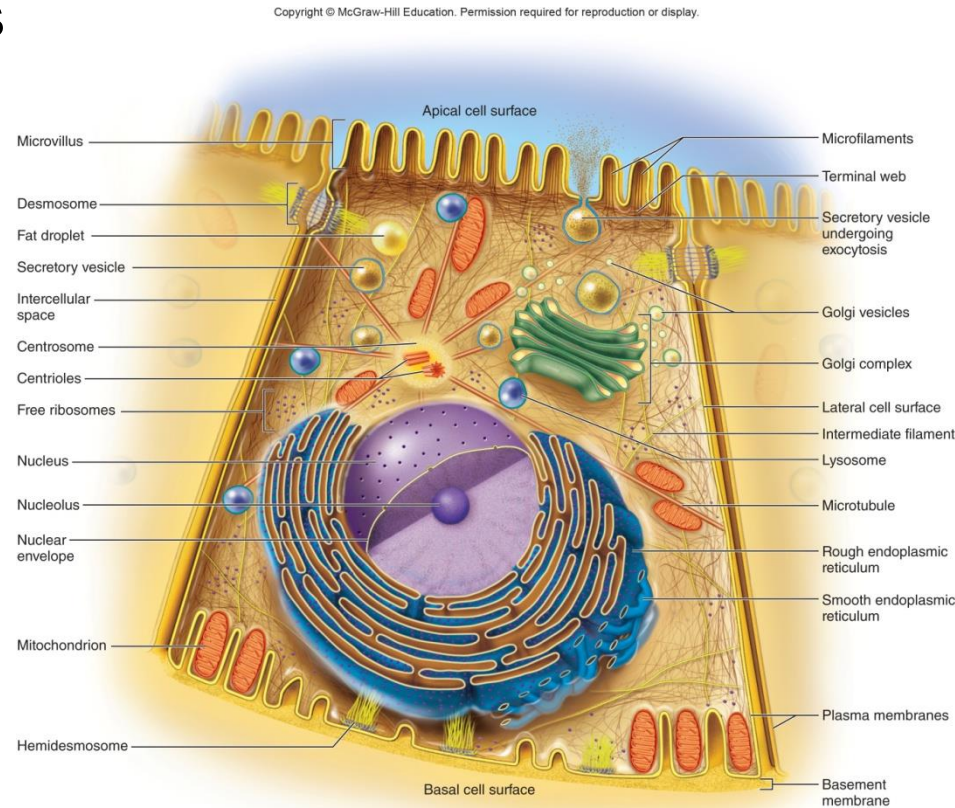


Figure 3.5

The Cell Surface

- **Expected Learning Outcomes**
 - Describe the structure of the plasma membrane.
 - Explain the functions of the lipid, protein, and carbohydrate components of the plasma membrane.
 - Describe a second-messenger system and discuss its importance in human physiology.
 - Describe the composition and functions of the glycocalyx that coats cell surfaces.
 - Describe the structure and functions of microvilli, cilia, and flagella.

The Plasma Membrane

- **Plasma membrane**—border of the cell
 - Appears as pair of dark parallel lines when viewed with electron microscope
 - Has intracellular and extracellular faces
 - Functions**
 - Defines cell boundaries
 - Governs interactions with other cells
 - Controls passage of materials in and out of cell

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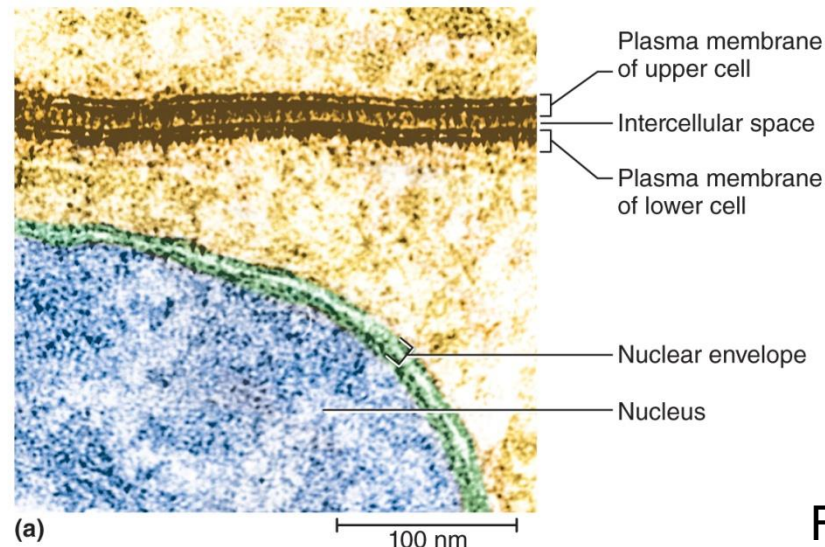
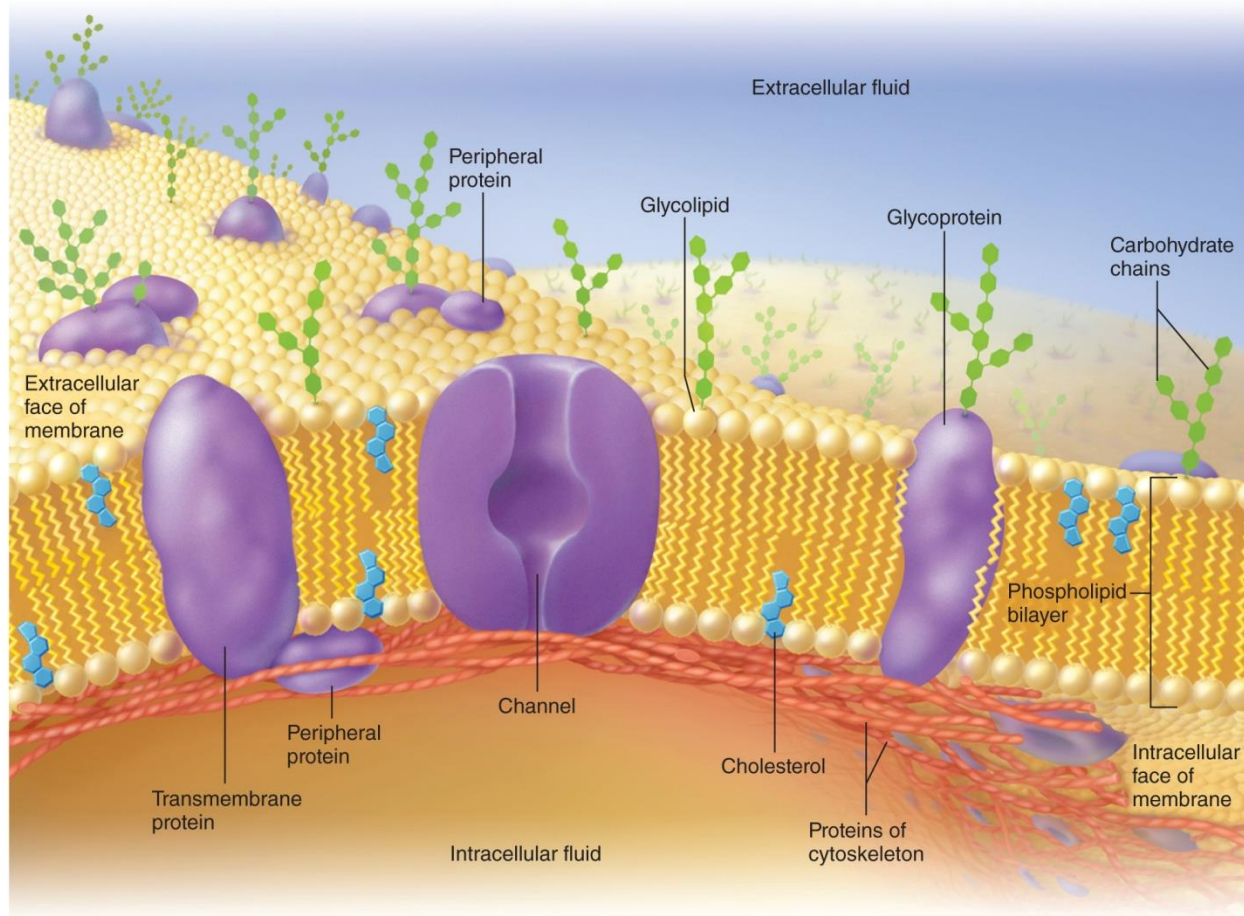


Figure 3.6a

a: © Don Fawcett/Science Source

The Plasma Membrane

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(b)

Figure 3.6b

Oily film of lipids with embedded proteins

Membrane Lipids

- **98% of membrane molecules are lipids**
- **Phospholipids**
 - 75% of membrane lipids are phospholipids
 - **Amphipatic** molecules arranged in a bilayer
 - **Hydrophilic** phosphate heads face water on each side of membrane
 - **Hydrophobic** tails—are directed toward the center, avoiding water
 - Drift laterally, keeping membrane fluid

Membrane Lipids

- **Cholesterol**
 - 20% of the membrane lipids
 - Holds phospholipids still and can stiffen membrane
- **Glycolipids**
 - 5% of the membrane lipids
 - Phospholipids with short carbohydrate chains on extracellular face
 - Contributes to **glycocalyx**—carbohydrate coating on cell surface

Membrane Proteins

- **Membrane proteins**
 - **2%** of the molecules but **50%** of the weight of membrane
- **Integral proteins—penetrate membrane**
 - **Transmembrane proteins** pass completely through
 - Hydrophilic regions contact cytoplasm, extracellular fluid
 - Hydrophobic regions pass through lipid of the membrane
 - Some drift in membrane; others are anchored to cytoskeleton

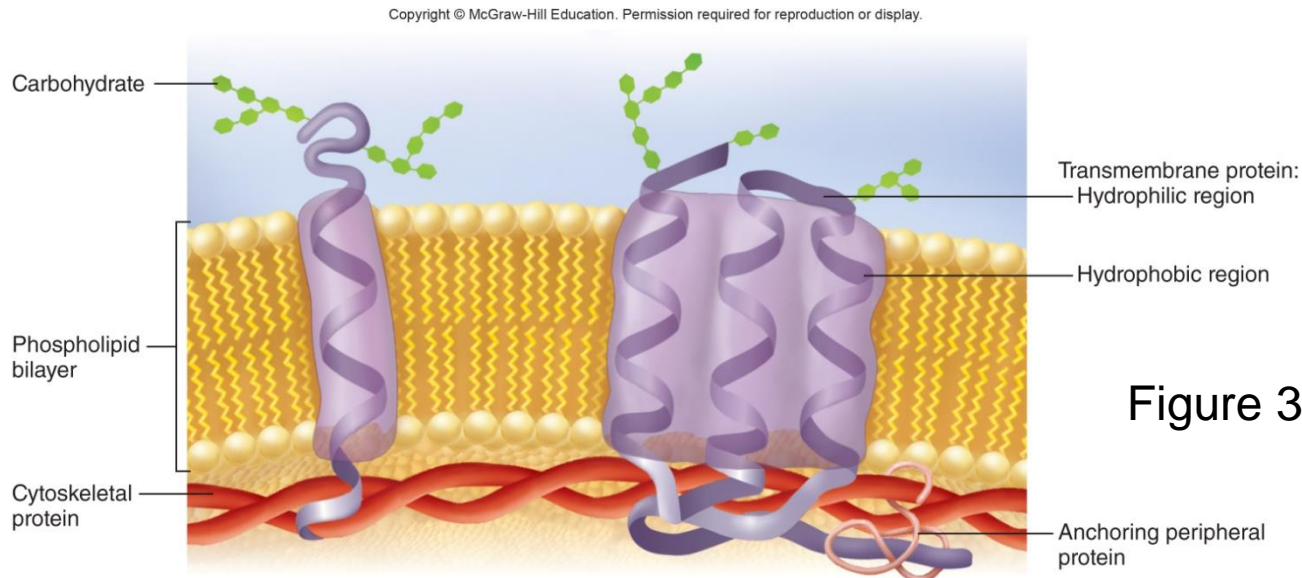


Figure 3.7

Membrane Proteins

- **Peripheral proteins**

- Adhere to one face of the membrane (do not penetrate it)
- Usually tethered to the cytoskeleton

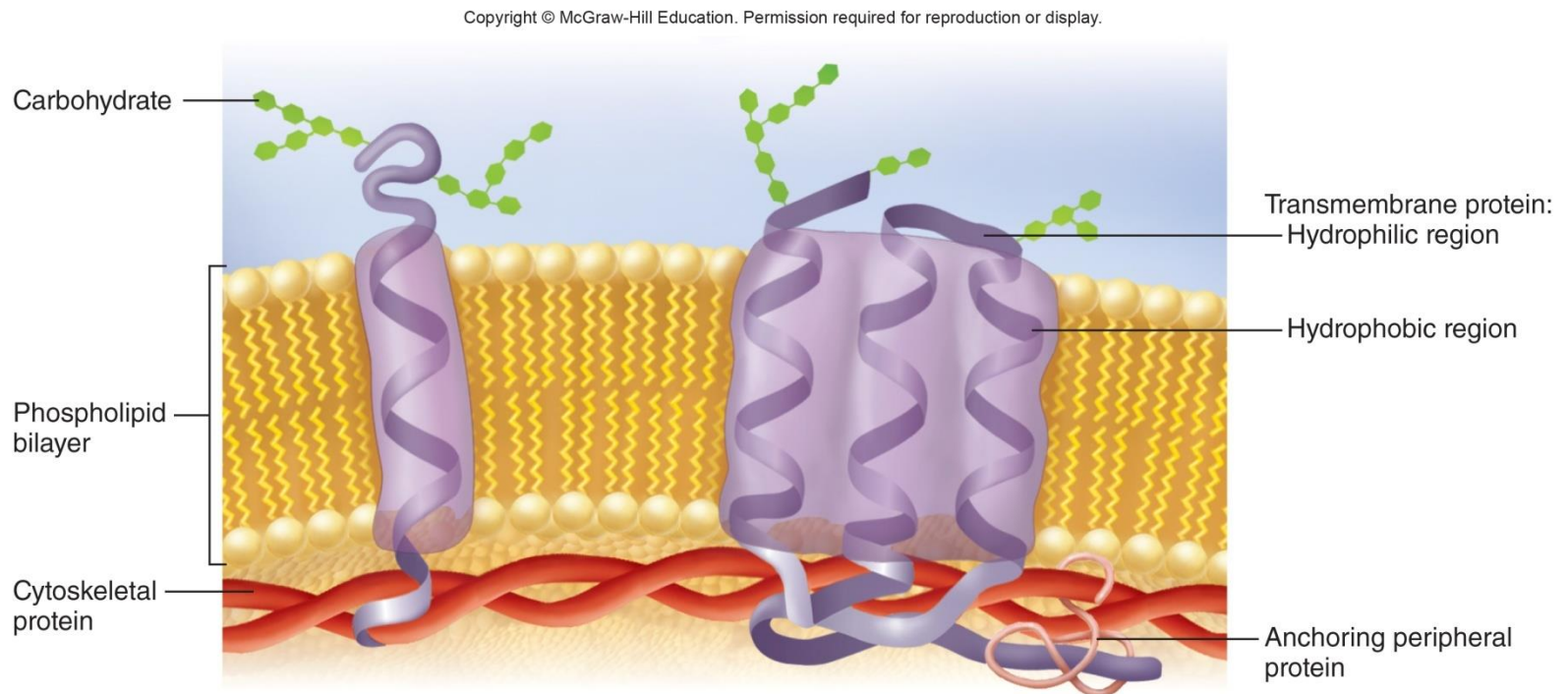


Figure 3.7

Membrane Proteins

- **Functions of membrane proteins include:**
 - Receptors, second-messenger systems, enzymes, channels, carriers, cell-identity markers, cell-adhesion molecules

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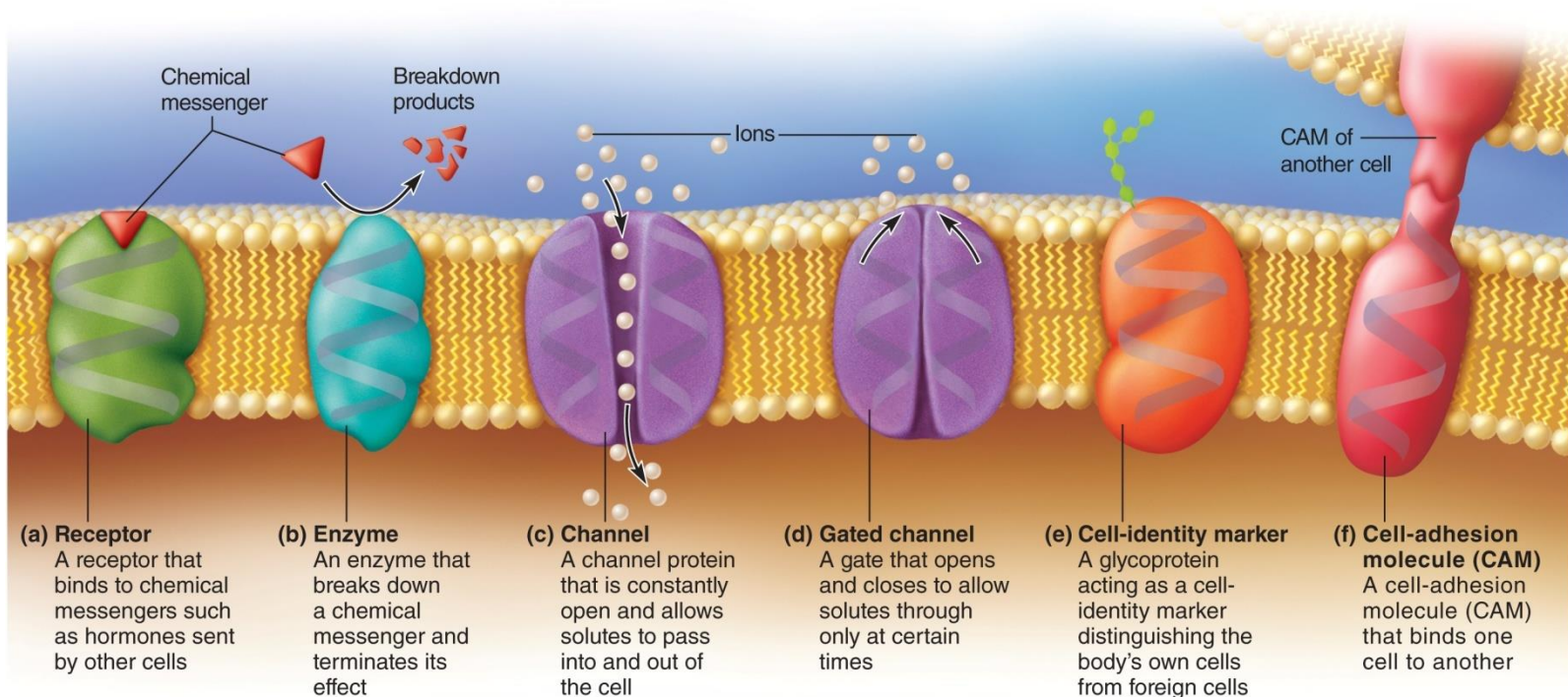


Figure 3.8

Membrane Proteins

- **Receptors**—bind chemical signals
- **Second messenger systems**—communicate within cell receiving chemical message
- **Enzymes**—catalyze reactions including digestion of molecules, production of second messengers
- **Channel proteins**—allow hydrophilic solutes and water to pass through membrane
 - Some are always open, some are gated
 - **Ligand-gated channels**—respond to chemical messengers
 - **Voltage-gated channels**—respond to charge changes
 - **Mechanically-gated channels**—respond to physical stress on cell
 - Crucial to nerve and muscle function

Membrane Proteins

- **Carriers**—bind solutes and transfer them across membrane
 - **Pumps**—carriers that consume ATP
- **Cell-identity markers**—glycoproteins acting as identification tags
- **Cell-adhesion molecules**—mechanically link cell to extracellular material

Second Messengers

- Chemical **first messenger** (epinephrine) binds to a surface receptor
- Receptor activates **G protein**
 - An intracellular peripheral protein that gets energy from guanosine triphosphate (**GTP**)
- G protein relays signal to **adenylate cyclase** which converts ATP to **cAMP** (second messenger)
- cAMP activates cytoplasmic **kinases**
- **Kinases add phosphate groups to other enzymes turning some on and others off**
- **Up to 60% of drugs work through G proteins and second messengers**

Second Messenger System

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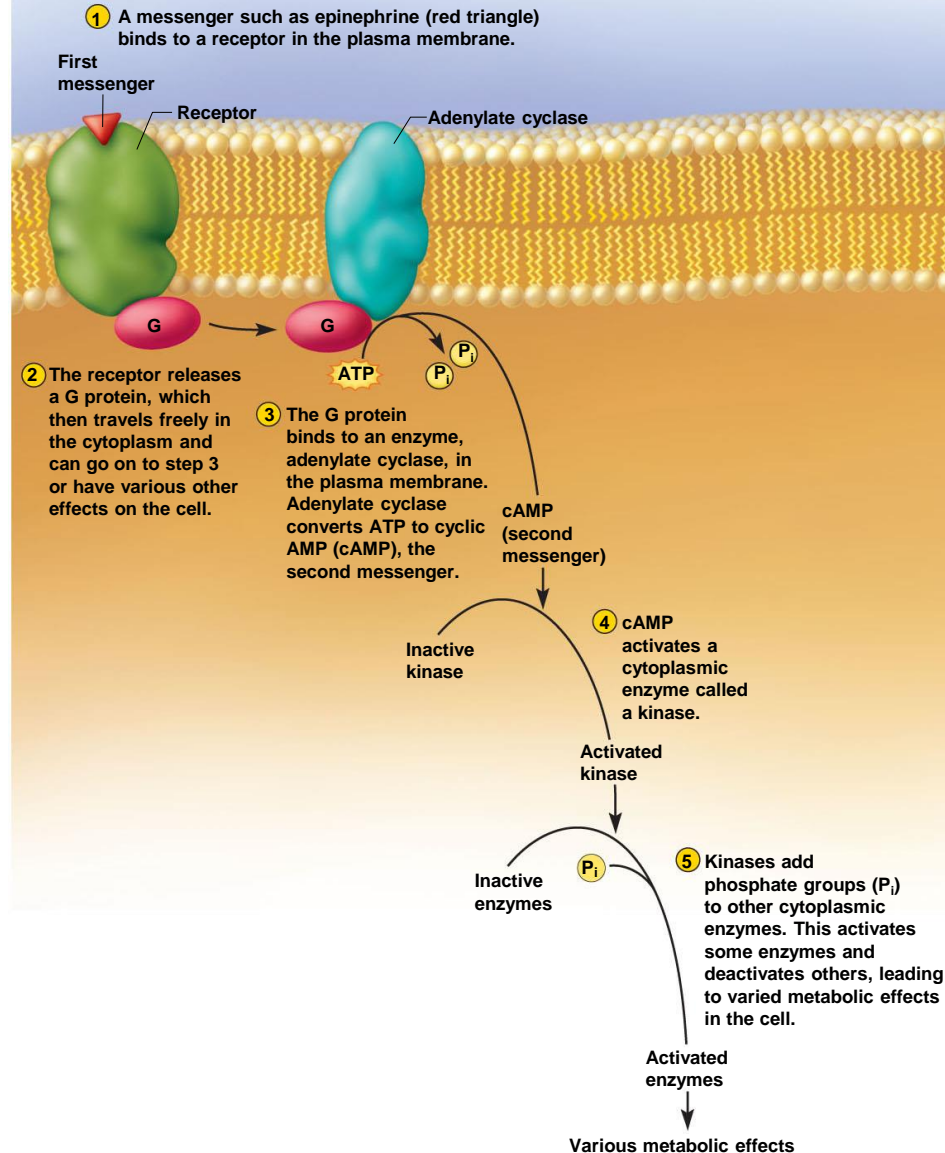


Figure 3.9

The Glycocalyx

- **Fuzzy coat external to plasma membrane**
 - Carbohydrate moieties of glycoproteins and glycolipids
 - Unique in everyone but identical twins
- **Functions**
 - Protection
 - Immunity to infection
 - Defense against cancer
 - Transplant compatibility
 - Cell adhesion
 - Fertilization
 - Embryonic development

Microvilli

- **Extensions of membrane (1–2 μm)**
 - Gives 15 to 40 times more surface area
 - Best developed in cells specialized in **absorption**
- On some absorptive cells they are very dense and appear as a fringe—“**brush border**”
 - Some microvilli contain actin filaments that are tugged toward center of cell to milk absorbed contents into cell

Microvilli

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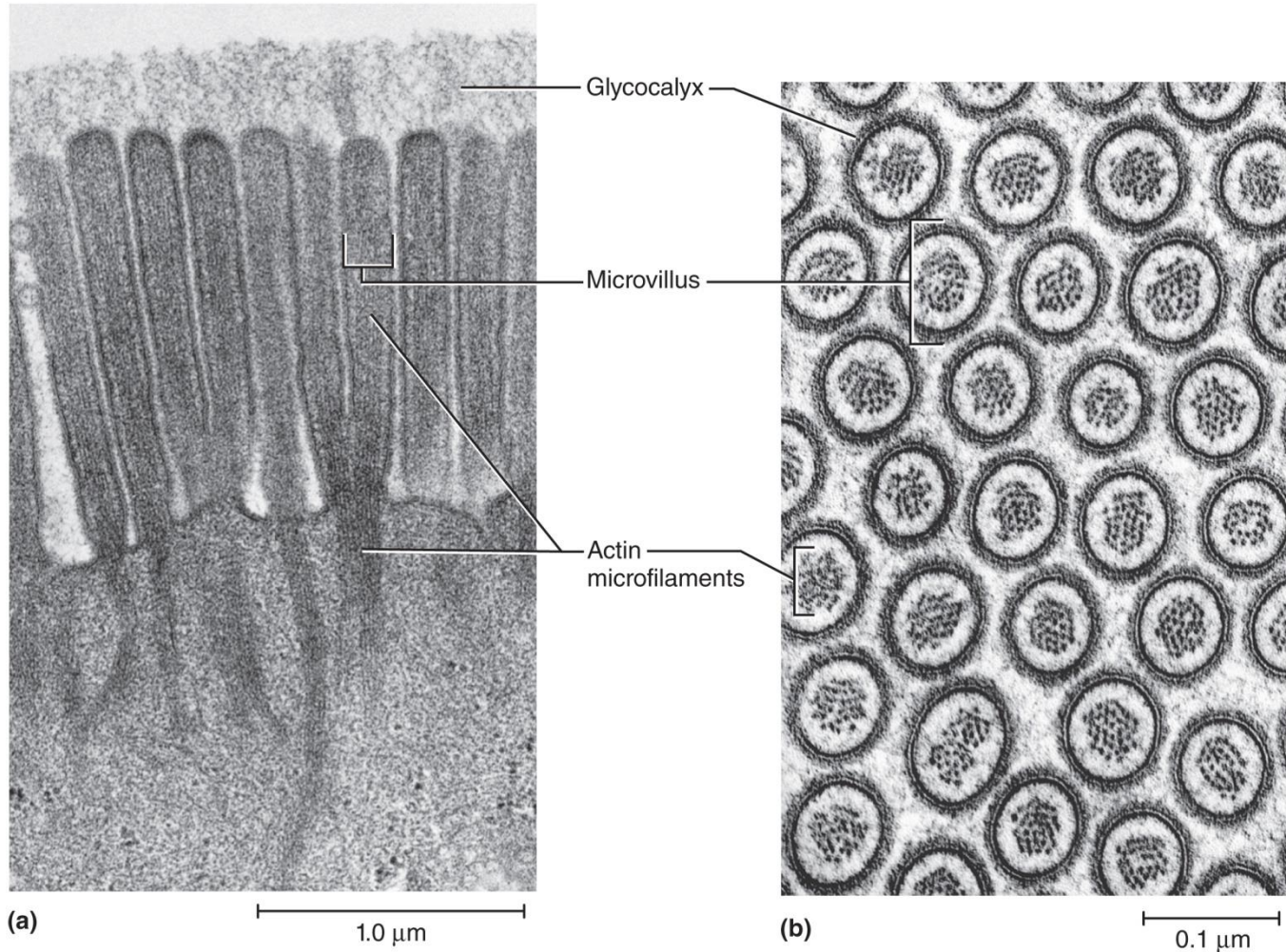


Figure 3.10a

Figure 3.10b

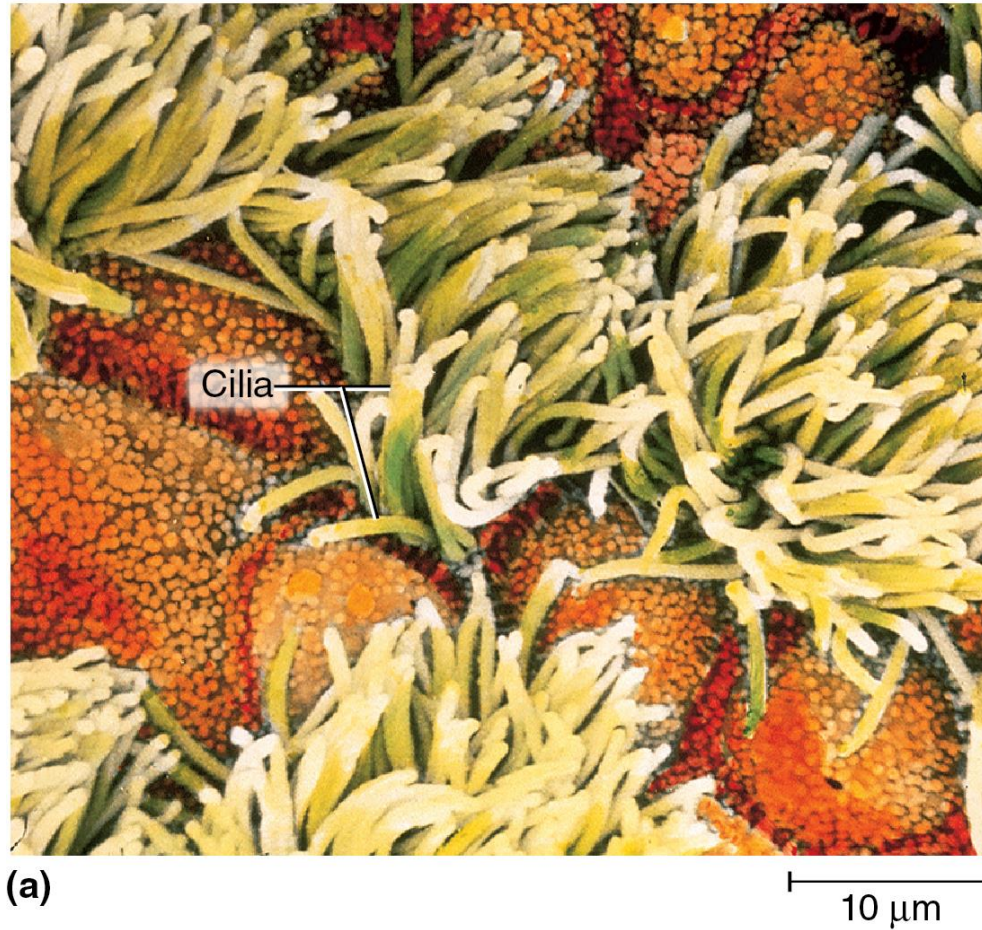
Actin microfilaments are centered in each microvilli 3-27

Cilia

- **Cilia**—hairlike processes 7–10 μm long
- Single, nonmotile **primary cilium** found on nearly every cell
 - “Antenna” for monitoring nearby conditions
 - Helps with balance in inner ear; light detection in retina
- **Multiple nonmotile cilia**
 - Found on sensory cells of nose
- **Ciliopathies—defects in structure and function of cilia**
- **Motile cilia**—respiratory tract, uterine tubes, ventricles of brain, ducts of testes
 - 50 to 200 on each cell
 - Beat in waves sweeping material across a surface in one direction
 - Power strokes followed by recovery strokes

Cilia

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Figure 3.11a
Cilia inside trachea

Cilia

- **Axoneme**—core of motile cilium
 - Has **9 + 2 structure** of **microtubules**
 - Two central microtubules surrounded by ring of nine pairs
 - Ring of nine pairs anchors cilium to cell as part of basal body
 - **Dynein arms** “crawl” up adjacent microtubule, bending the cilium
 - Uses energy from ATP

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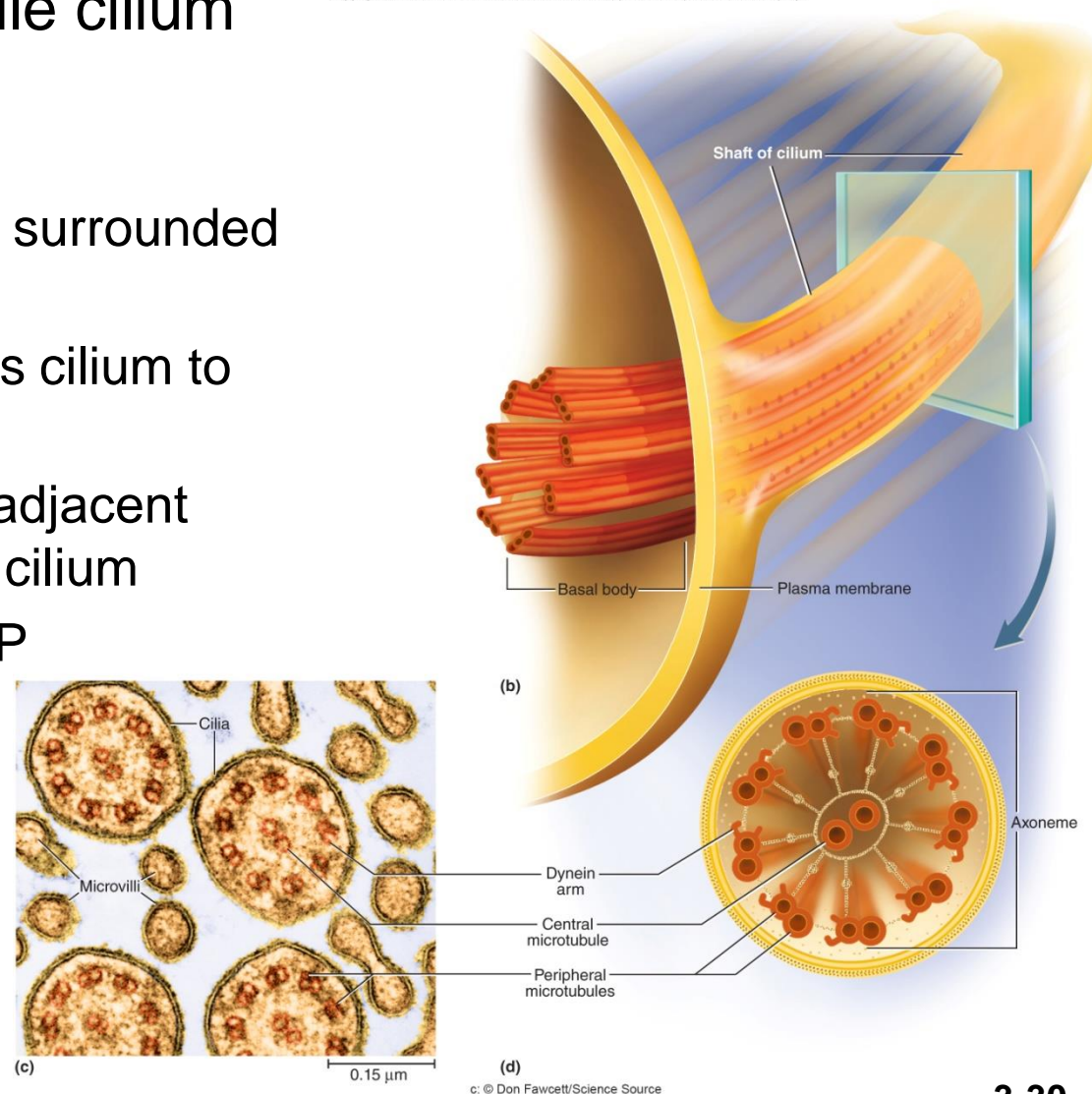
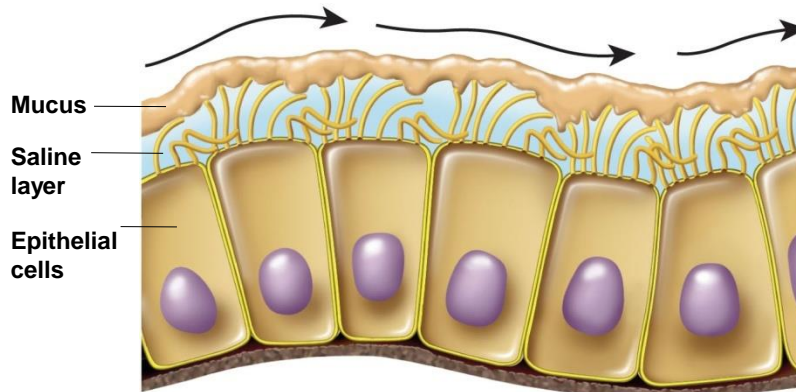


Figure 3.11 b,c, d

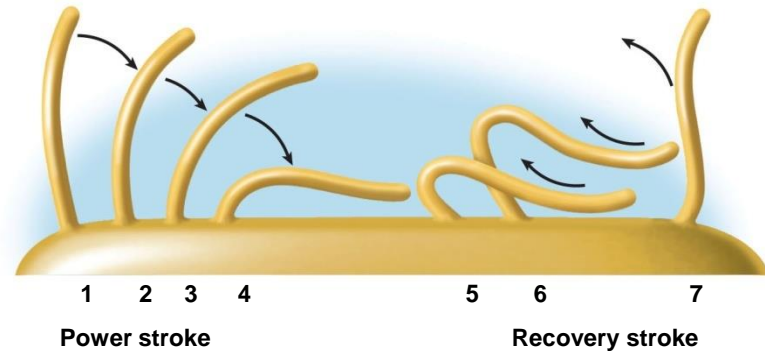
Cilia

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(a)

Figure 3.12



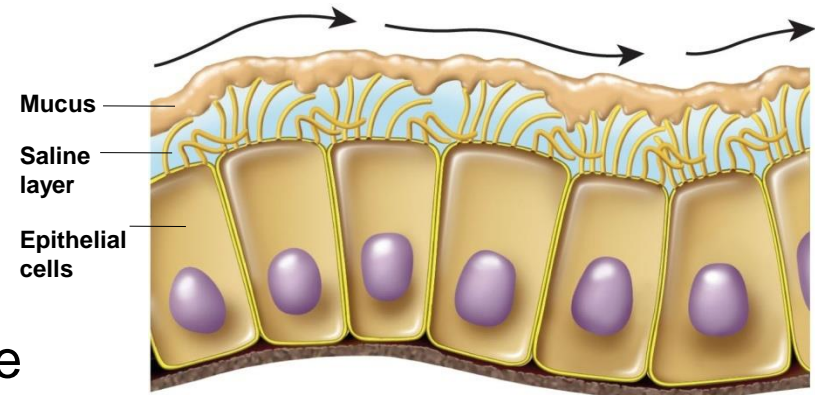
(b)

- **Cilia beat freely within a saline layer at cell surface**
 - Chloride pumps pump Cl^- into ECF
 - Na^+ and H_2O follow
- **Mucus floats on top of saline layer**

Cystic Fibrosis

- **Cystic fibrosis**—hereditary disease in which cells make chloride pumps, but fail to install them in the plasma membrane
 - Chloride pumps fail to create adequate saline layer on cell surface
- **Thick mucus plugs pancreatic ducts and respiratory tract**
 - Inadequate digestion of nutrients and absorption of oxygen
 - Chronic respiratory infections
 - Life expectancy of 30

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(a)

Figure 3.12a

Flagella

- **Tail of a sperm—only functional flagellum in humans**
- **Whip-like structure with axoneme identical to cilium's**
 - Much longer than cilium
 - Stiffened by coarse fibers that support the tail
- **Movement is undulating, snake-like, corkscrew**
 - No power stroke and recovery strokes

Pseudopods

- **Pseudopods**—continually changing extensions of the cell that vary in shape and size
 - Can be used for cellular locomotion, capturing foreign particles

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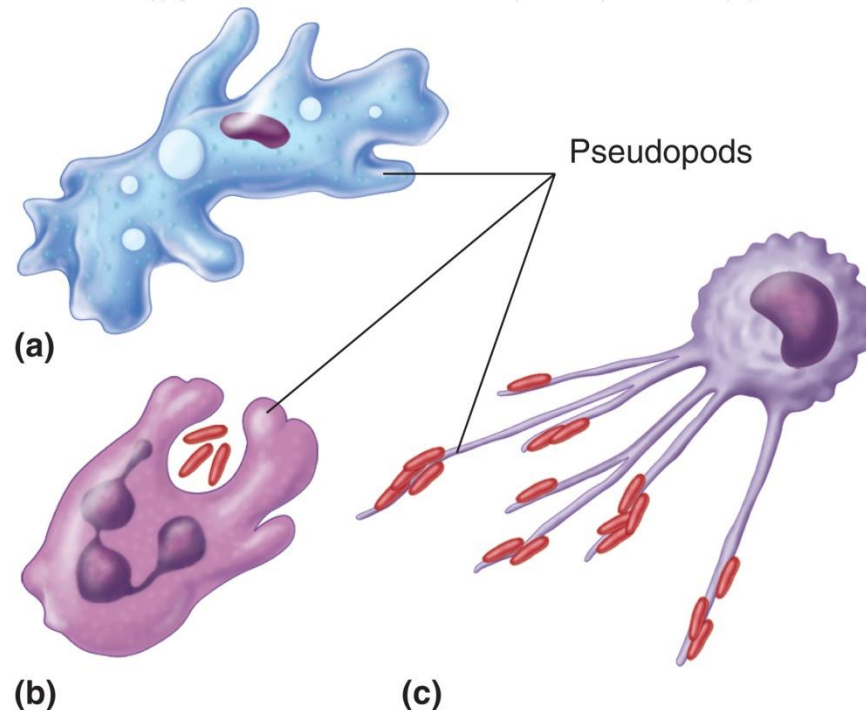


Figure 3.13

Membrane Transport

- **Expected Learning Outcomes**
 - Explain what is meant by a selectively permeable membrane.
 - Describe various mechanisms for transporting material through the plasma membrane.
 - Define *osmolarity* and *tonicity* and explain their importance.

Membrane Transport

- Plasma membrane is **selectively permeable**—allowing some things through, but preventing others from passing
- **Passive mechanisms** require no ATP
 - Random molecular motion of particles provides necessary energy
 - Filtration, diffusion, osmosis
- **Active mechanisms** consume ATP
 - Active transport and vesicular transport
- **Carrier-mediated mechanisms** use a membrane protein to transport substances across membrane

Filtration

- **Filtration**—particles are driven through membrane by **physical pressure**
- **Examples**
 - Filtration of water and small solutes through gaps in capillary walls
 - Allows delivery of water and nutrients to tissues
 - Allows removal of waste from capillaries in kidneys

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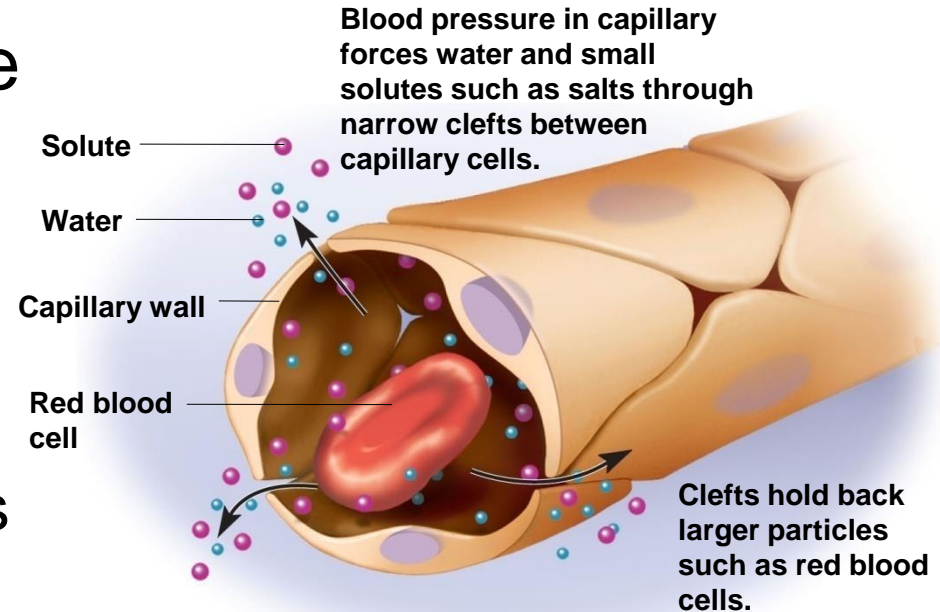


Figure 3.14

Simple Diffusion

- **Simple diffusion**—net movement of particles from place of high concentration to place of lower concentration
 - Due to constant, spontaneous molecular motion
 - Molecules collide and bounce off each other
- Substances diffuse down their **concentration gradient**
 - Does not require a membrane
 - Substance can diffuse through a membrane if the membrane is permeable to the substance

Simple Diffusion

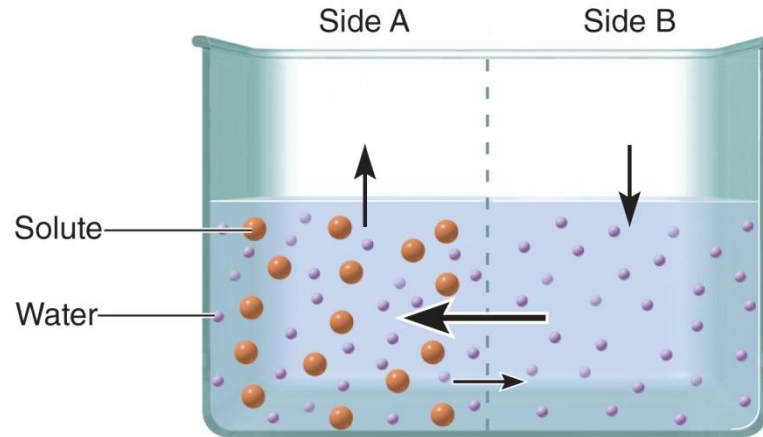
- **Factors affecting diffusion rate through a membrane**
 - **Temperature:** ↑ temp., ↑ motion of particles
 - **Molecular weight:** larger molecules move slower
 - **Steepness of concentrated gradient:** ↑ difference, ↑ rate
 - **Membrane surface area:** ↑ area, ↑ rate
 - **Membrane permeability:** ↑ permeability, ↑ rate

Osmosis

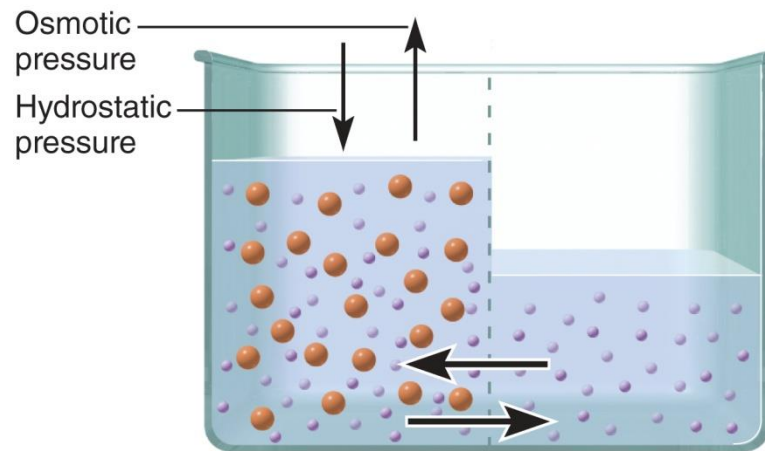
- **Osmosis**—net flow of water through a selectively permeable membrane
 - Water moves from the side where it (water) is more concentrated to the side where it is less concentrated
 - Solute particles that cannot pass through the membrane “draw” water from the other side
- **Crucial consideration for I.V. fluids**
- **Osmotic imbalances underlie diarrhea, constipation, edema**
- Water can diffuse through phospholipid bilayers, but osmosis is enhanced by **aquaporins**—channel proteins in membrane specialized for water passage
 - Cells can speed osmosis by installing more aquaporins

Osmosis

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(a) Start



(b) 30 minutes later

Figure 3.15

Osmosis

- **Osmotic pressure**—
hydrostatic pressure
required to stop osmosis
 - Increases as amount of
nonpermeating solute rises
- **Reverse osmosis**—
process of applying
mechanical pressure to
override osmotic pressure
 - Allows purification of water

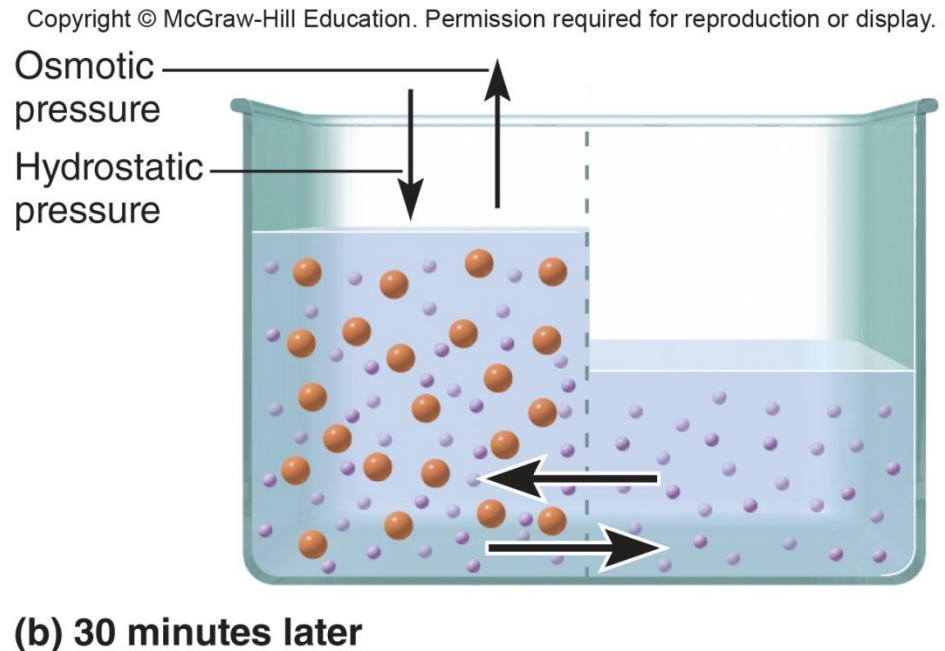


Figure 3.15b

Osmolarity and Tonicity

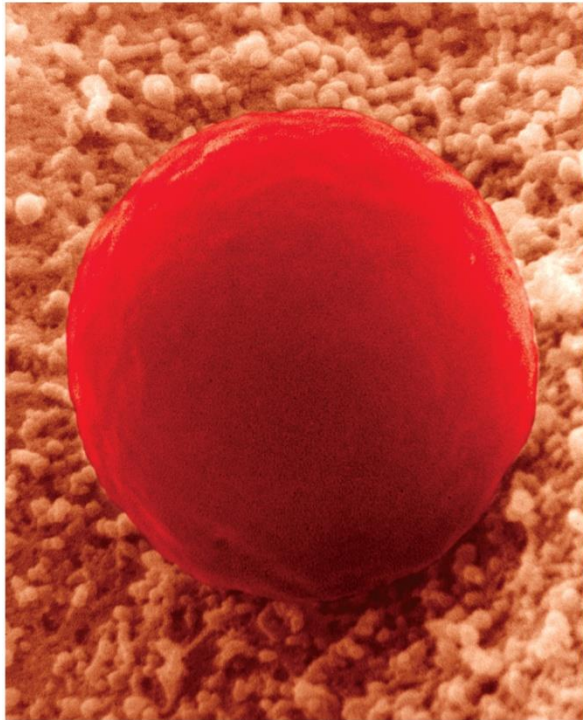
- **One osmole (osm)** = 1 mole of dissolved particles
 - Takes into account whether solute ionizes in water
 - 1 M glucose is 1 osm/L
 - 1 M NaCl is 2 osm/L
- **Osmolarity**—number of osmoles per liter of solution
 - Body fluids contain a mix of many chemicals, and osmolarity is the total osmotic concentration of all solutes
 - Blood plasma, tissue fluid, and intracellular fluid are 300 milliosmoles per liter (mOsm/L)
 - Osmolality is number of osm per kg of water
 - In physiology osmolality and osmolarity are nearly the same

Osmolarity and Tonicity

- **Tonicity**—ability of a surrounding solution (bath) to affect fluid volume and pressure in a cell
 - Depends on concentration of nonpermeating solutes
- **Hypotonic solution**—causes cell to absorb water and swell
 - Has a lower concentration of nonpermeating solutes than intracellular fluid (ICF)
 - Distilled water is an extreme example
- **Hypertonic solution**—causes cell to lose water and shrivel (crenate)
 - Has a higher concentration of nonpermeating solutes than ICF
- **Isotonic solution**—causes no change in cell volume
 - Concentrations of nonpermeating solutes in bath and ICF are the same
 - Normal saline (0.9% NaCl) is an example

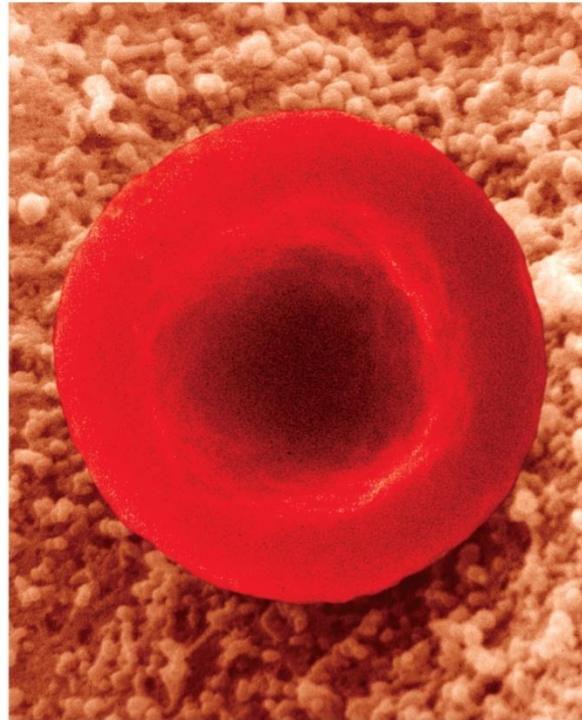
Effects of Tonicity on RBCs

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(a) Hypotonic

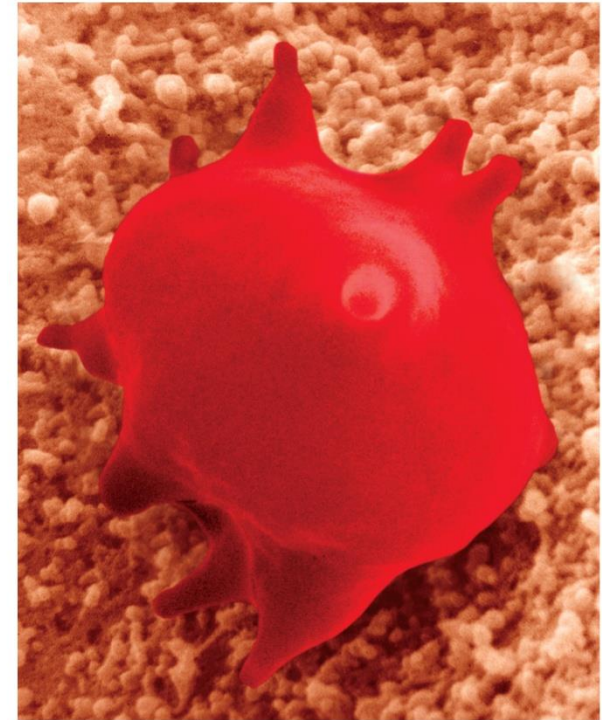
Figure 3.16a



(b) Isotonic

a–c: ©Dr. David M. Phillips/Visuals Unlimited

Figure 3.16b



(c) Hypertonic

Figure 3.16c

Hypotonic, isotonic, and hypertonic solutions affect the fluid volume of a red blood cell. Notice the crenated and swollen cells.

Carrier-Mediated Transport

- **Transport proteins** in membrane carry solutes into or out of cell (or organelle)
- **Specificity**
 - Transport proteins are specific for particular solutes
 - Solute (**ligand**) binds to receptor site on carrier protein
 - Solute is released unchanged on other side of membrane
- **Saturation**
 - As solute concentration rises, the rate of transport rises, but only to a point—**transport maximum (T_m)**

Carrier-Mediated Transport

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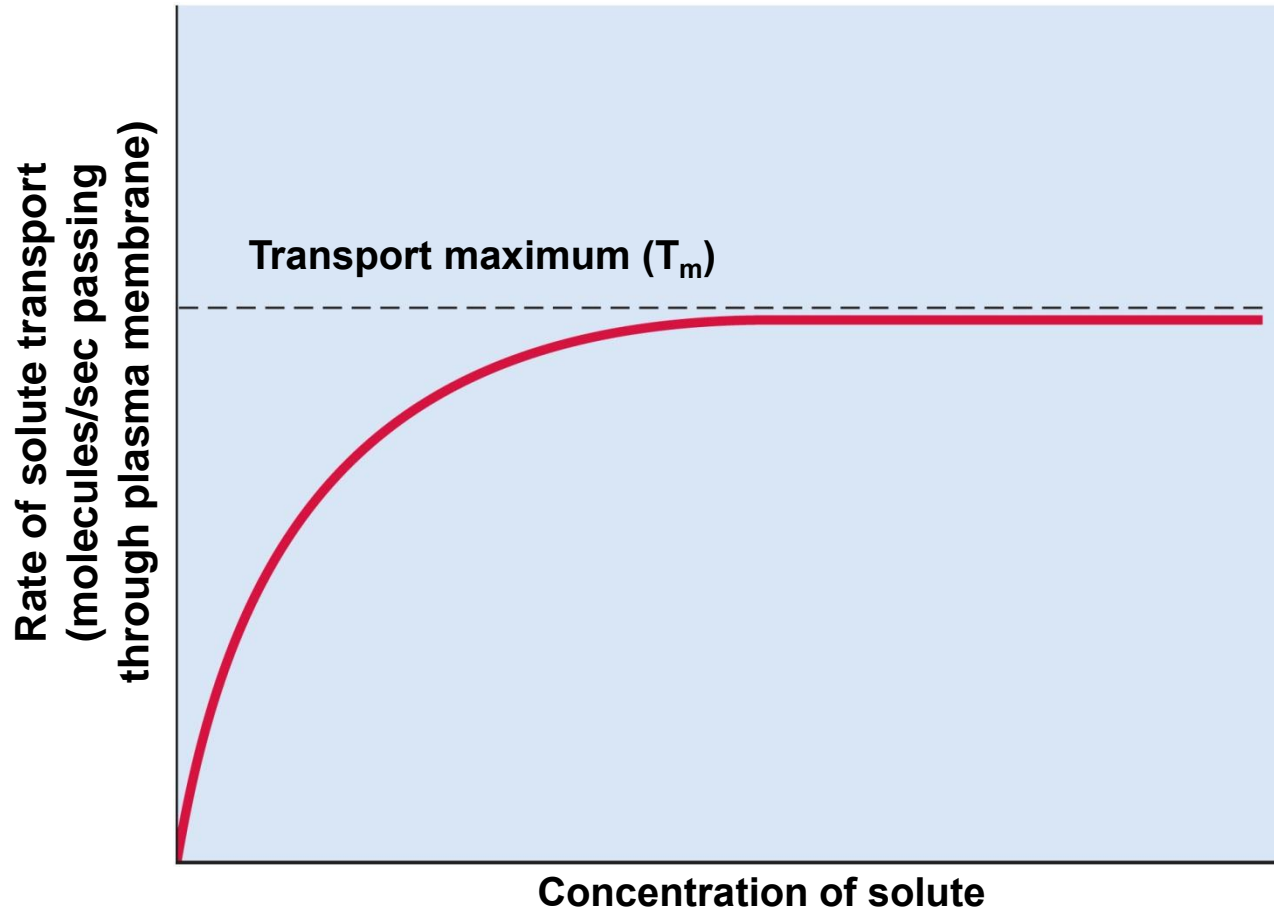


Figure 3.17

- **Transport maximum**—transport rate at which all carriers are occupied

Carrier-Mediated Transport

- **Three kinds of carriers**
 - **Uniport**—carries one type of solute
 - Example: Calcium pump
 - **Symport**—carries two or more solutes simultaneously in same direction (**cotransport**)
 - Example: sodium-glucose transporters
 - **Antiport**—Carries two or more solutes in opposite directions (**countertransport**)
 - Example: sodium-potassium pump removes Na^+ , brings in K^+
- **Three mechanisms of carrier-mediated transport**
 - Facilitated diffusion, primary active transport, secondary active transport

Carrier-Mediated Transport

- **Facilitated diffusion**—carrier moves solute down its concentration gradient
- **Does not consume ATP**
- **Solute attaches to binding site on carrier, carrier changes conformation, then releases solute on other side of membrane**

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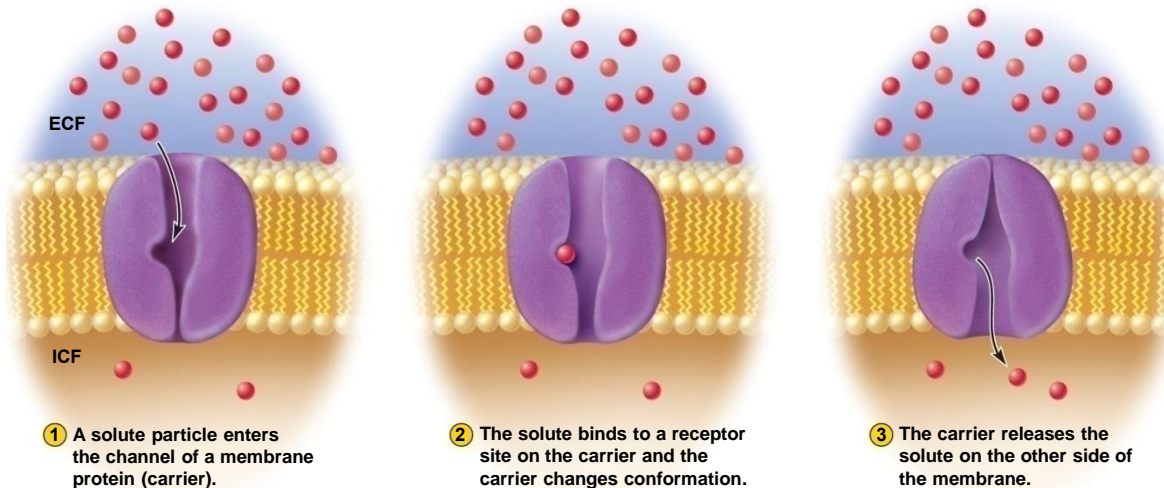


Figure 3.18

Carrier-Mediated Transport

- **Primary active transport**—carrier moves solute through a membrane up its concentration gradient
- **The carrier protein uses ATP for energy**
- **Examples:**
 - **Calcium pump** (uniport) uses ATP while expelling calcium from cell to where it is already more concentrated
 - **Sodium–potassium pump** (antiport) uses ATP while expelling sodium and importing potassium into cell

Carrier-Mediated Transport

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- The sodium-potassium pump ($\text{Na}^+ - \text{K}^+$ pump)
- Each pump cycle consumes one ATP and exchanges three Na^+ for two K^+
- Keeps K^+ concentration higher and Na^+ concentration lower within the cell than in ECF
- Necessary because Na^+ and K^+ constantly leak through membrane
 - Half of daily calories utilized for $\text{Na}^+ - \text{K}^+$ pump

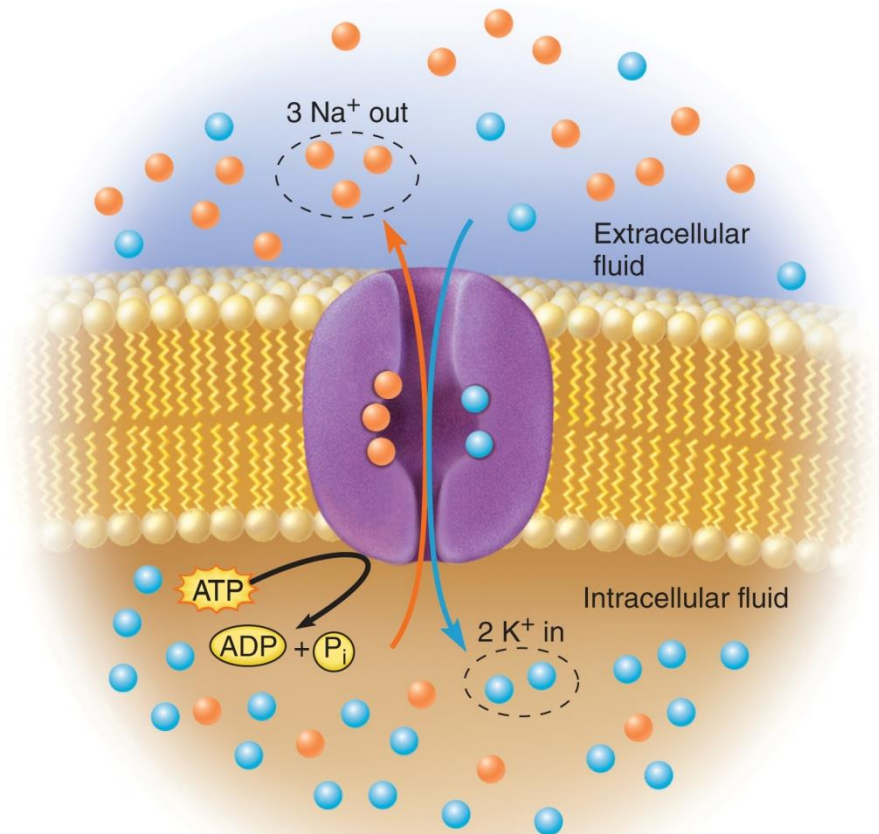


Figure 3.20

Carrier-Mediated Transport

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- **Na⁺–K⁺ pump functions**
 - Maintains steep Na⁺ concentration gradient allowing for **secondary active transport**
 - Regulates solute concentration and thus osmosis and thus **cell volume**
 - Maintains negatively charged resting **membrane potential**
 - **Produces heat**

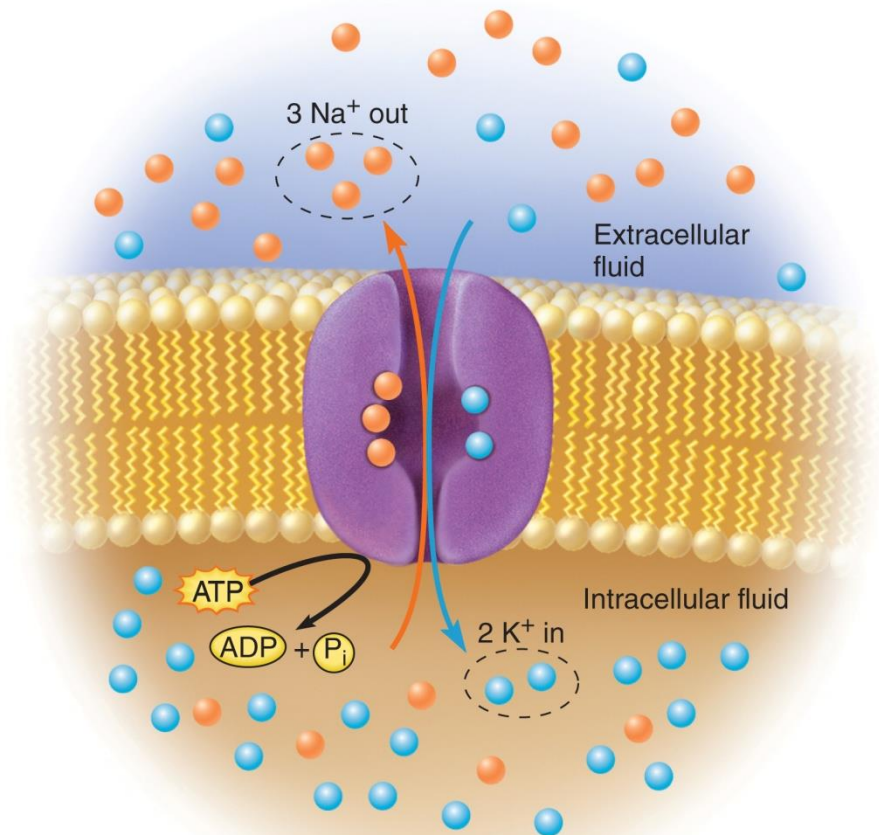


Figure 3.20

Carrier-Mediated Transport

- **Secondary active transport**
 - Carrier moves solute through membrane but only uses ATP indirectly
 - Example: **sodium-glucose transporter (SGLT)** (symport)
 - Moves glucose into cell while simultaneously carrying sodium down its gradient
 - Depends on the primary transport performed by $\text{Na}^+\text{-K}^+$ pump
 - Does not itself use ATP

Carrier-Mediated Transport

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- **SGLTs** work in kidney cells that have **$\text{Na}^+ - \text{K}^+$ pump** at other end of cell
 - Prevents loss of glucose to urine

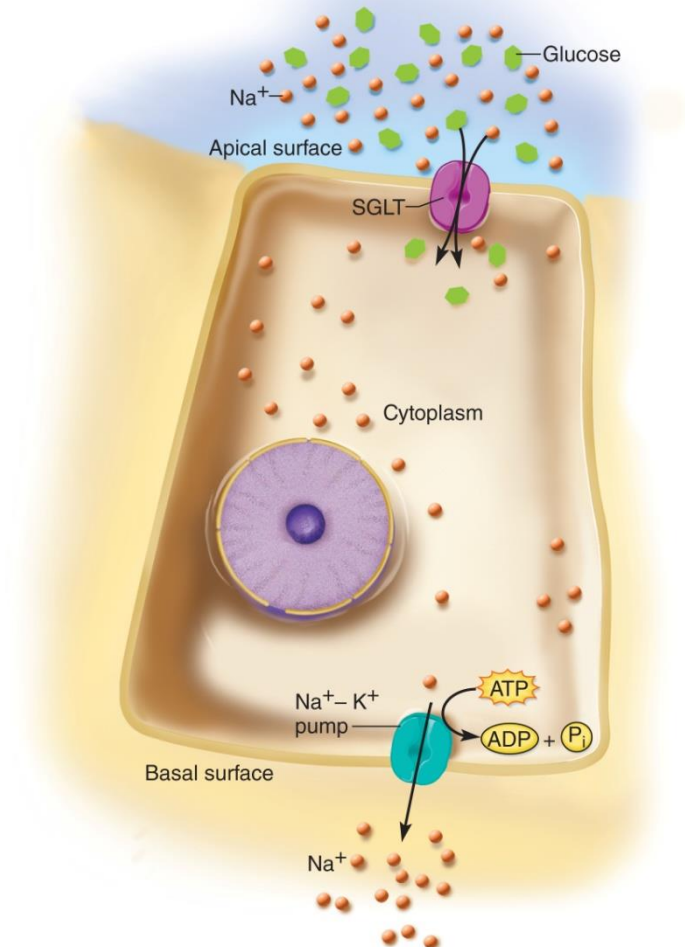


Figure 3.19

Vesicular Transport

- **Vesicular transport**—moves large particles, fluid droplets, or numerous molecules at once through the membrane in **vesicles**—bubble-like enclosures of membrane
- **Endocytosis**—vesicular processes that bring material into cell
 - **Phagocytosis**—“cell eating,” engulfing large particles
 - Pseudopods; phagosomes; macrophages
 - **Pinocytosis**—“cell drinking,” taking in droplets of ECF containing molecules useful in the cell
 - Membrane caves in, then pinches off pinocytic vesicle
 - **Receptor-mediated endocytosis**—particles bind to specific receptors on plasma membrane
 - Clathrin-coated vesicle
- **Exocytosis**—discharging material from the cell
- **Utilizes motor proteins energized by ATP**

Vesicular Transport

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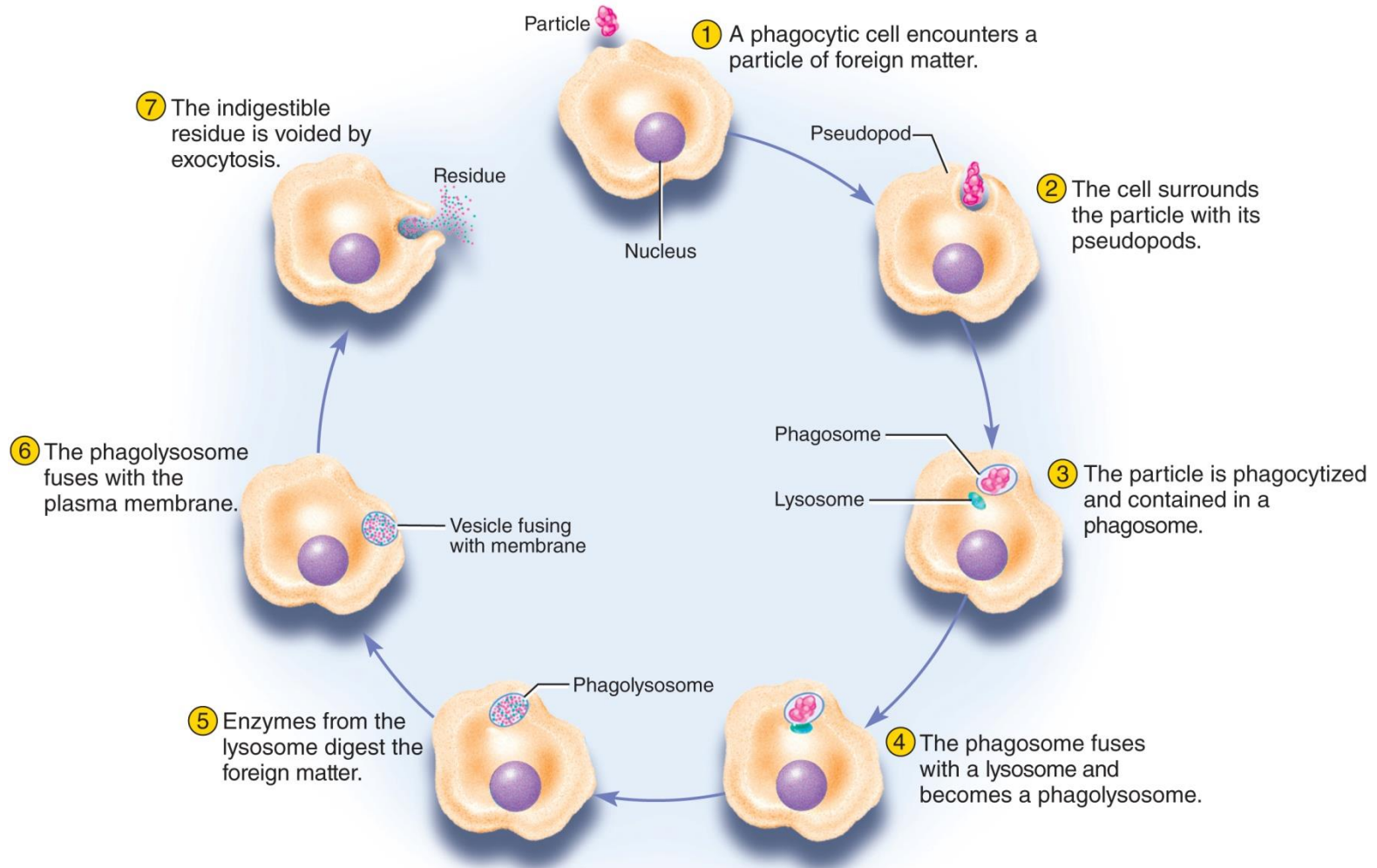


Figure 3.21

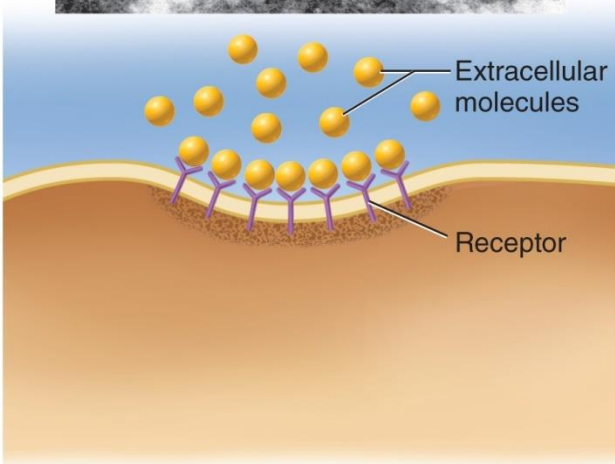
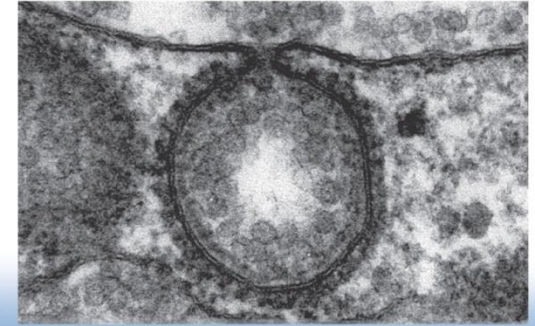
Phagocytosis keeps tissues free of debris and infectious microbes

Vesicular Transport

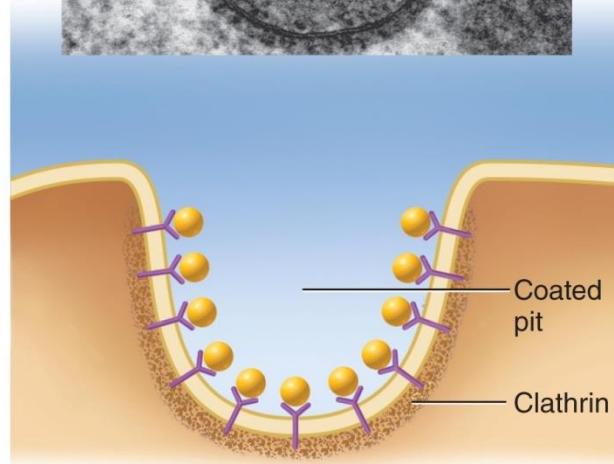
- **Receptor-mediated endocytosis**
 - More selective endocytosis
 - Enables cells to take in specific molecules that bind to extracellular receptors
- **Clathrin-coated vesicle in cytoplasm**
 - Uptake of LDL from bloodstream

Vesicular Transport

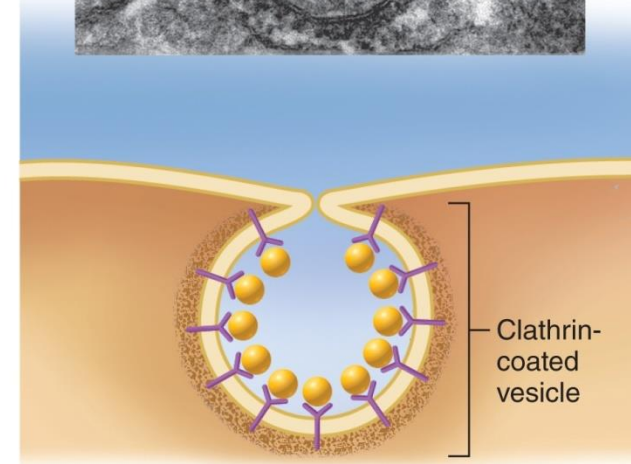
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- ① Extracellular molecules bind to receptors on plasma membrane; receptors cluster together.



- ② Plasma membrane sinks inward, forms clathrin-coated pit.



- ③ Pit separates from plasma membrane, forms clathrin-coated vesicle containing concentrated molecules from ECF.

(all): Company of Biologists, Ltd.

Figure 3.22

Receptor-mediated endocytosis

Vesicular Transport

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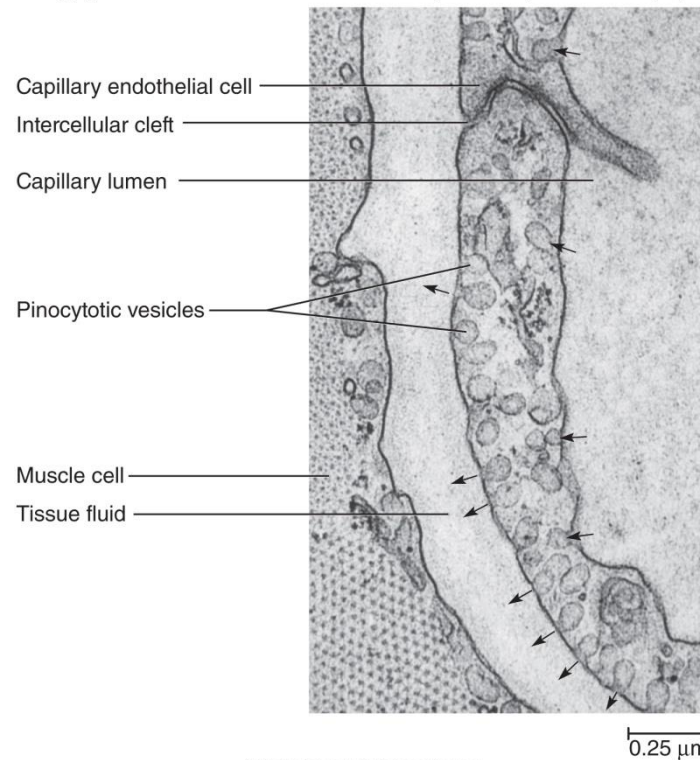


Figure 3.23

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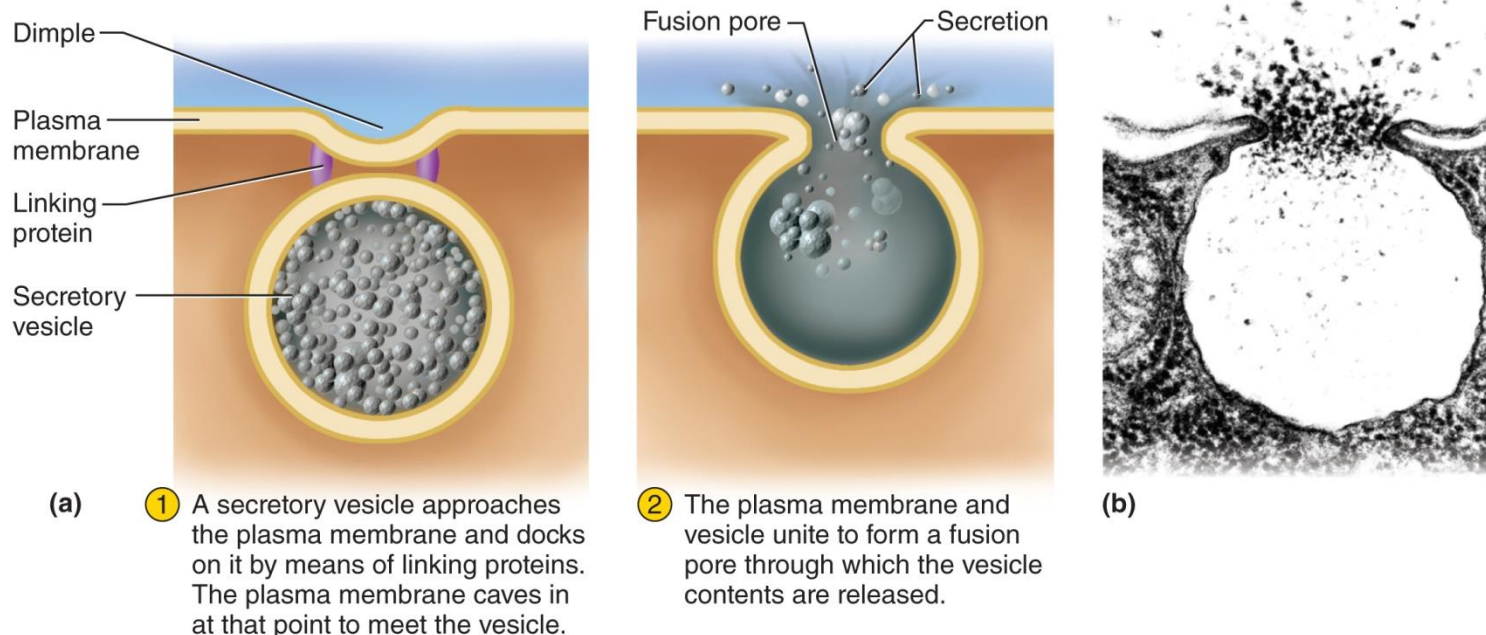
- **Transcytosis**—transport of material across the cell by capturing it on one side and releasing it on the other
- **Receptor-mediated endocytosis** moves it into the cell and **exocytosis** moves it out the other side

Vesicular Transport

- **Exocytosis**

- Secreting material
- Replacement of plasma membrane removed by endocytosis

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b: Courtesy of Dr. Birgit Satir, Albert Einstein College of Medicine

Figure 3.24 a,b

The Cell Interior

- **Expected Learning Outcomes**
 - List the main organelles of a cell, describe their structure, and explain their functions.
 - Describe the cytoskeleton and its functions.
 - Give some examples of cell inclusions and explain how inclusions differ from organelles.

The Cytoskeleton

- **Cytoskeleton**—network of protein filaments and cylinders
 - Determines cell shape, supports structure, organizes cell contents, directs movement of materials within cell, contributes to movements of the cell as a whole
- **Composed of: microfilaments, intermediate fibers, microtubules**

The Cytoskeleton

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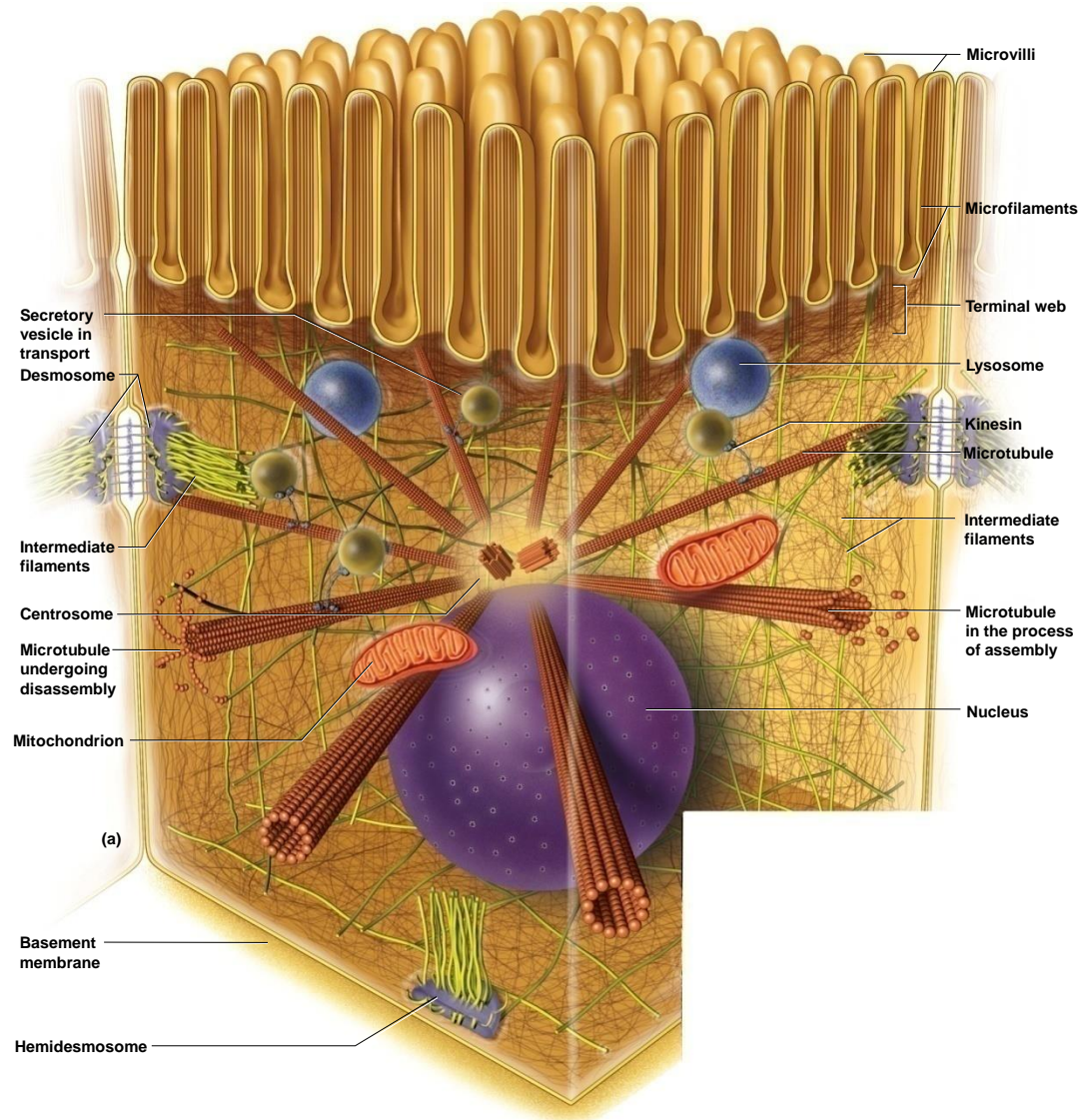


Figure 3.25a

The Cytoskeleton

- **Microfilaments**

- 6 nm thick
- Made of actin protein
- Forms terminal web

- **Intermediate filaments**

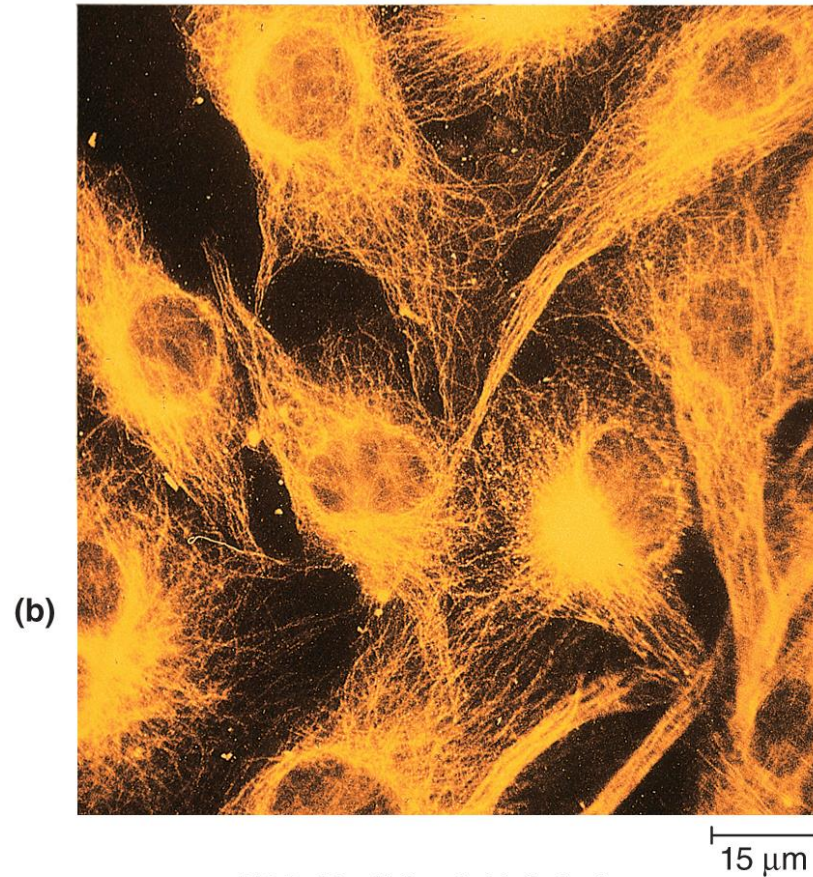
- 8–10 nm thick
- Within skin cells, made of protein keratin
- Give cell shape, resist stress

- **Microtubules**

- 25 nm thick
- Consist of protofilaments made of protein tubulin
- Radiate from centrosome; can come and go
- Maintain cell shape, hold organelles, act as railroad tracks for walking motor proteins, make axonemes of cilia and flagella, form mitotic spindle

EM and Fluorescent Antibodies Demonstrate Cytoskeleton

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Figure 3.25b

Microtubules

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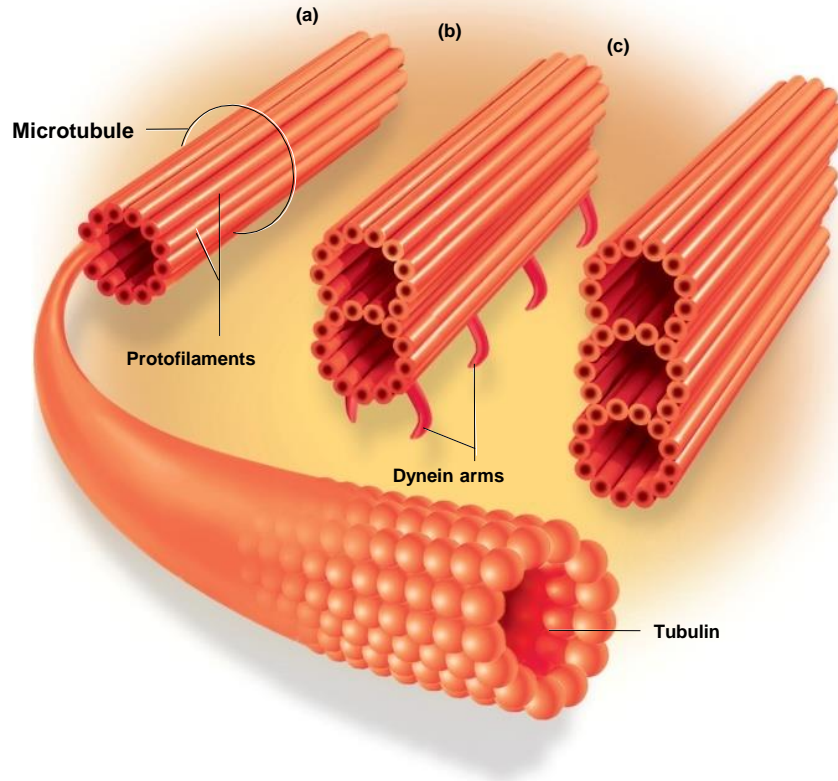


Figure 3.26

Organelles

- **Internal structures** of a cell, carry out specialized metabolic tasks
- **Membranous organelles**
 - Nucleus, mitochondria, lysosomes, peroxisomes, endoplasmic reticulum, and Golgi complex
- **Nonmembranous organelles**
 - Ribosomes, centrosomes, centrioles, basal bodies

The Nucleus

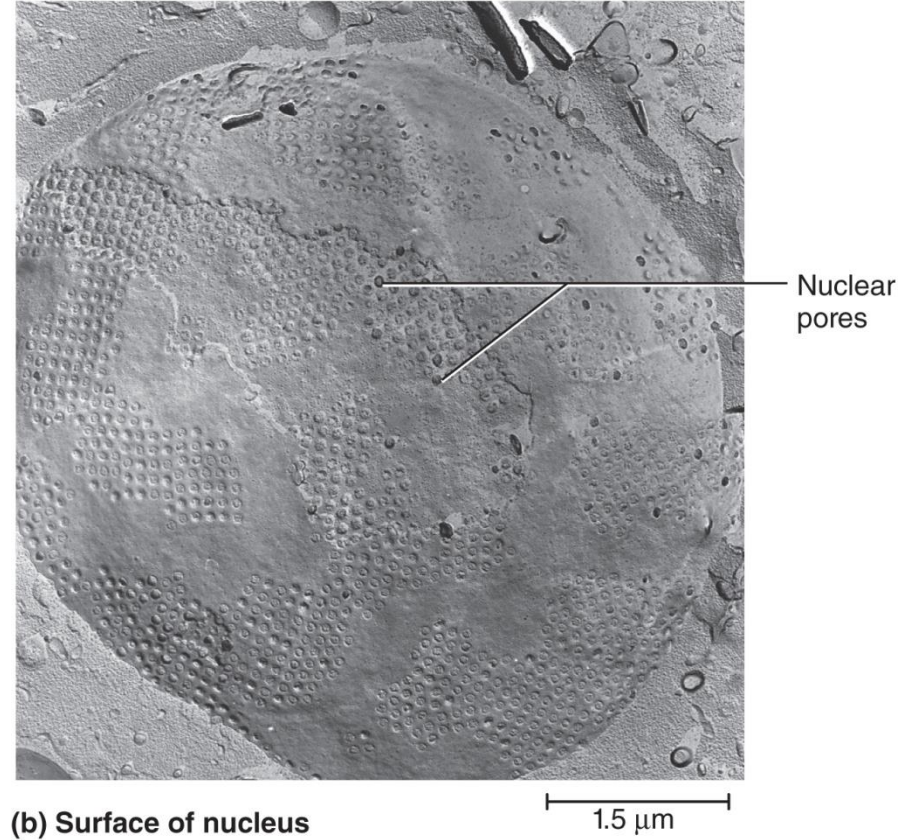
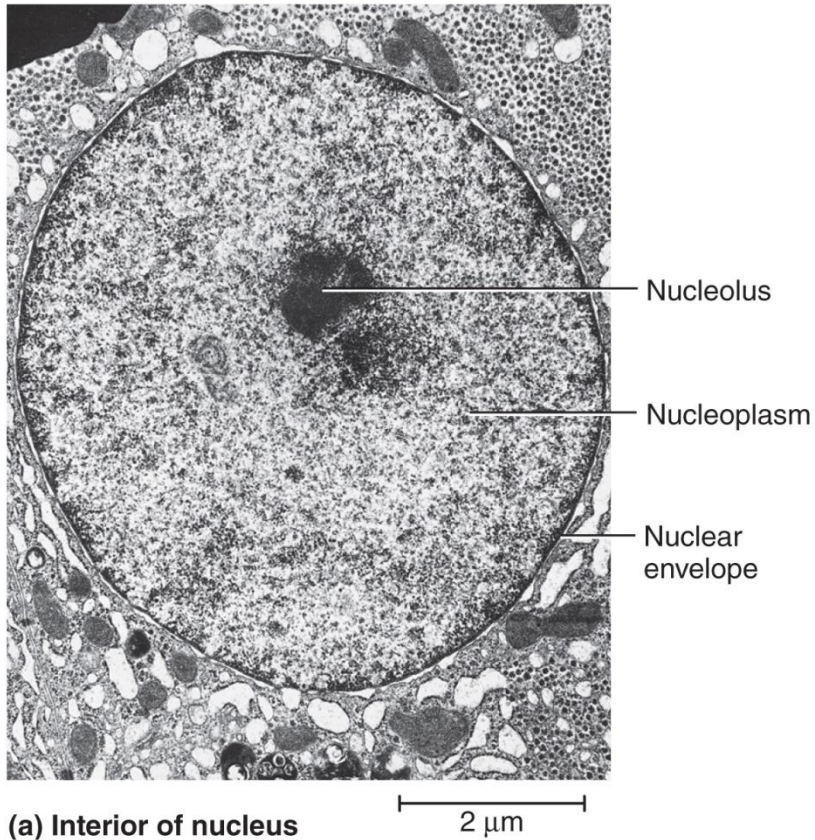
- **Nucleus**—largest organelle (5 μm in diameter)
 - Most cells have one nucleus
 - A few cell types are **anuclear** or **multinucleate**
- **Nuclear envelope**—double membrane around nucleus
 - Perforated by **nuclear pores** formed by rings of proteins
 - Regulate molecular traffic through envelope
 - Hold the two membrane layers together

The Nucleus

- **Nuclear envelope is supported by nuclear lamina**
 - Web of protein filaments
 - Provides points of attachment for chromatin
 - Helps regulate cell life cycle
- **Nucleoplasm**—material in nucleus
 - **Chromatin** (thread-like) composed of DNA and protein
 - **Nucleoli**—masses where **ribosomes** are produced

The Nucleus

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a: ©Richard Chao; b: ©E.G. Pollock

Figure 3.27a

Figure 3.27b

Endoplasmic Reticulum

- **Endoplasmic reticulum**—system of channels (**cisternae**) enclosed by membrane
- **Rough endoplasmic reticulum**—parallel, flattened sacs covered with **ribosomes**
 - Continuous with outer membrane of nuclear envelope
 - Produces phospholipids and proteins of the plasma membrane
 - Synthesizes proteins that are packaged in other organelles or secreted from cell

Endoplasmic Reticulum

- **Smooth endoplasmic reticulum**
 - Lack ribosomes
 - Cisternae more tubular and branching
 - Cisternae thought to be continuous with rough ER
 - Synthesizes steroids and other lipids
 - Detoxifies alcohol and other drugs
 - Calcium storage
- **Rough and smooth ER are functionally different parts of the same network**

Endoplasmic Reticulum

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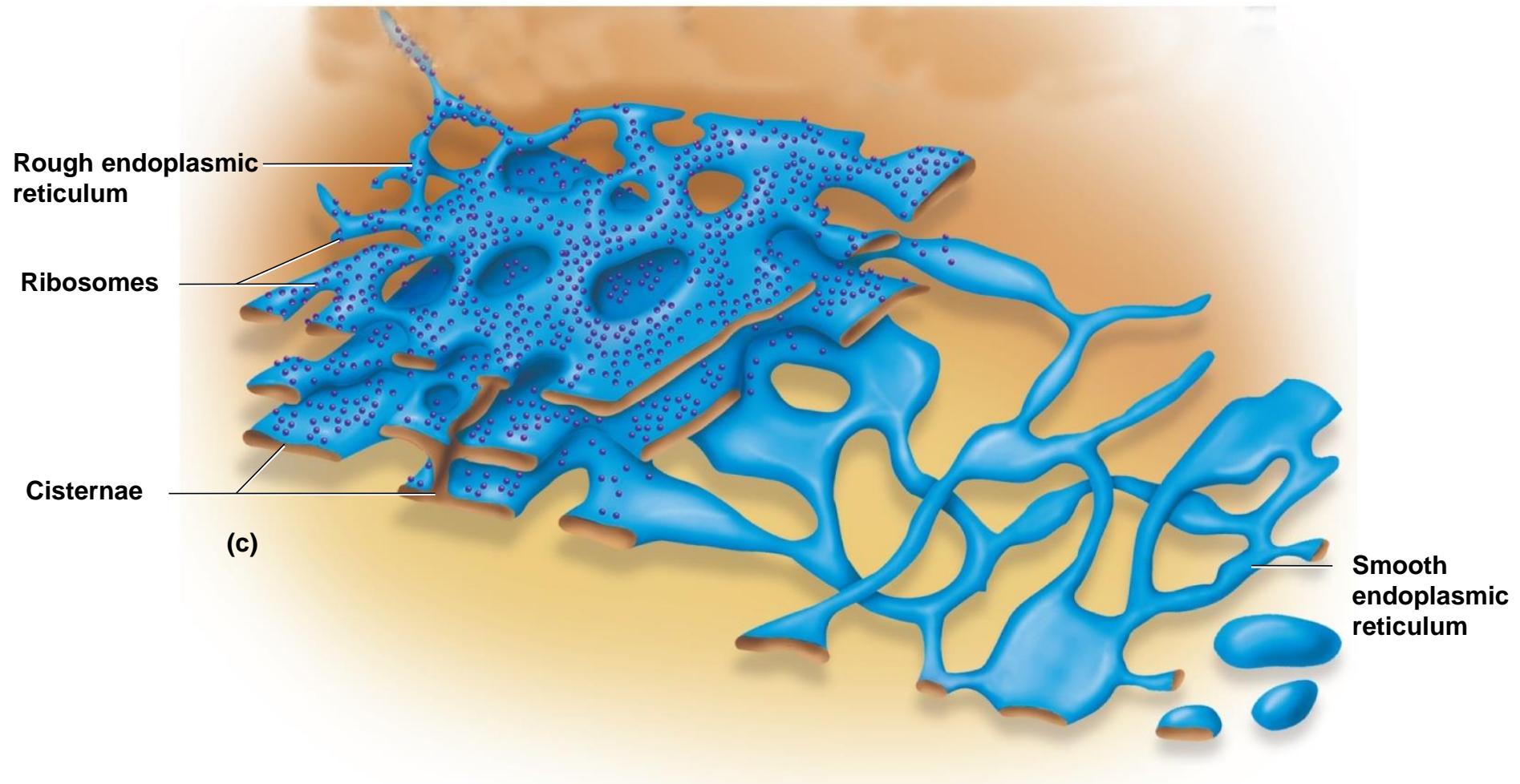


Figure 3.28c

Ribosomes

- **Ribosomes**—small granules of **protein and RNA**
 - Found in nucleoli, in cytosol, and on outer surfaces of rough ER, and nuclear envelope
- They “read” coded genetic messages (**messenger RNA**) and assemble amino acids into proteins specified by the code

Golgi Complex

- **Golgi complex**—a system of cisternae that synthesizes carbohydrates and puts finishing touches on protein synthesis
 - Receives newly synthesized proteins from rough ER
 - Sorts proteins, splices some, adds carbohydrate moieties to some, and packages them into membrane-bound **Golgi vesicles**
 - Some vesicles become lysosomes
 - Some vesicles migrate to plasma membrane and fuse to it
 - Some become secretory vesicles that store a protein product for later release

Golgi Complex

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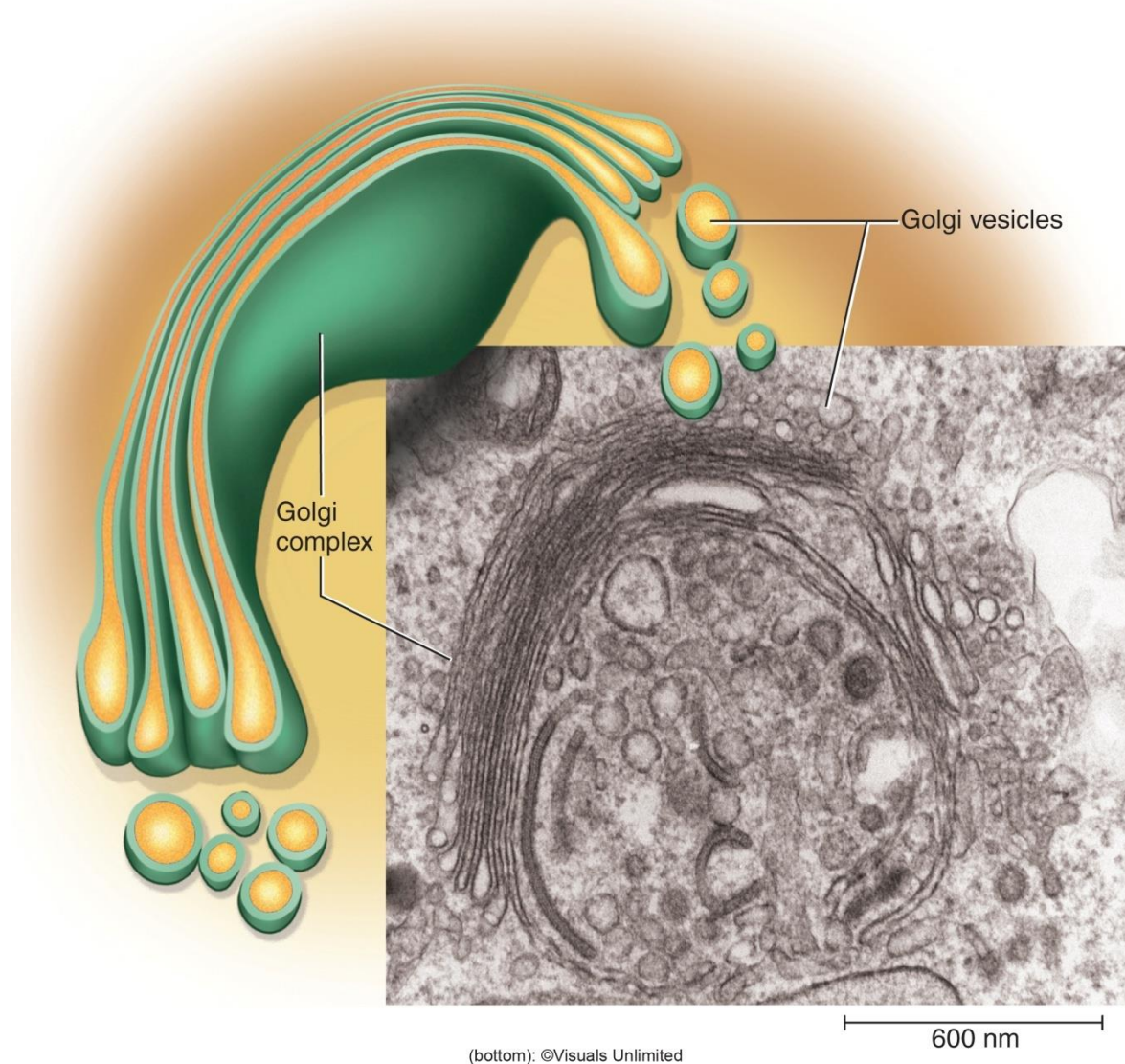


Figure 3.29

Lysosomes

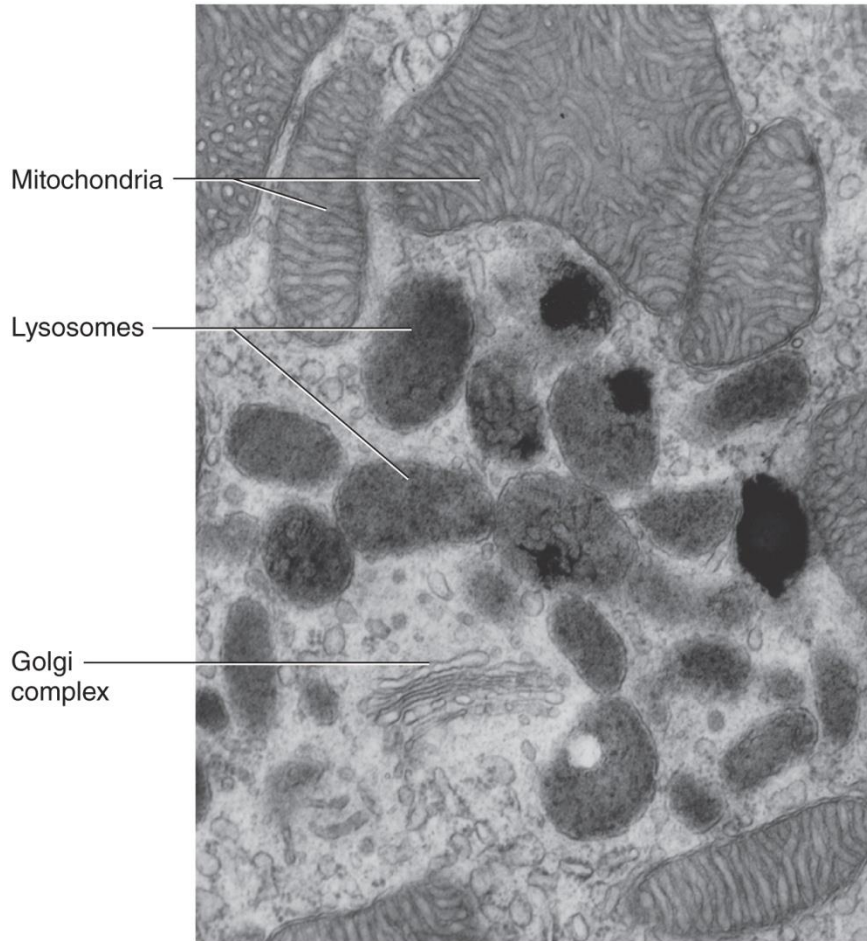
- **Lysosomes**—package of enzymes bound by a membrane
 - Generally round, but variable in shape
- **Functions**
 - Intracellular hydrolytic digestion of proteins, nucleic acids, complex carbohydrates, phospholipids, and other substances
 - **Autophagy**—digestion of cell's surplus organelles
 - **Autolysis**—“cell suicide”: digestion of a surplus cell by itself

Peroxisomes

- **Peroxisomes**—resemble lysosomes but contain different enzymes and are produced by endoplasmic reticulum
- **Function is to use molecular oxygen to oxidize organic molecules**
 - Reactions produce hydrogen peroxide (H_2O_2)
 - **Catalase** breaks down excess peroxide to H_2O and O_2
 - Neutralize free radicals, detoxify alcohol, other drugs, and a variety of blood-borne toxins
 - Break down fatty acids into acetyl groups for mitochondrial use in ATP synthesis
- **In all cells, but abundant in liver and kidney**

Lysosome and Peroxisomes

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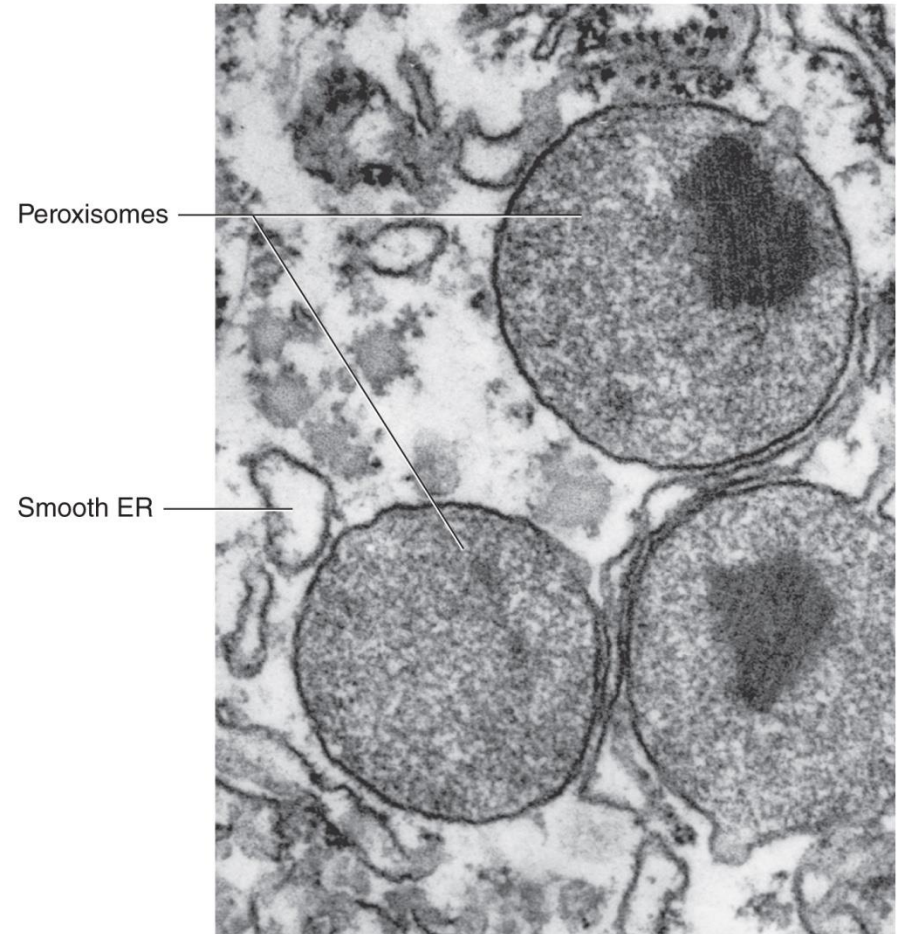


(a) Lysosomes

1 μ m

(a-b): ©Don Fawcett/Science Source

Figure 3.30a



(b) Peroxisomes

0.3 μ m

Figure 3.30b

Proteosomes

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- **Proteosomes**—hollow, cylindrical organelle that disposes of surplus proteins
 - Contain enzymes that break down tagged, targeted proteins into short peptides and amino acids

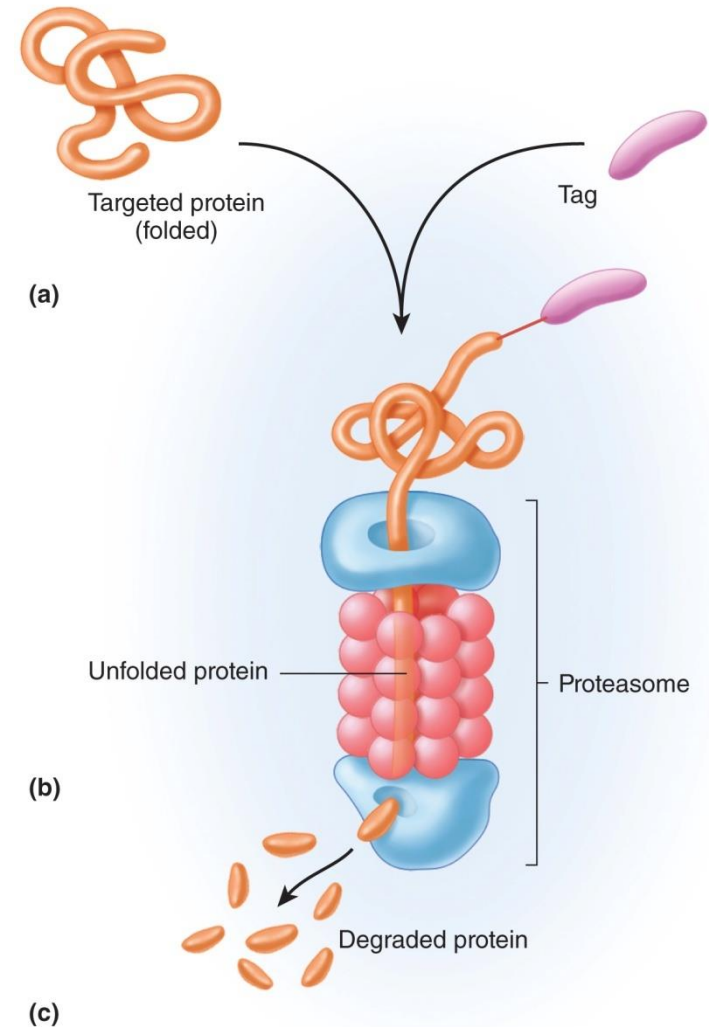
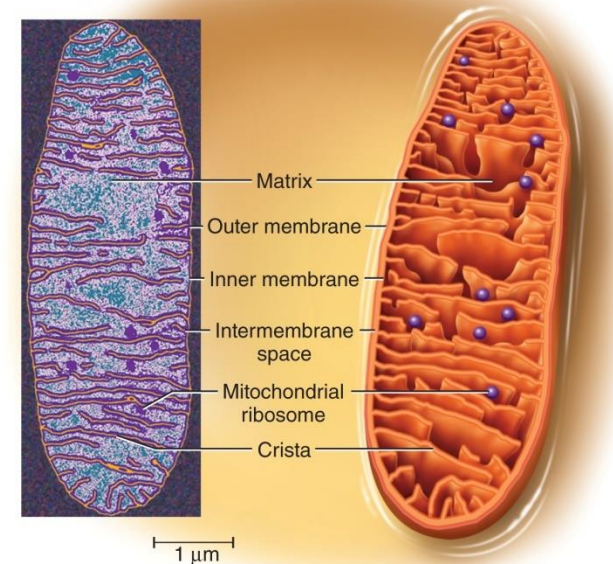


Figure 3.31

Mitochondria

- **Mitochondria**—organelles specialized for synthesizing **ATP**
- **Continually change shape from spheroidal to thread-like**
- **Surrounded by a double membrane**
 - Inner membrane has folds called **cristae**
 - Spaces between cristae called **matrix**
 - Matrix contains ribosomes, enzymes used for ATP synthesis, small circular DNA molecule
 - Mitochondrial DNA (mtDNA)
- **“Powerhouses” of the cell**
 - Energy is extracted from organic molecules and transferred to ATP

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Figure 3.32

Mitochondrion

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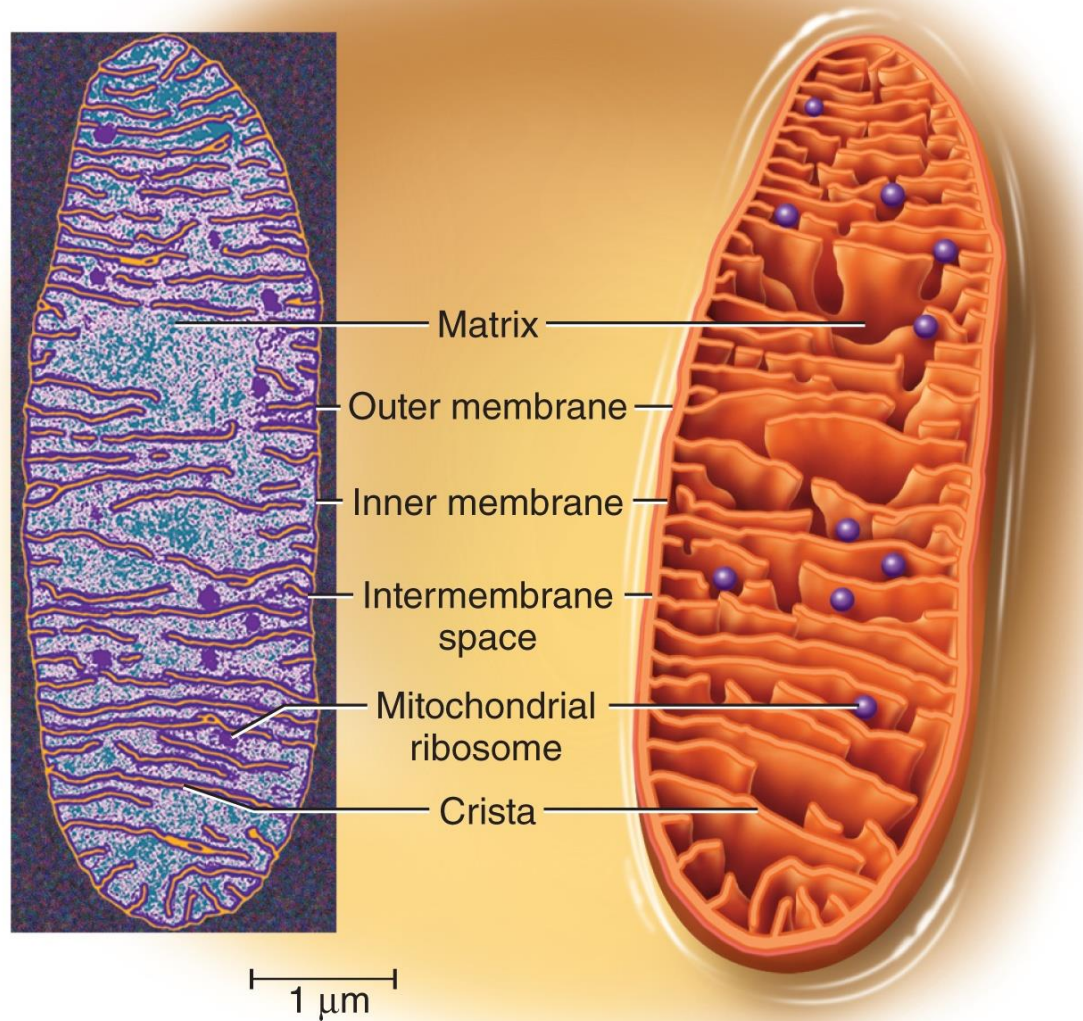


Figure 3.32

(left): ©Dr. Donald Fawcett & Dr. Porter/Visuals Unlimited

Evolution of Mitochondrion

- **Mitochondria evolved from bacteria that invaded another primitive cell, survived in its cytoplasm, and became permanent residents.**
 - The bacterium provided inner membrane; host cell's phagosome provided outer membrane
 - Mitochondrial ribosomes resemble bacterial ribosomes
 - mtDNA resembles circular DNA of bacteria
 - mtDNA is inherited through the mother
 - mtDNA mutates more rapidly than nuclear DNA
 - Responsible for hereditary diseases affecting tissues with high energy demands

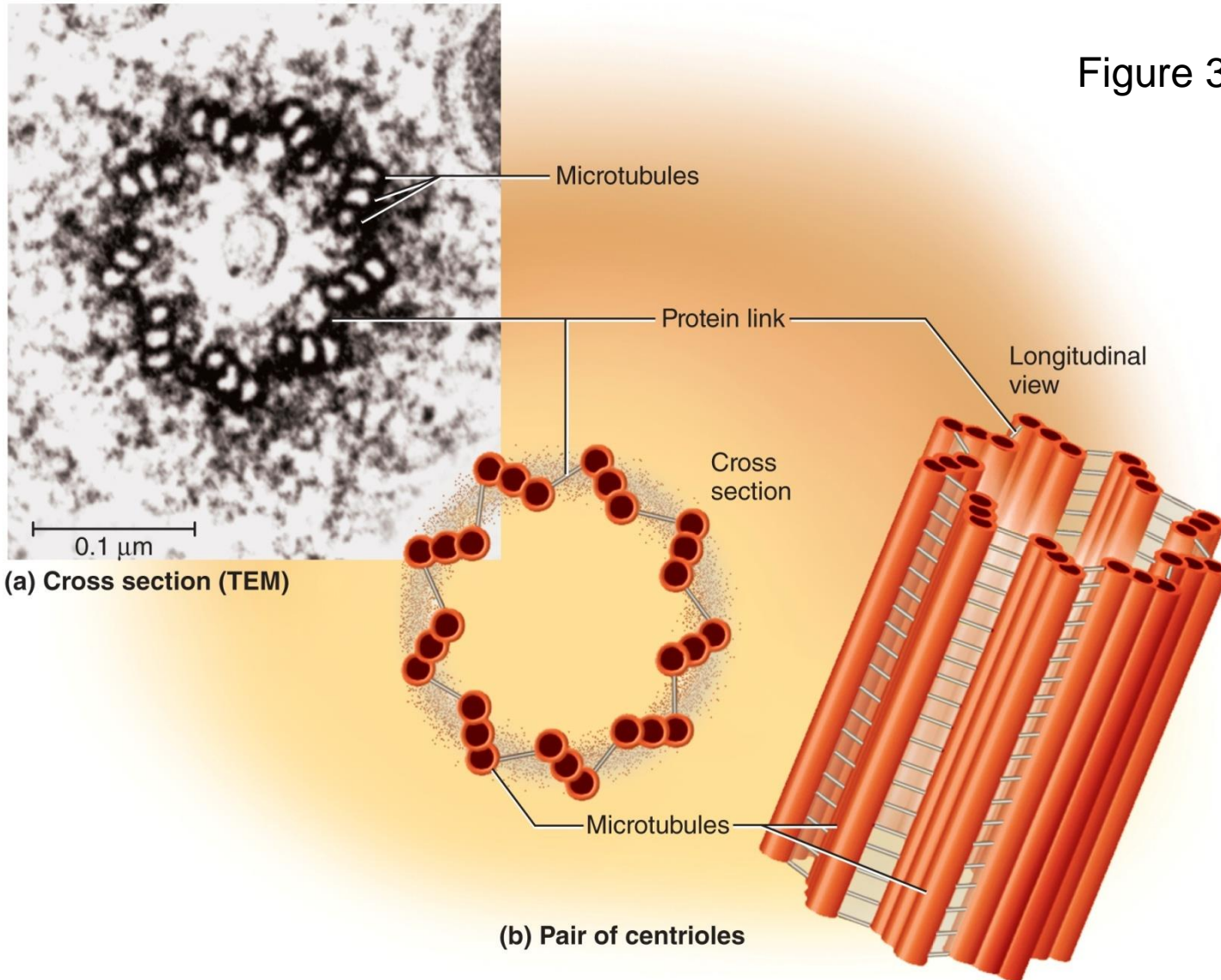
Centrioles

- **Centriole**—a short cylindrical assembly of microtubules arranged in nine groups of three microtubules each
- Two centrioles lie perpendicular to each other within the **centrosome**—small clear area in cell
 - Play important role in cell division
- **Form basal bodies of cilia and flagella**
 - Each basal body is a centriole that originated in centriolar organizing center and then migrated to the membrane

Centrioles

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Figure 3.33a,b



a: From Manley McGill, D.P. Highfield, T.M. Monahan, and Brinkley, B.R. "Effects of Nucleic Acid Specific Dyes on Centrioles of Mammalian Cells," published in the *Journal of Ultrastructure Research* 57, 43–53 (1976), pg. 48, fig. 6, with permission from Elsevier

Inclusions

- **Two kinds of inclusions**
 - **Stored cellular products**
 - Glycogen granules, pigments, and fat droplets
 - **Foreign bodies**
 - Viruses, intracellular bacteria, dust particles, and other debris phagocytized by a cell
- **Never enclosed in a unit membrane**
- **Not essential for cell survival**