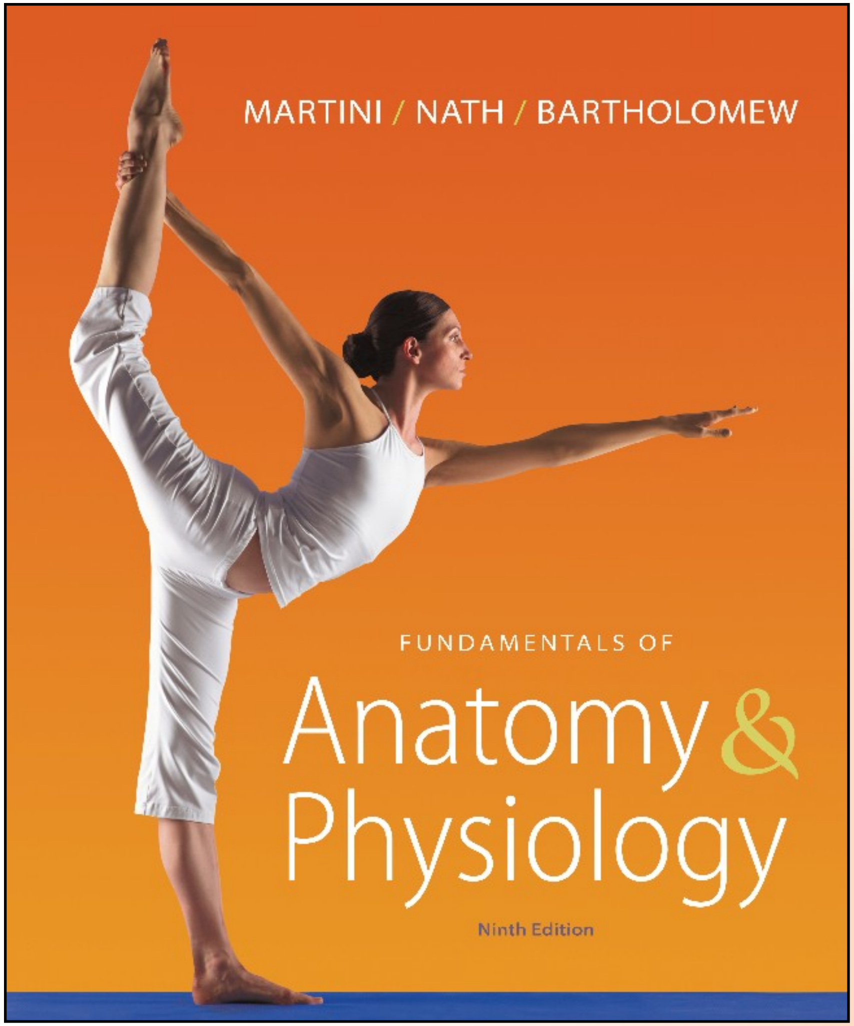


3

The Cellular Level of Organization

PowerPoint® Lecture Presentations prepared by
Jason LaPres
Lone Star College—North Harris

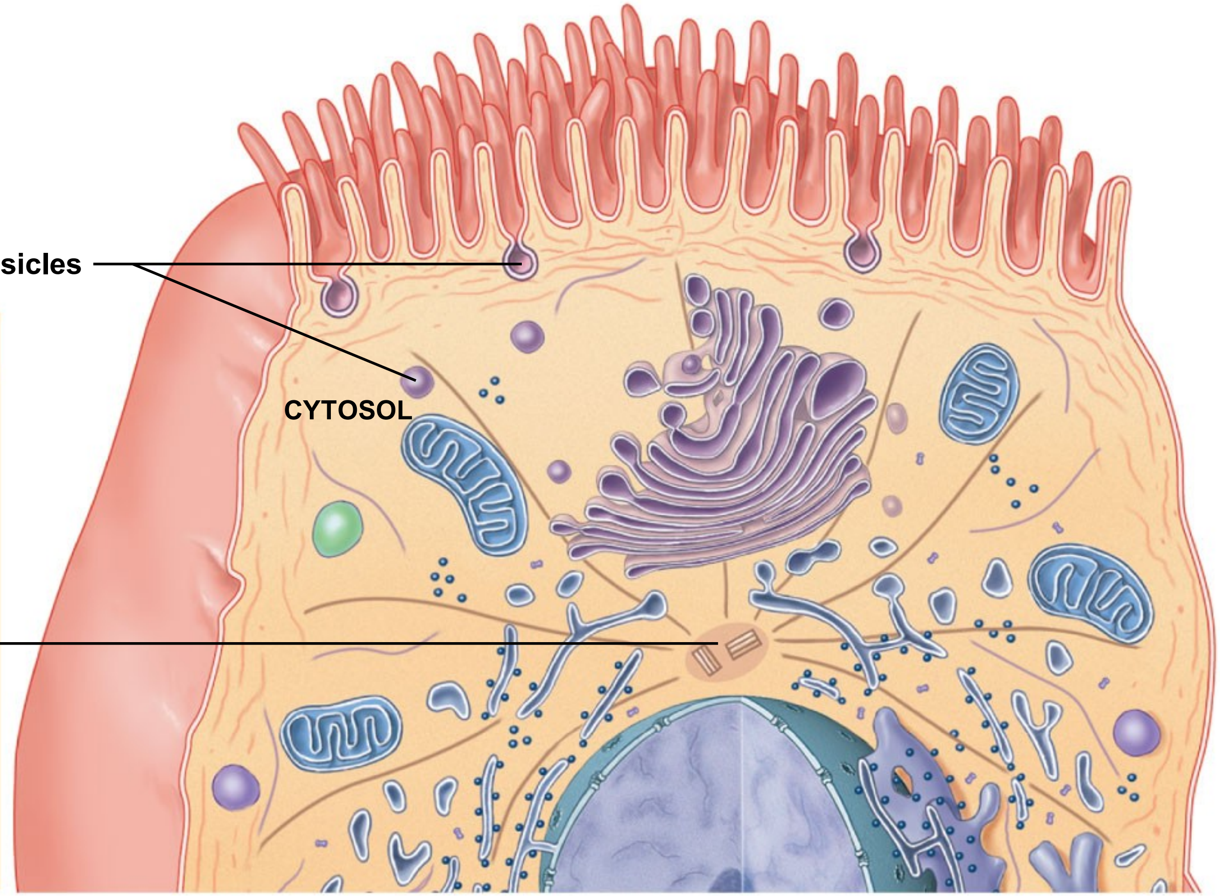
An Introduction to Cells

- Cell Theory
  - Developed from Robert Hooke’s research
    - Cells are the building blocks of all plants and animals
    - All cells come from the division of preexisting cells
    - Cells are the smallest units that perform all vital physiological functions
    - Each cell maintains homeostasis at the cellular level

An Introduction to Cells

- **Sex Cells** (*Germ Cells*)
  - *Reproductive cells*
  - Male *sperm*
  - Female *oocyte* (a cell that develops into an egg)
- **Somatic Cells**
  - *Soma* = body
  - All body cells except sex cells

Figure 3-1 Anatomy of a Model Cell



Centrosome and Centrioles

Cytoplasm contains two centrioles at right angles; each centriole is composed of 9 microtubule triplets in a 9 + 0 array

Functions
Essential for movement of chromosomes during cell division; organization of microtubules in cytoskeleton

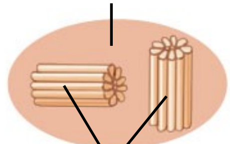


Figure 3-1 Anatomy of a Model Cell

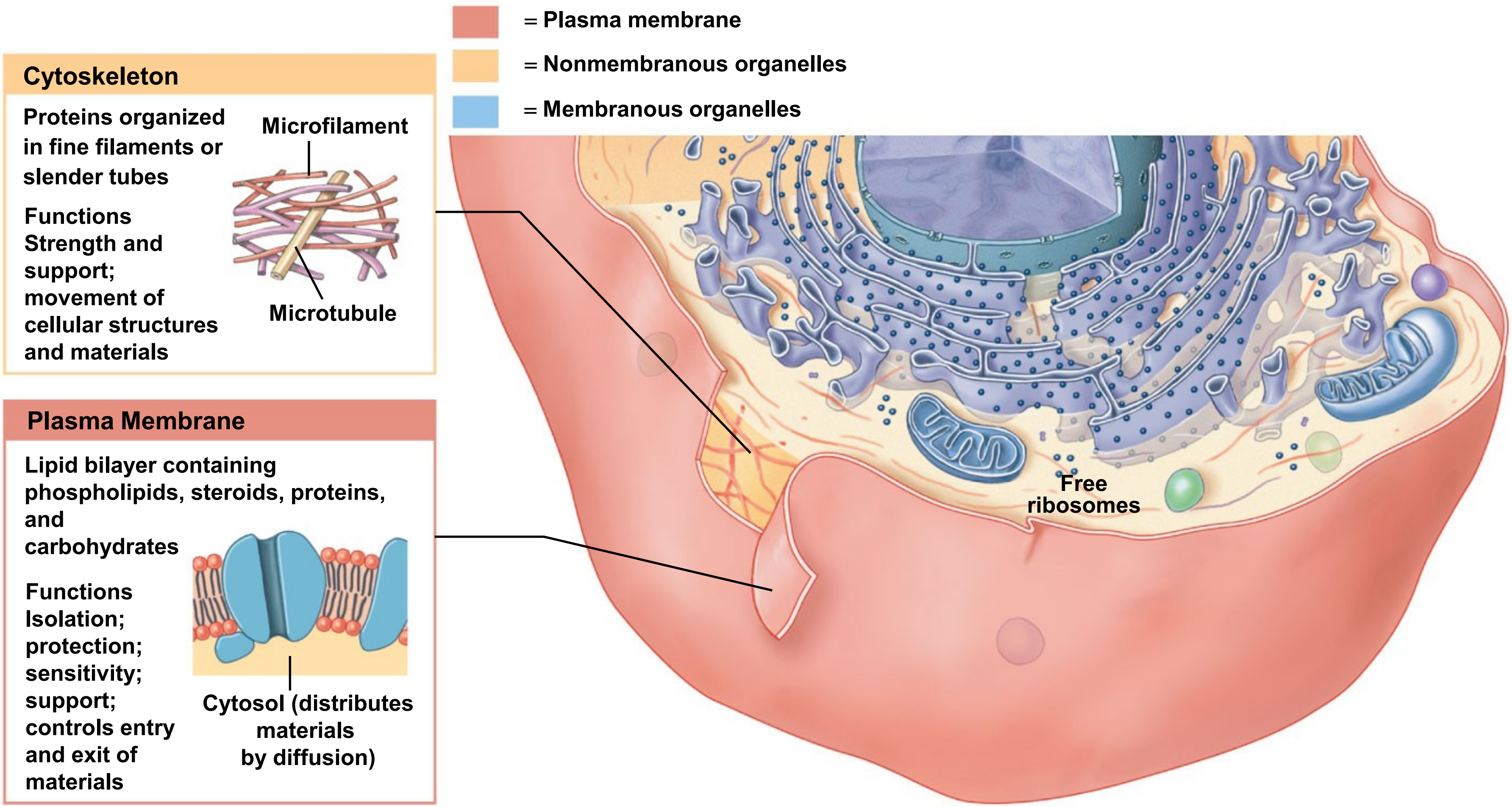
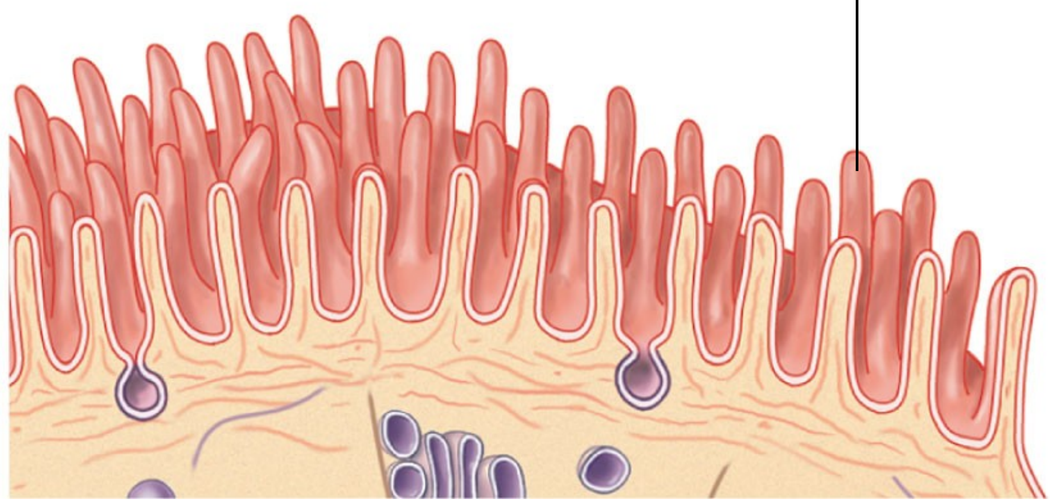


Figure 3-1 Anatomy of a Model Cell

Microvilli

Membrane extensions containing microfilaments

Function
Increase surface area to facilitate absorption of extra-cellular materials



= Plasma membrane

= Nonmembranous organelles

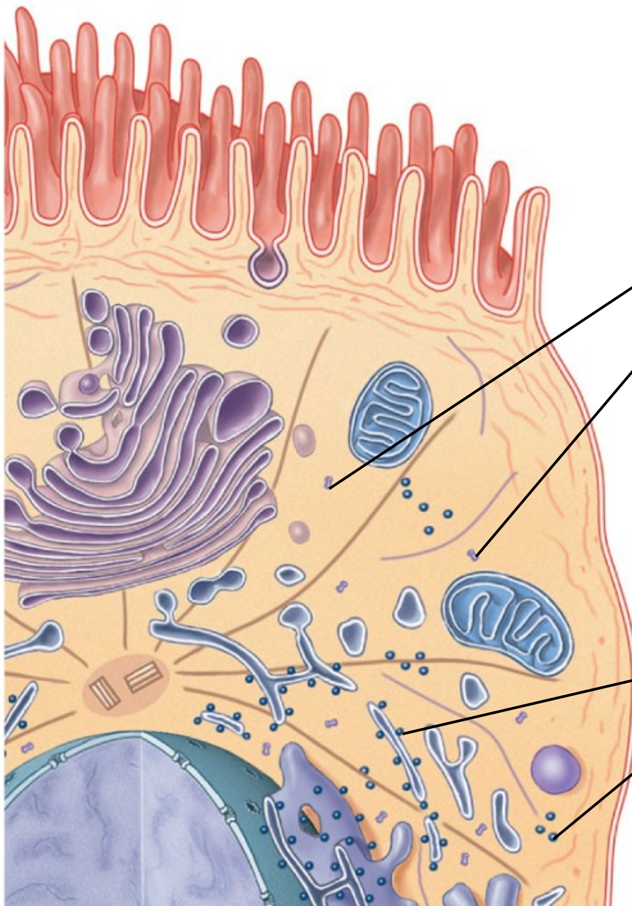
= Membranous organelles

Figure 3-1 Anatomy of a Model Cell

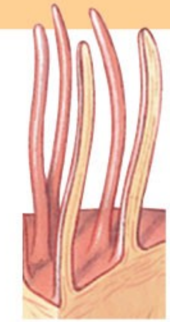
= Plasma membrane

= Nonmembranous organelles

= Membranous organelles



Cilia



Cilia are long extensions containing microtubule doublets in a 9 + 2 array (not shown in the model cell)

Function
Movement of material over cell surface

Proteasomes

Hollow cylinders of proteolytic enzymes with regulatory proteins at their ends

Functions
Breakdown and recycling of damaged or abnormal intracellular proteins

Ribosomes

RNA + proteins; fixed ribosomes bound to rough endoplasmic reticulum, free ribosomes scattered in cytoplasm

Function
Protein synthesis

Figure 3-1 Anatomy of a Model Cell

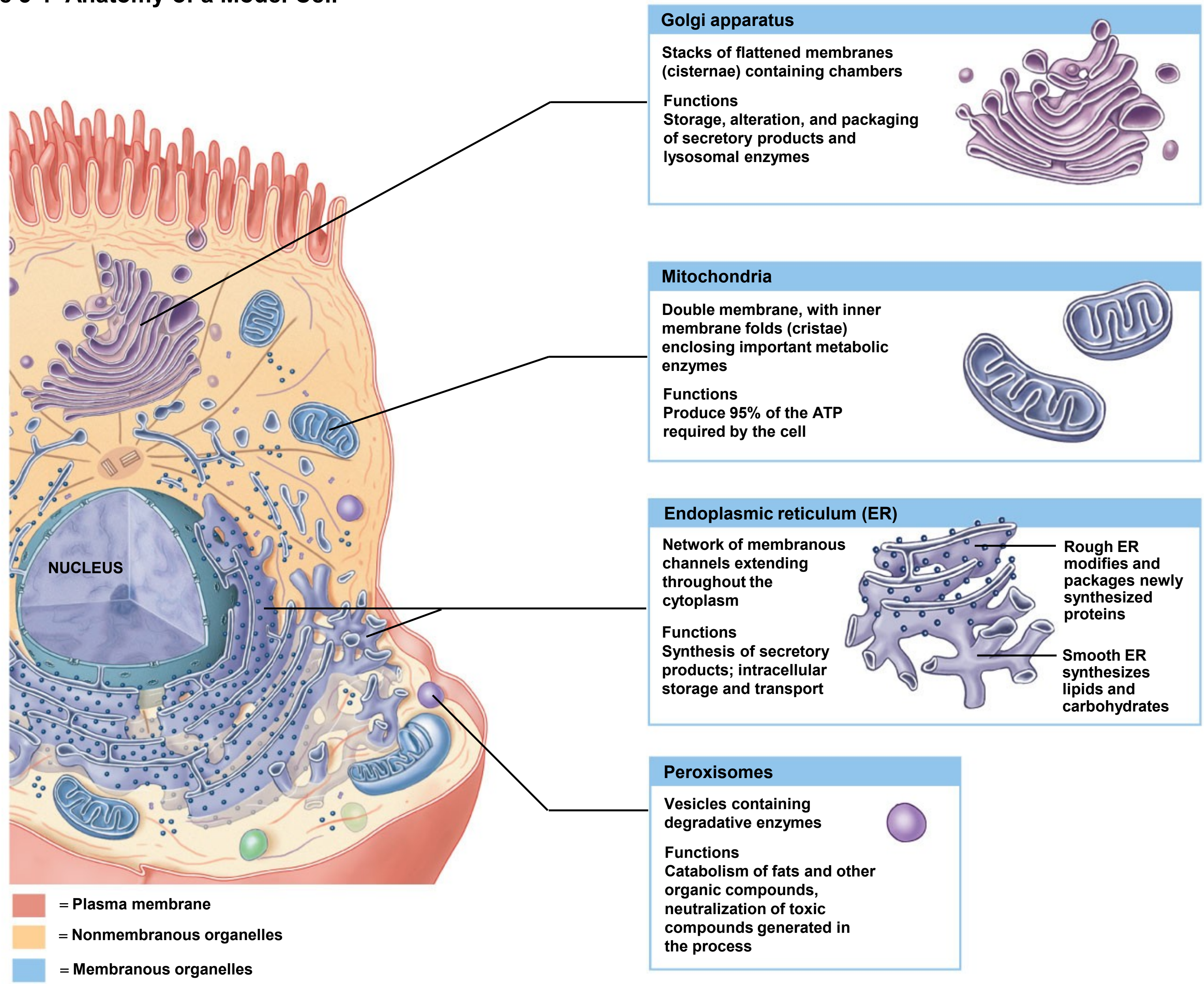
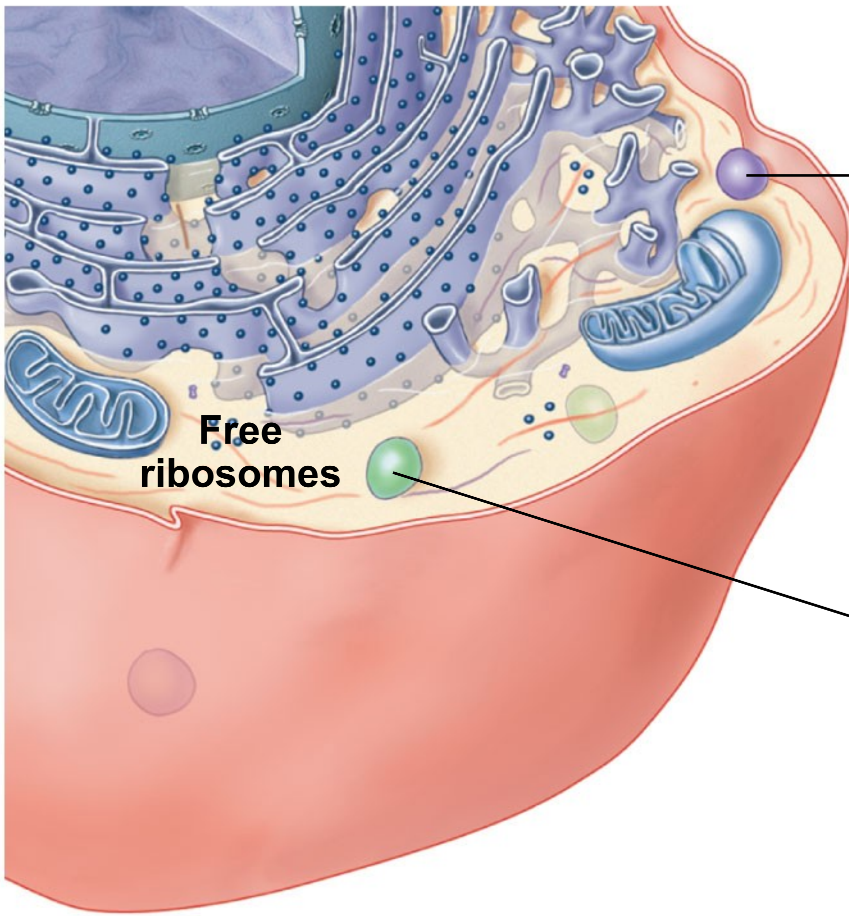


Figure 3-1 Anatomy of a Model Cell

= Plasma membrane

= Nonmembranous organelles

= Membranous organelles



Peroxisomes

Vesicles containing degradative enzymes

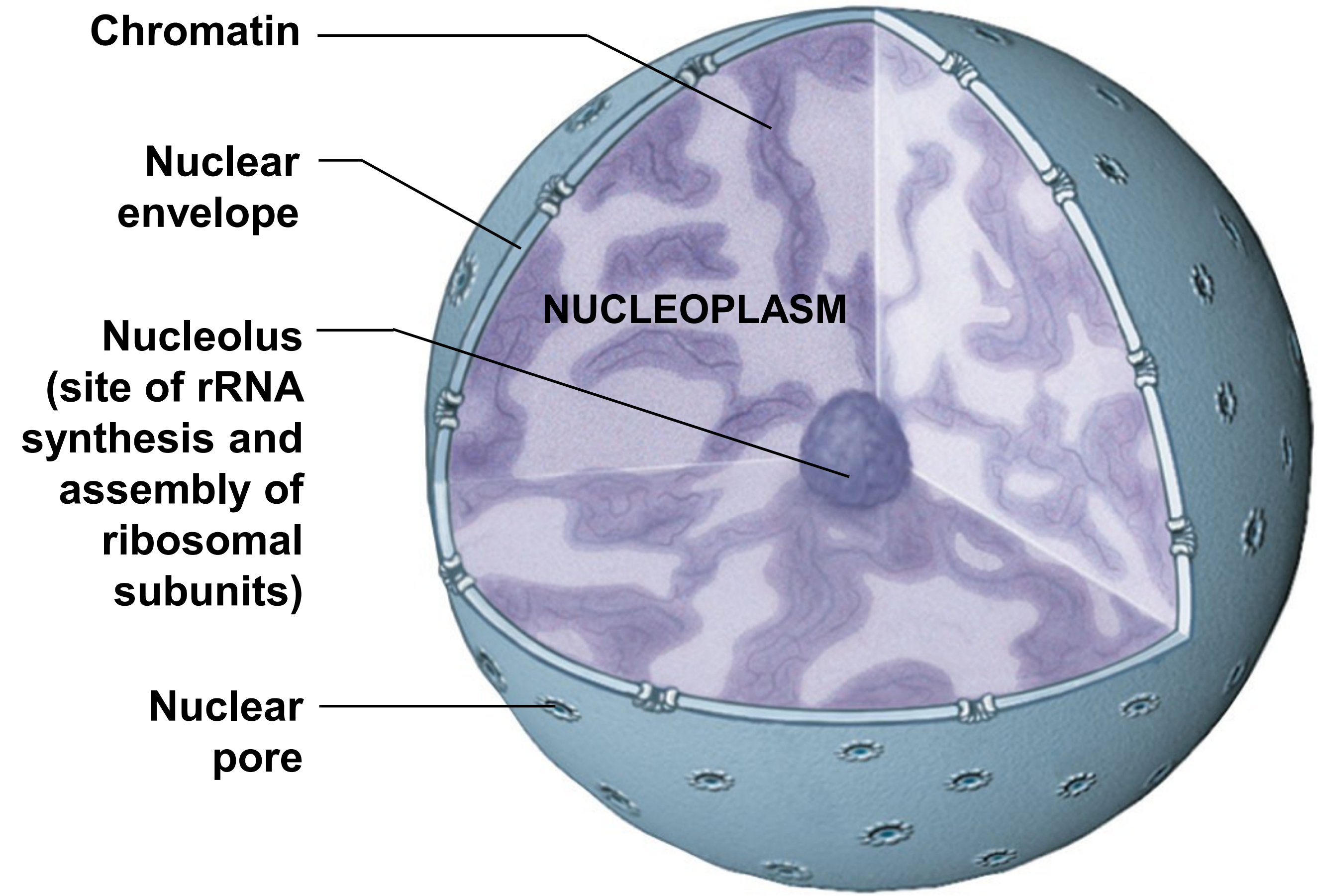
Functions
Catabolism of fats and other organic compounds, neutralization of toxic compounds generated in the process

Lysosomes

Vesicles containing digestive enzymes

Functions
Intracellular removal of damaged organelles or pathogens

Figure 3-1 Anatomy of a Model Cell



NUCLEUS

Nucleoplasm containing nucleotides, enzymes, nucleoproteins, and chromatin; surrounded by a double membrane, the nuclear envelope

Functions:
Control of metabolism; storage and processing of genetic information; control of protein synthesis

3-1 Plasma Membrane

- Extracellular Fluid (Interstitial Fluid)
  - A watery medium that surrounds a cell
  - **Plasma membrane** *(***cell membrane***)* separates cytoplasm from the extracellular fluid
  - Cytoplasm
    - Cytosol = liquid
    - Intracellular structures collectively known as organelles

3-1 Plasma Membrane

- Functions of the Plasma Membrane
  - *Physical Isolation*
    - Barrier
  - *Regulation of Exchange with the Environment*
    - Ions and nutrients enter
    - Wastes eliminated and cellular products released

3-1 Plasma Membrane

- Functions of the Plasma Membrane
  - *Sensitivity to the Environment*
    - Extracellular fluid composition
    - Chemical signals
  - *Structural Support*
    - Anchors cells and tissues

3-1 Plasma Membrane

- Membrane Lipids
  - **Phospholipid bilayer**
    - Hydrophilic heads — toward watery environment, both sides
    - Hydrophobic fatty-acid tails — inside membrane
    - Barrier to ions and water — soluble compounds

3-1 Plasma Membrane

- Membrane Proteins
  - **Integral Proteins**
    - Within the membrane
  - **Peripheral Proteins**
    - Bound to inner or outer surface of the membrane

3-1 Plasma Membrane

- Membrane Proteins
  - **Anchoring Proteins** (stabilizers)
    - Attach to inside or outside structures
  - *Recognition Proteins (identifiers)*
    - Label cells as normal or abnormal
  - *Enzymes*
    - Catalyze reactions

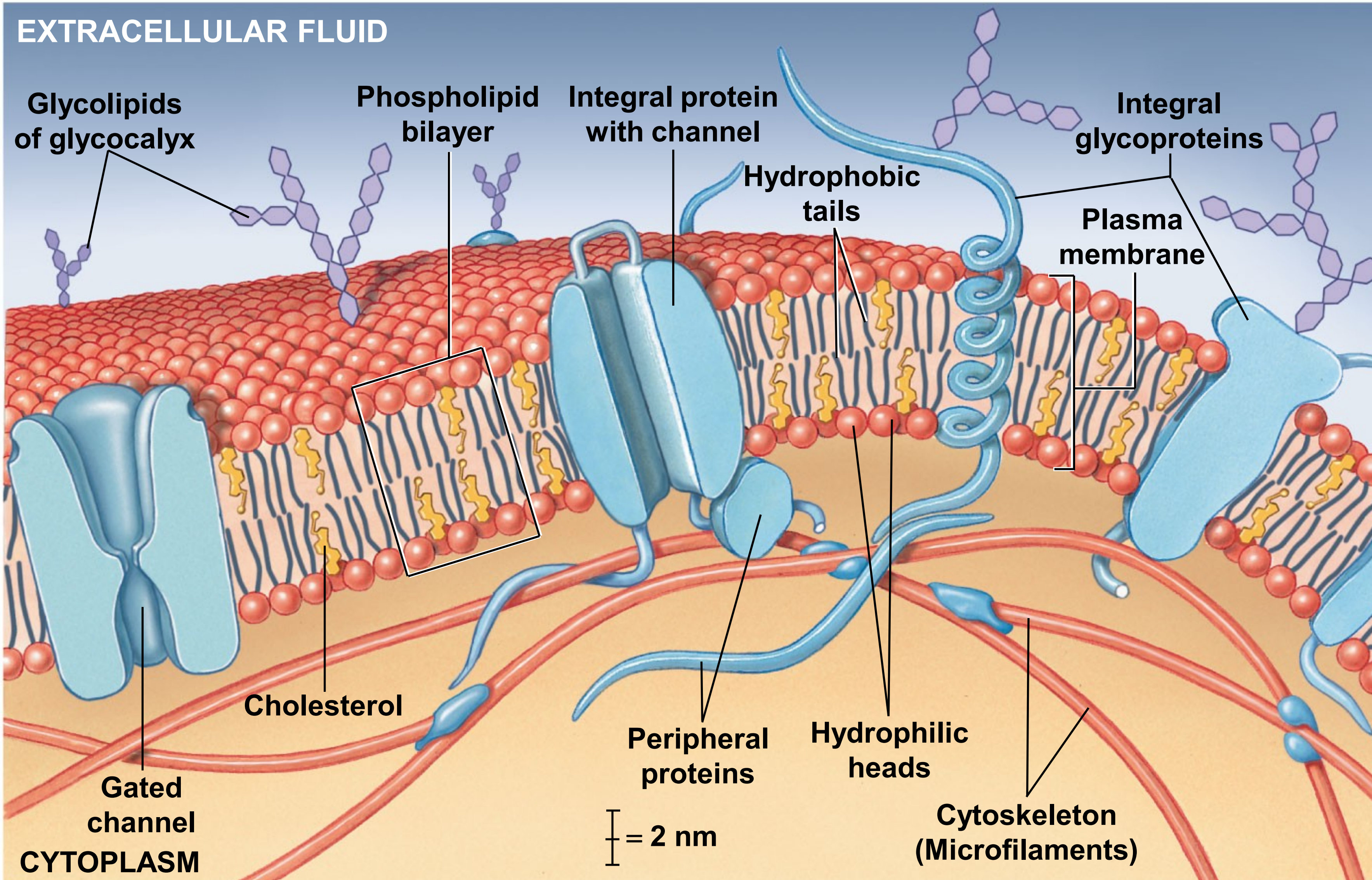
3-1 Plasma Membrane

- Membrane Proteins
  - **Receptor Proteins**
    - Bind and respond to **ligands** (ions, hormones)
  - **Carrier Proteins**
    - Transport specific solutes through membrane
  - **Channels**
    - Regulate water flow and solutes through membrane

3-1 Plasma Membrane

- Membrane Carbohydrates
  - *Proteoglycans, glycoproteins*, and *glycolipids*
    - Extend outside cell membrane
    - Form sticky "sugar coat" (**glycocalyx**)
  - Functions of the glycocalyx
    - *Lubrication and Protection*
    - *Anchoring and Locomotion*
    - *Specificity in Binding* (receptors)
    - *Recognition* (immune response)

Figure 3-2 The Plasma Membrane



3-2 Organelles and the Cytoplasm

- **Cytoplasm**
  - All materials inside the cell and outside the nucleus
    - **Cytosol** (*intracellular fluid*)
      - Dissolved materials
        - Nutrients, ions, proteins, and waste products
      - High potassium/low sodium
      - High protein
      - High carbohydrate/low amino acid and fat
    - **Organelles**
      - Structures with specific functions

3-2 Organelles and the Cytoplasm

- The Organelles
  - **Nonmembranous organelles**
    - No membrane
    - Direct contact with cytosol
    - Include the *cytoskeleton, microvilli, centrioles, cilia, ribosomes,* and *proteasomes*
  - **Membranous organelles**
    - Covered with plasma membrane
    - Isolated from cytosol
    - Include the *endoplasmic reticulum (ER), the Golgi apparatus, lysosomes, peroxisomes,* and *mitochondria*

3-2 Organelles and the Cytoplasm

- **Nonmembranous Organelles**
  - Six types of nonmembranous organelles
    1. Cytoskeleton
    2. Microvilli
    3. Centrioles
    4. Cilia
    5. Ribosomes
    6. Proteasomes

3-2 Organelles and the Cytoplasm

- The **Cytoskeleton**
  - Structural proteins for shape and strength
    - **Microfilaments**
    - **Intermediate filaments**
    - **Microtubules**

3-2 Organelles and the Cytoplasm

- The Cytoskeleton
  - **Microfilaments —** thin filaments composed of the protein **actin**
    - Provide additional mechanical strength
    - Interact with proteins for consistency
    - Pair with thick filaments of *myosin* for muscle movement

3-2 Organelles and the Cytoplasm

- The Cytoskeleton
  - **Intermediate filaments —** mid-sized between microfilaments and thick filaments
    - Durable (**collagen**)
    - Strengthen cell and maintain shape
    - Stabilize organelles
    - Stabilize cell position

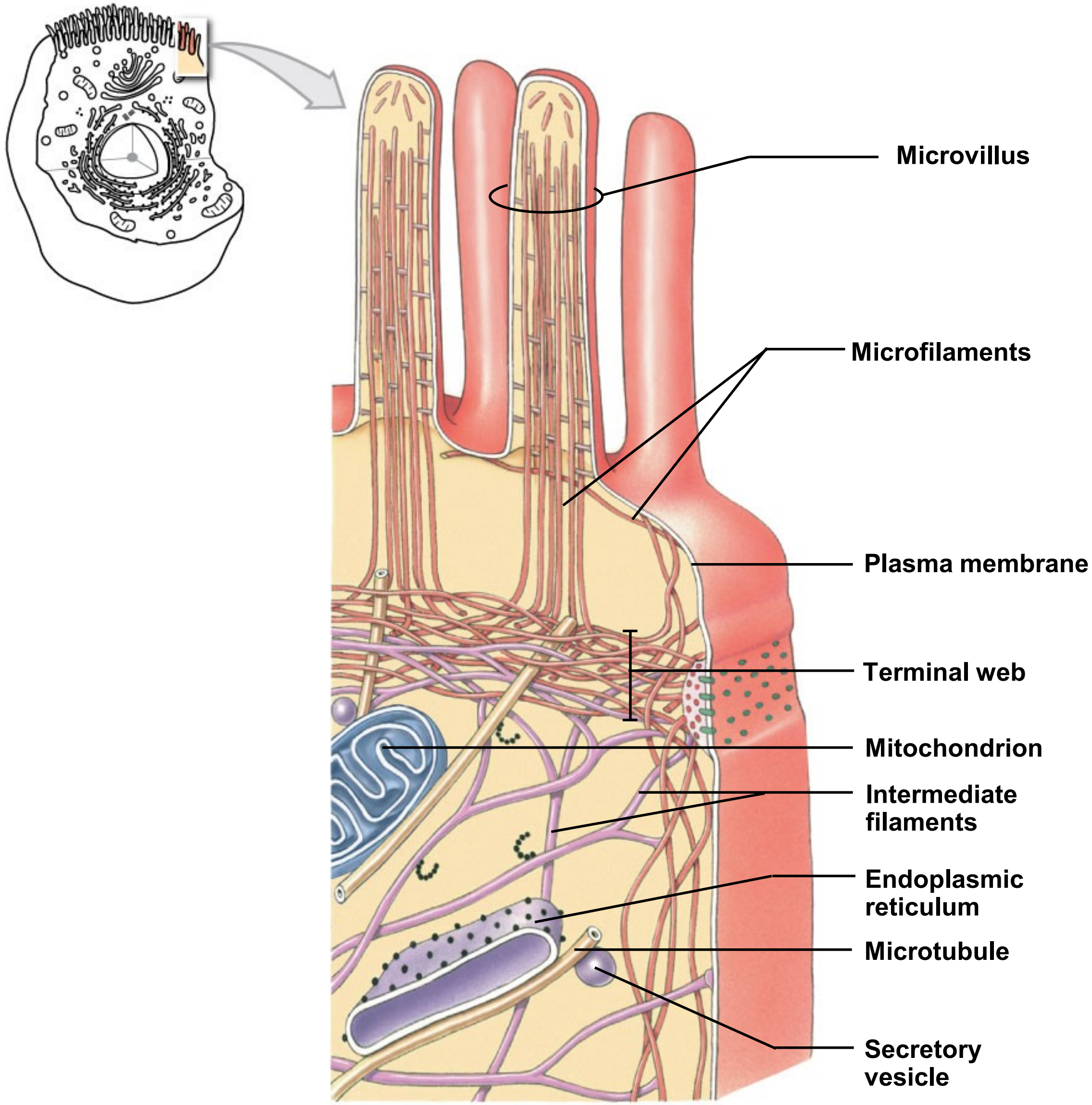
3-2 Organelles and the Cytoplasm

- The Cytoskeleton
  - **Microtubules — large, hollow tubes of tubulin** protein
    - Attach to *centrosome*
    - Strengthen cell and anchor organelles
    - Change cell shape
    - Move vesicles within cell (*kinesin* and *dynein*)
    - Form *spindle apparatus*

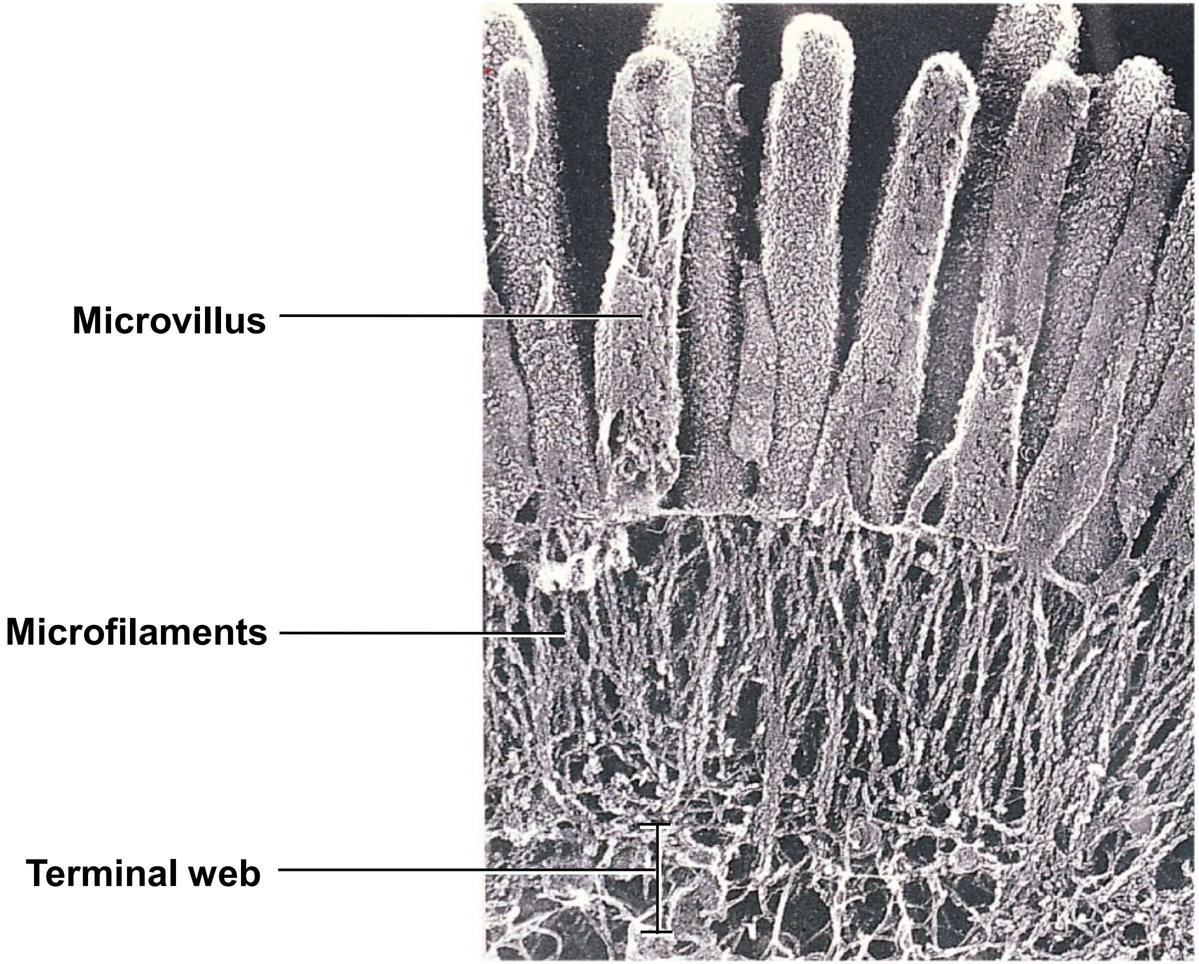
3-2 Organelles and the Cytoplasm

- The Cytoskeleton
  - **Thick filaments**
    - **Myosin** protein in muscle cells

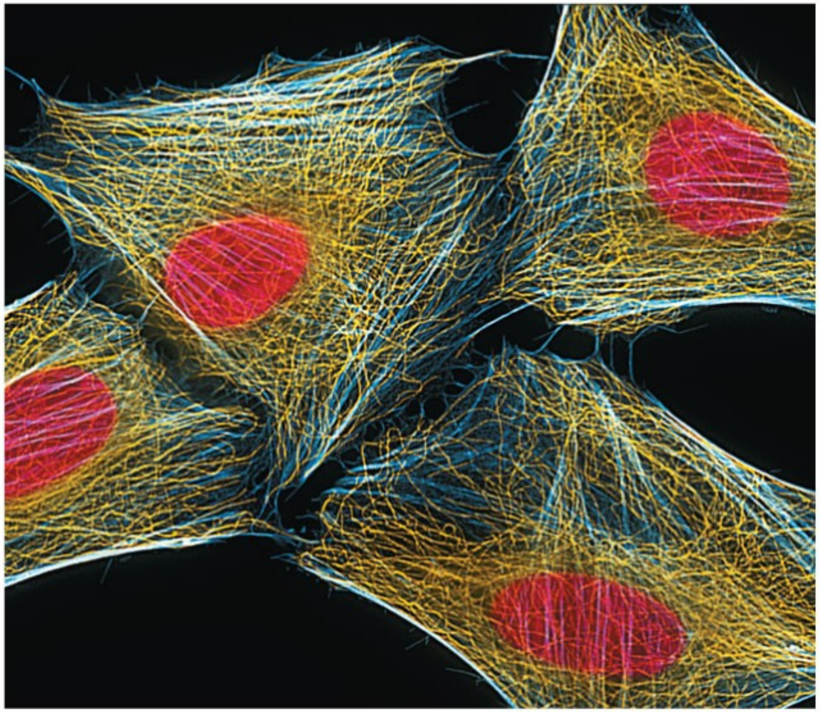
Figure 3-3a The Cytoskeleton



a The cytoskeleton provides strength and structural support for the cell and its organelles. Interactions between cytoskeletal components are also important in moving organelles and in changing the shape of the cell.



b The microfilaments and microvilli of an intestinal cell. Such an image, produced by a scanning electron microscope, is called a scanning electron micrograph (SEM) (SEM × 30,000).

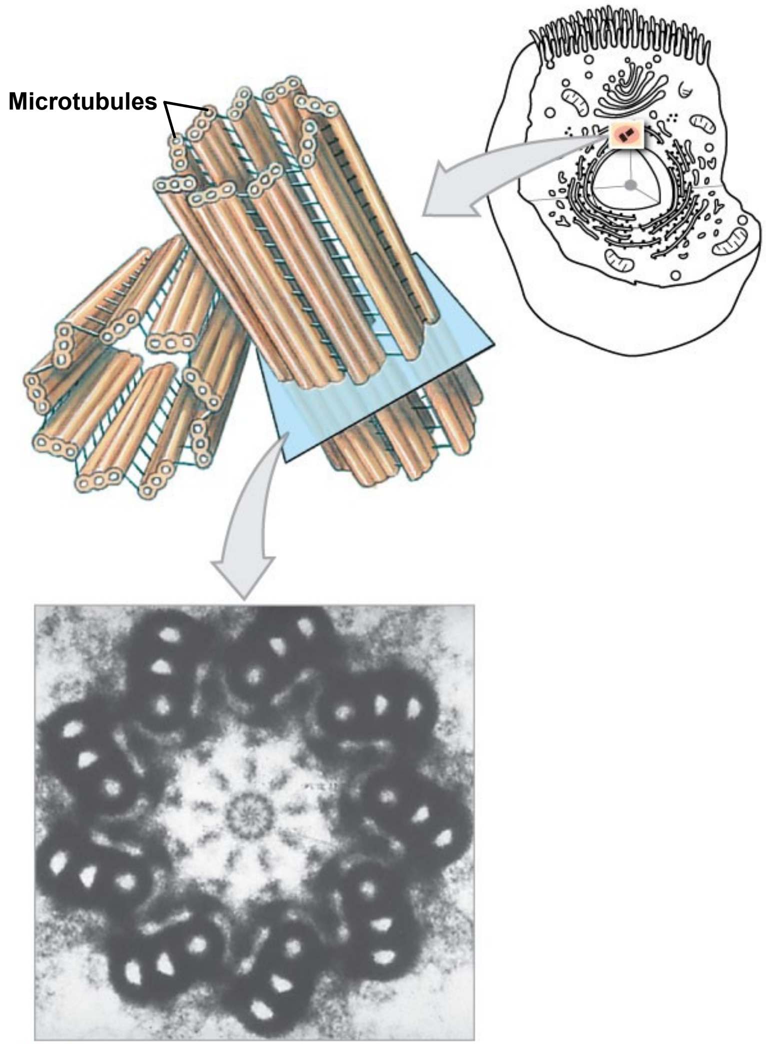


c Microtubules (yellow) in a living cell, as seen after special fluorescent labeling (LM × 3200).

3-2 Organelles and the Cytoplasm

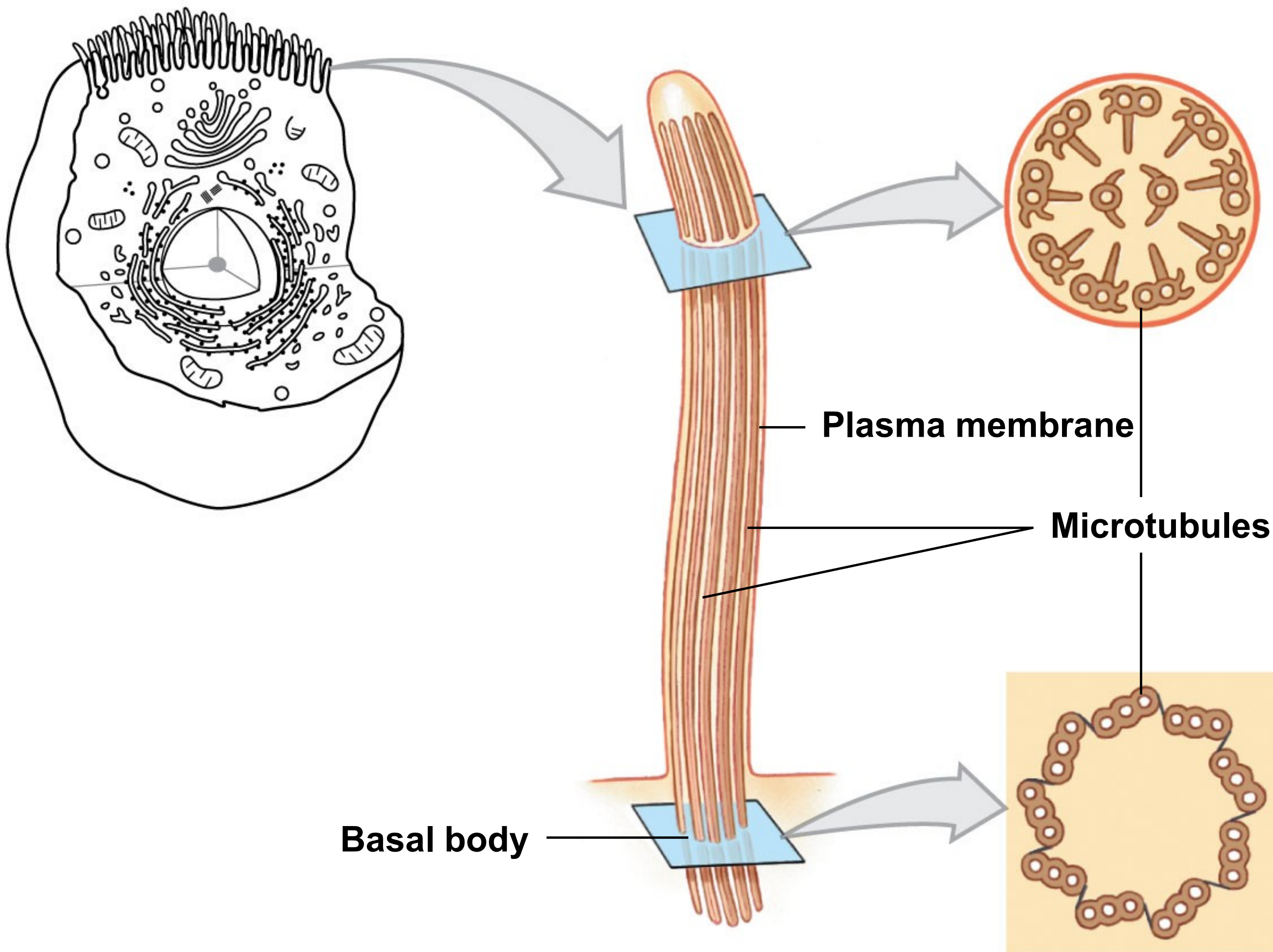
- **Microvilli**
  - Increase surface area for absorption
  - Attach to cytoskeleton
- **Centrioles** in the **Centrosome**
  - Centrioles form spindle apparatus during cell division
  - Centrosome cytoplasm surrounding centriole
- **Cilia**
  - Small hair-like extensions
  - Cilia move fluids across the cell surface

Figure 3-4a Centrioles and Cilia



a Centriole. A centriole consists of nine microtubule triplets (known as a 9 + 0 array). A pair of centrioles orientated at right angles to one another occupies the centrosome. This micrograph, produced by a transmission electron microscope, is called a TEM.

Figure 3-4b Centrioles and Cilia



b **Cilium.** A cilium contains nine pairs of microtubules surrounding a central pair (9 + 2 array). The basal body to which the cilium is anchored has a structure similar to that of a centriole.

c Ciliary movement. Action of a single cilium. During the power stroke, the cilium is relatively stiff; during the return stroke, it bends and returns to its original position.

3-2 Organelles and the Cytoplasm

- **Ribosomes**
  - Build polypeptides in protein synthesis
  - Two types
    1. **Free ribosomes** in cytoplasm
       - Manufacture proteins for cell
    2. **Fixed ribosomes** attached to *ER*
       - Manufacture proteins for secretion
- **Proteasomes**
  - Contain enzymes (*proteases*)
  - Disassemble damaged proteins for recycling

3-2 Organelles and the Cytoplasm

- Membranous Organelles
  - Five types of membranous organelles
    1. **Endoplasmic reticulum (ER)**
    2. **Golgi apparatus**
    3. **Lysosomes**
    4. **Peroxisomes**
    5. **Mitochondria**

3-2 Organelles and the Cytoplasm

- **Endoplasmic Reticulum (ER)**
  - *Endo-* = within, *plasm* = cytoplasm, *reticulum* = network
  - **Cisternae** are storage chambers within membranes
  - Functions
    1. *Synthesis* of proteins, carbohydrates, and lipids
    2. *Storage* of synthesized molecules and materials
    3. *Transport* of materials within the ER
    4. *Detoxification* of drugs or toxins

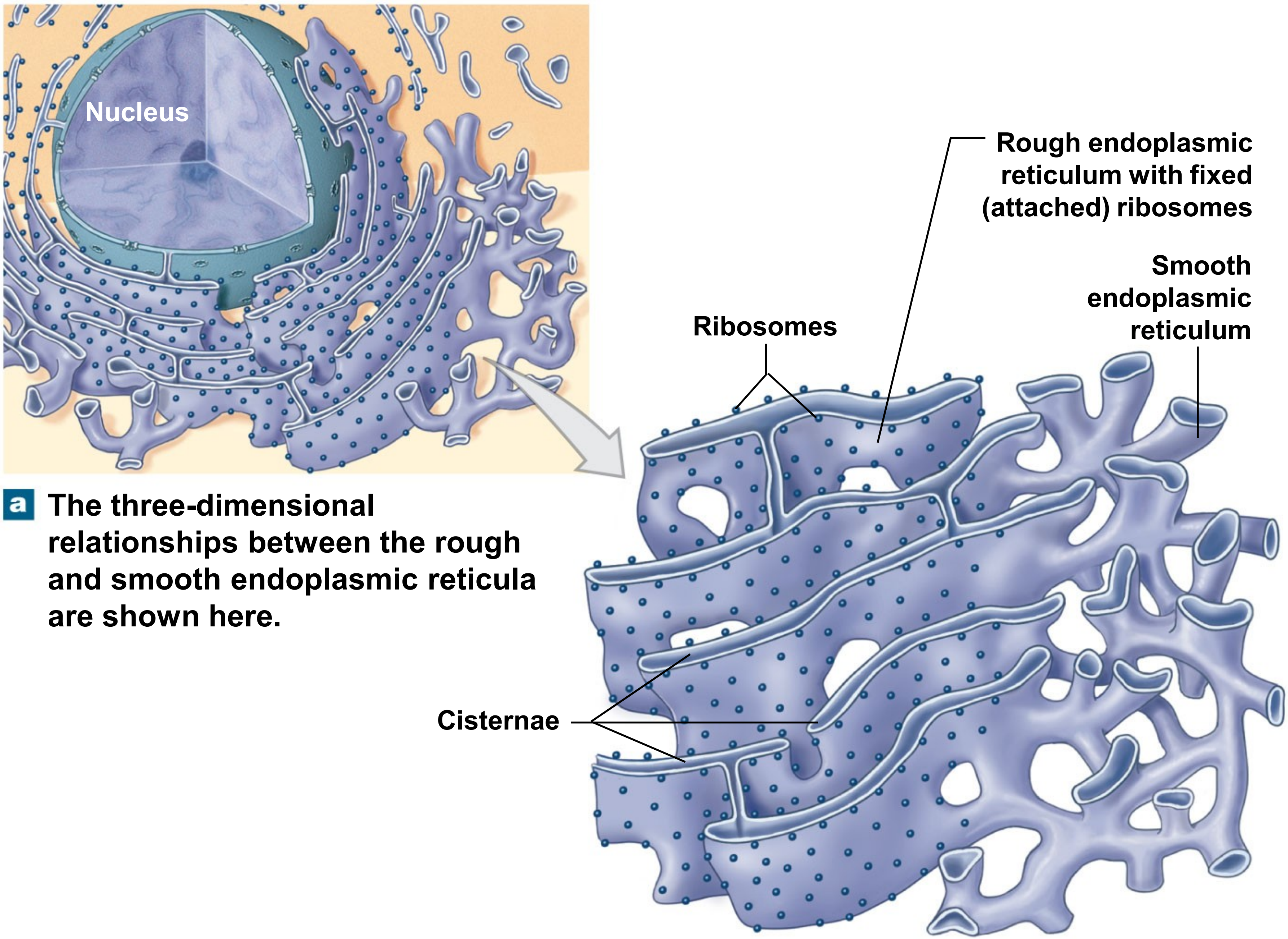
3-2 Organelles and the Cytoplasm

- Endoplasmic Reticulum (ER)
  - *Smooth endoplasmic reticulum (SER)*
    - No ribosomes attached
    - Synthesizes lipids and carbohydrates
      - Phospholipids and cholesterol (membranes)
      - Steroid hormones (reproductive system)
      - Glycerides (storage in liver and fat cells)
      - Glycogen (storage in muscles)

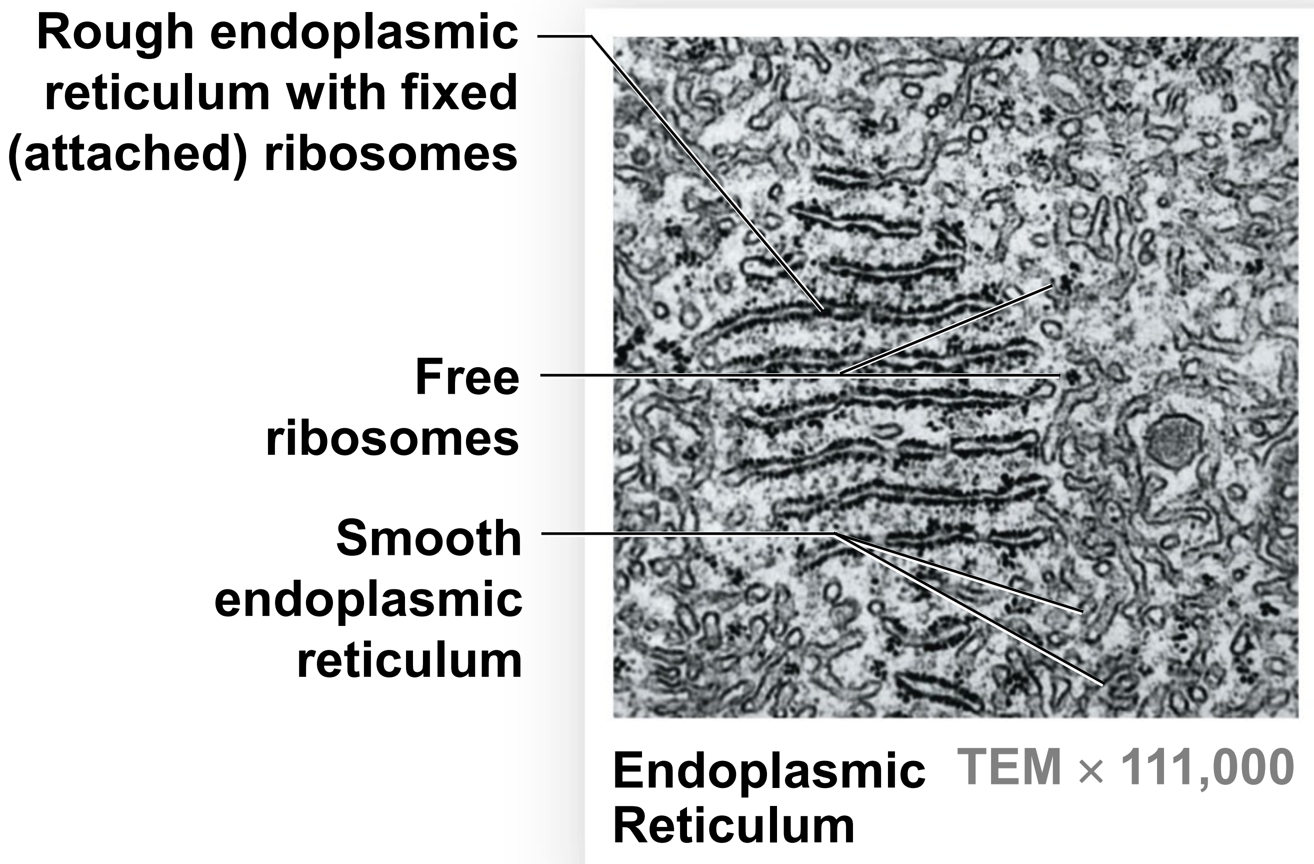
3-2 Organelles and the Cytoplasm

- **Endoplasmic Reticulum (ER)**
  - *Rough endoplasmic reticulum (RER)*
    - Surface covered with ribosomes
      - Active in protein and glycoprotein synthesis
      - Folds polypeptide protein structures
      - Encloses products in **transport vesicles**

Figure 3-5a The Endoplasmic Reticulum



a The three-dimensional relationships between the rough and smooth endoplasmic reticula are shown here.

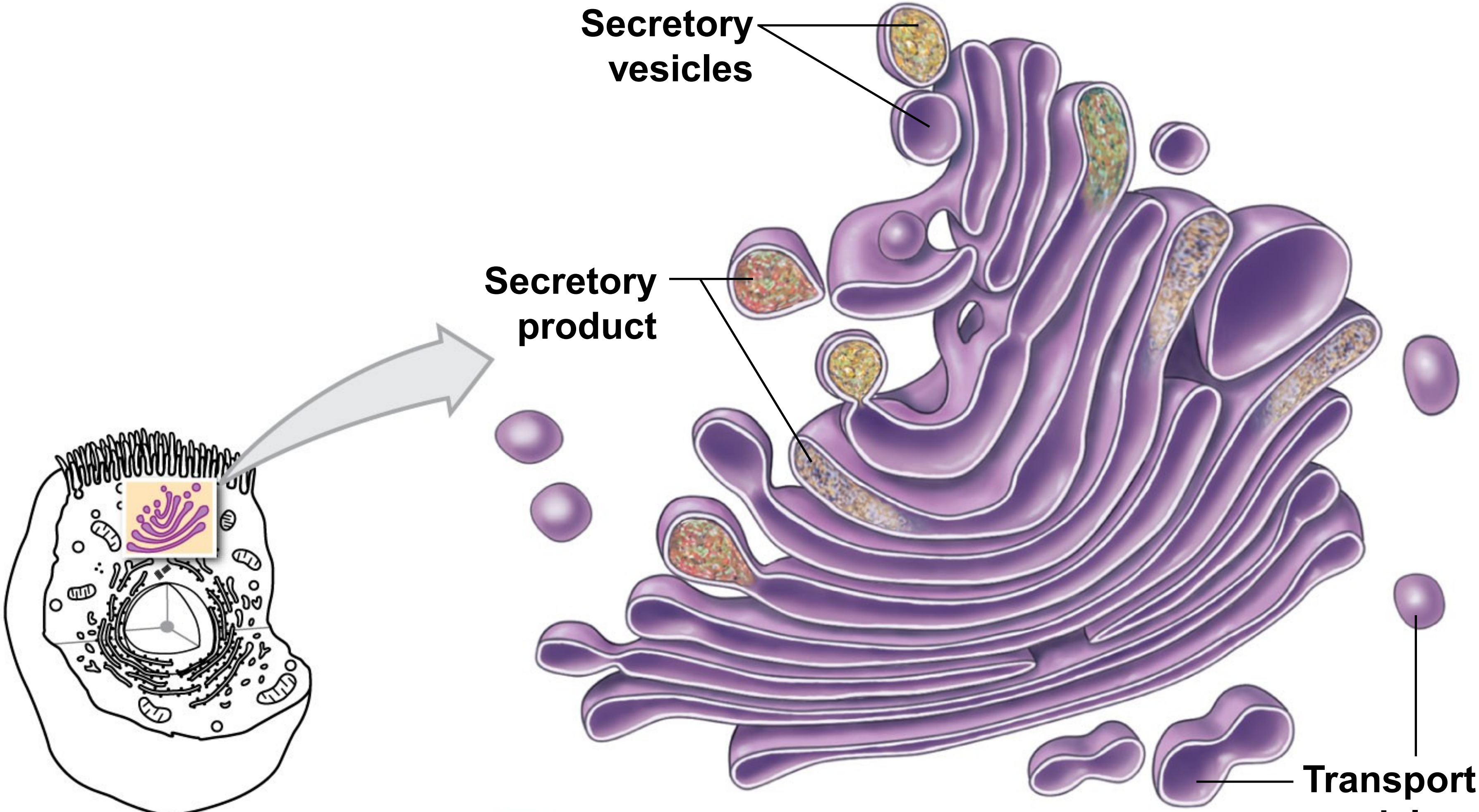


b Rough endoplasmic reticulum and free ribosomes in the cytoplasm of a cell.

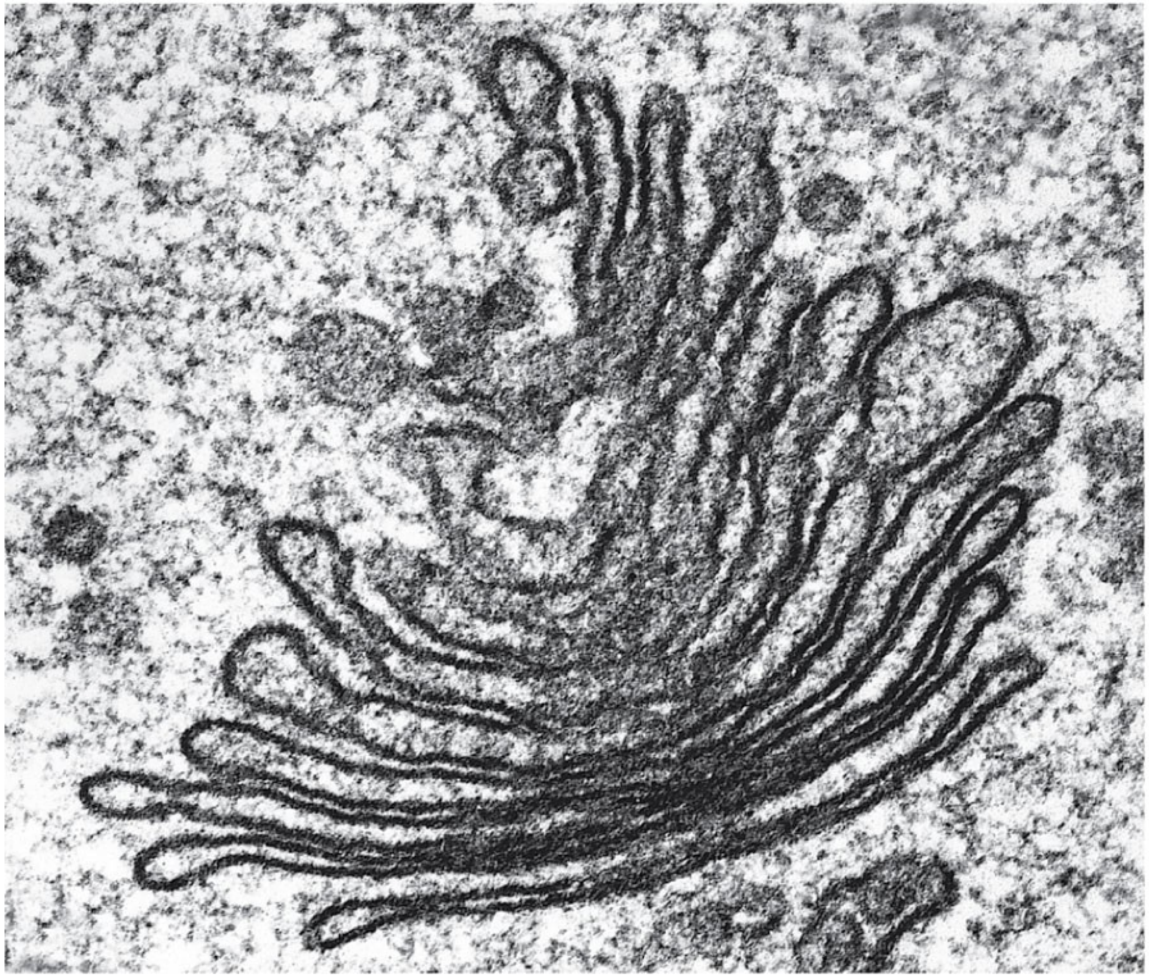
3-2 Organelles and the Cytoplasm

- **Golgi Apparatus**
  - Vesicles enter forming face and exit maturing face
  - Functions
    1. Modifies and packages secretions
        - Hormones or enzymes
        - Released through exocytosis
    2. Renews or modifies the plasma membrane
    3. Packages special enzymes within vesicles for use in the cytoplasm

Figure 3-6a The Golgi Apparatus



a Here is a three-dimensional view of the Golgi apparatus with a cut edge.



Golgi apparatus TEM × 42,000

b This is a sectional view of the Golgi apparatus of an active secretory cell.

Figure 3-7 Protein Synthesis

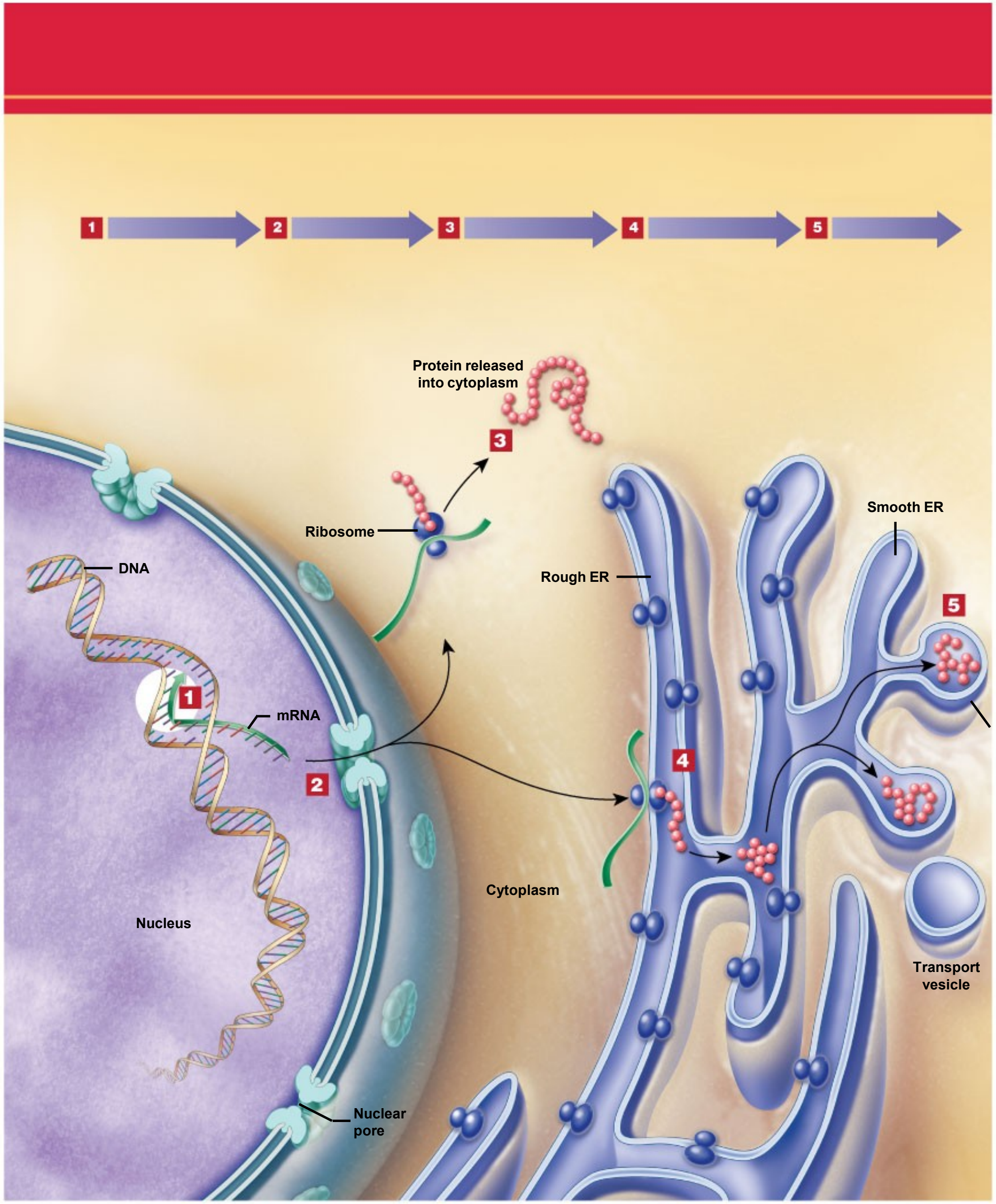


Figure 3-7 Protein Synthesis

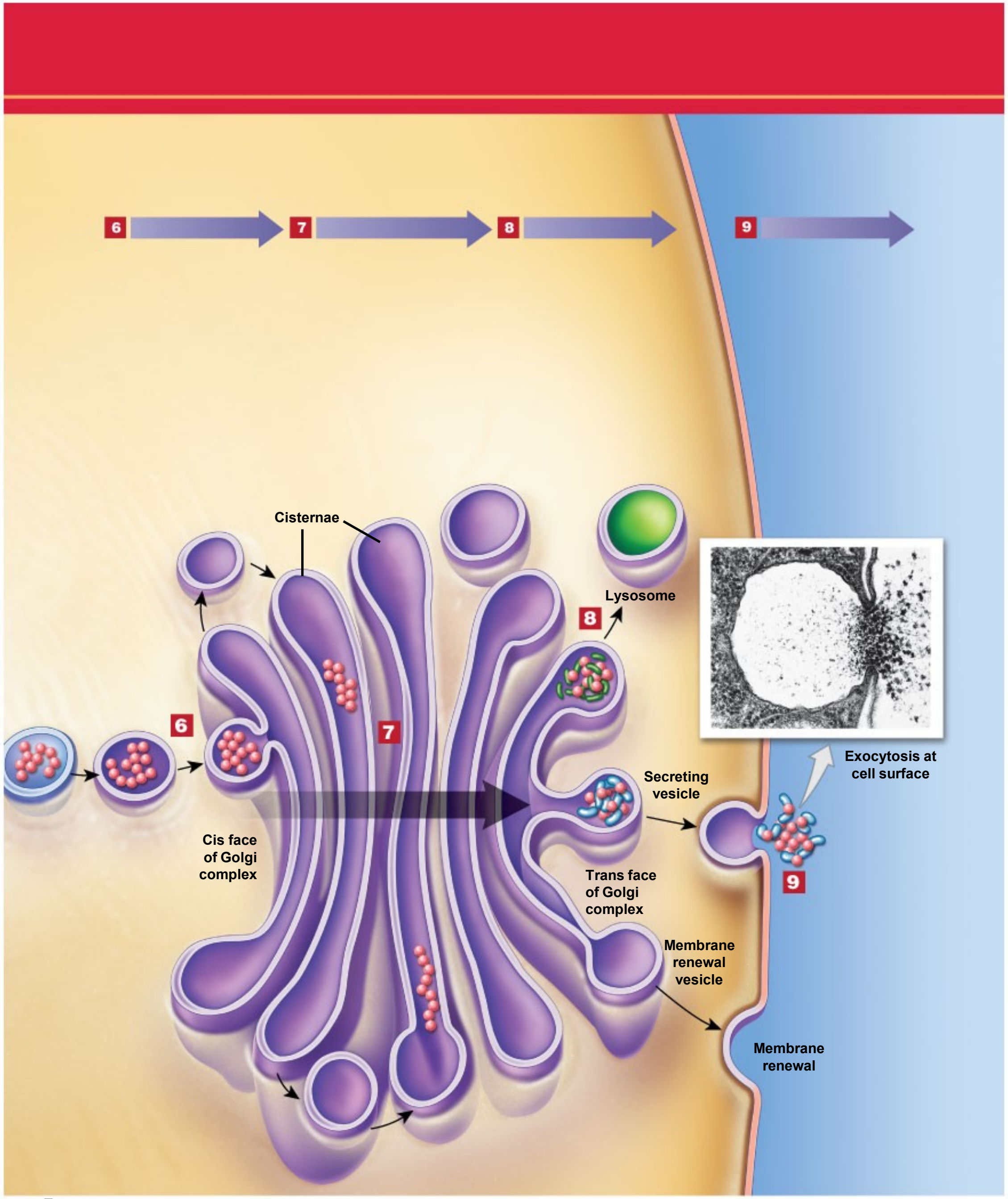


Figure 3-7 Protein Synthesis

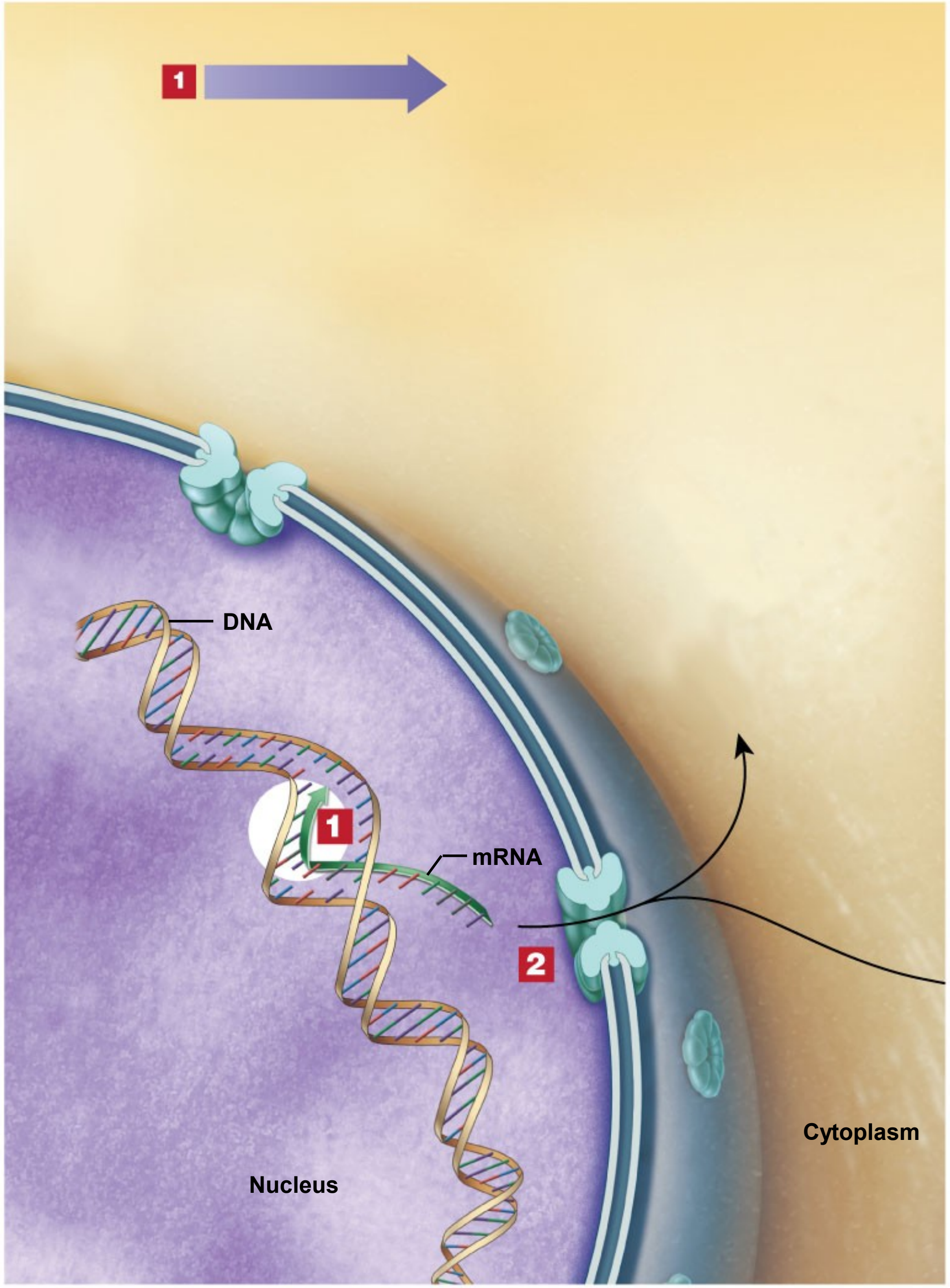


Figure 3-7 Protein Synthesis

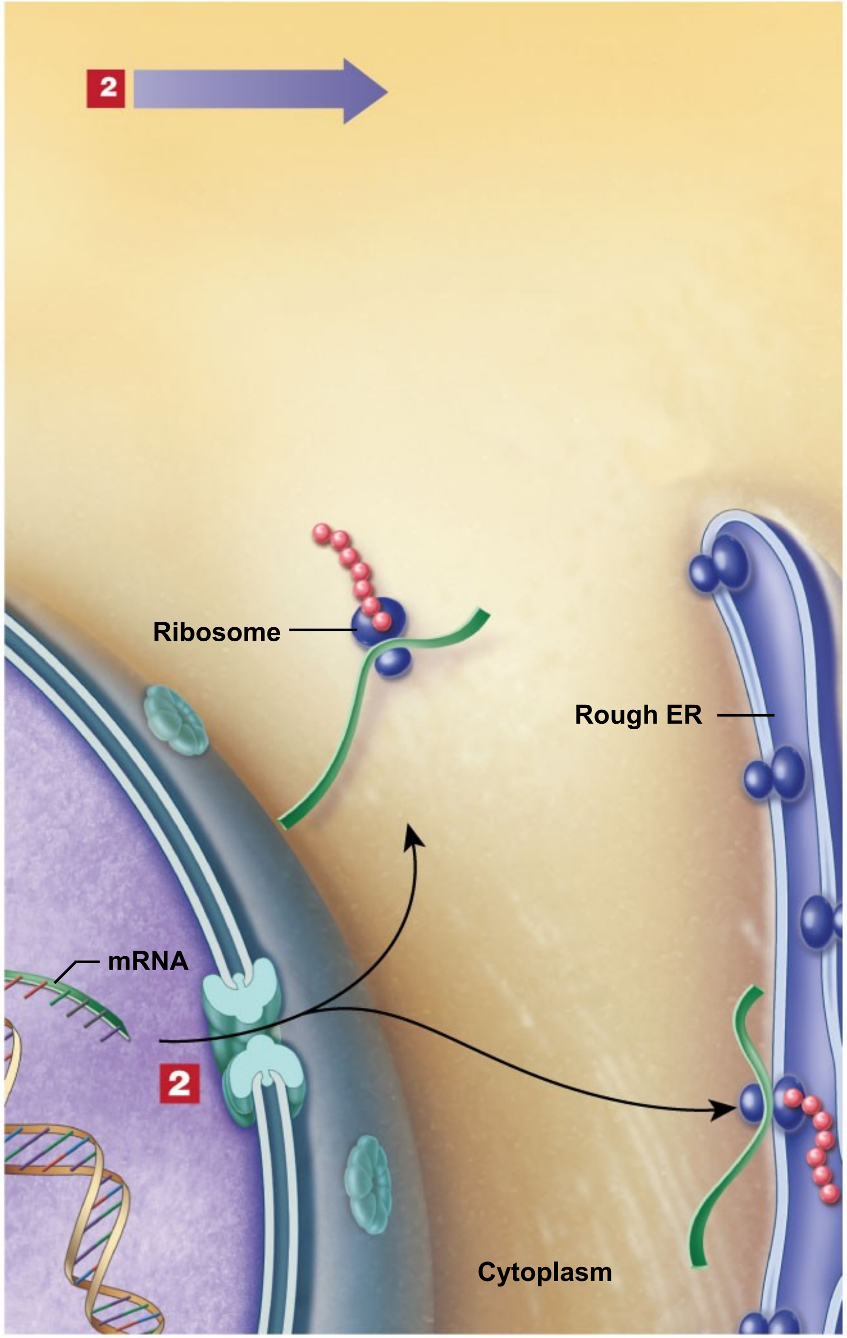


Figure 3-7 Protein Synthesis

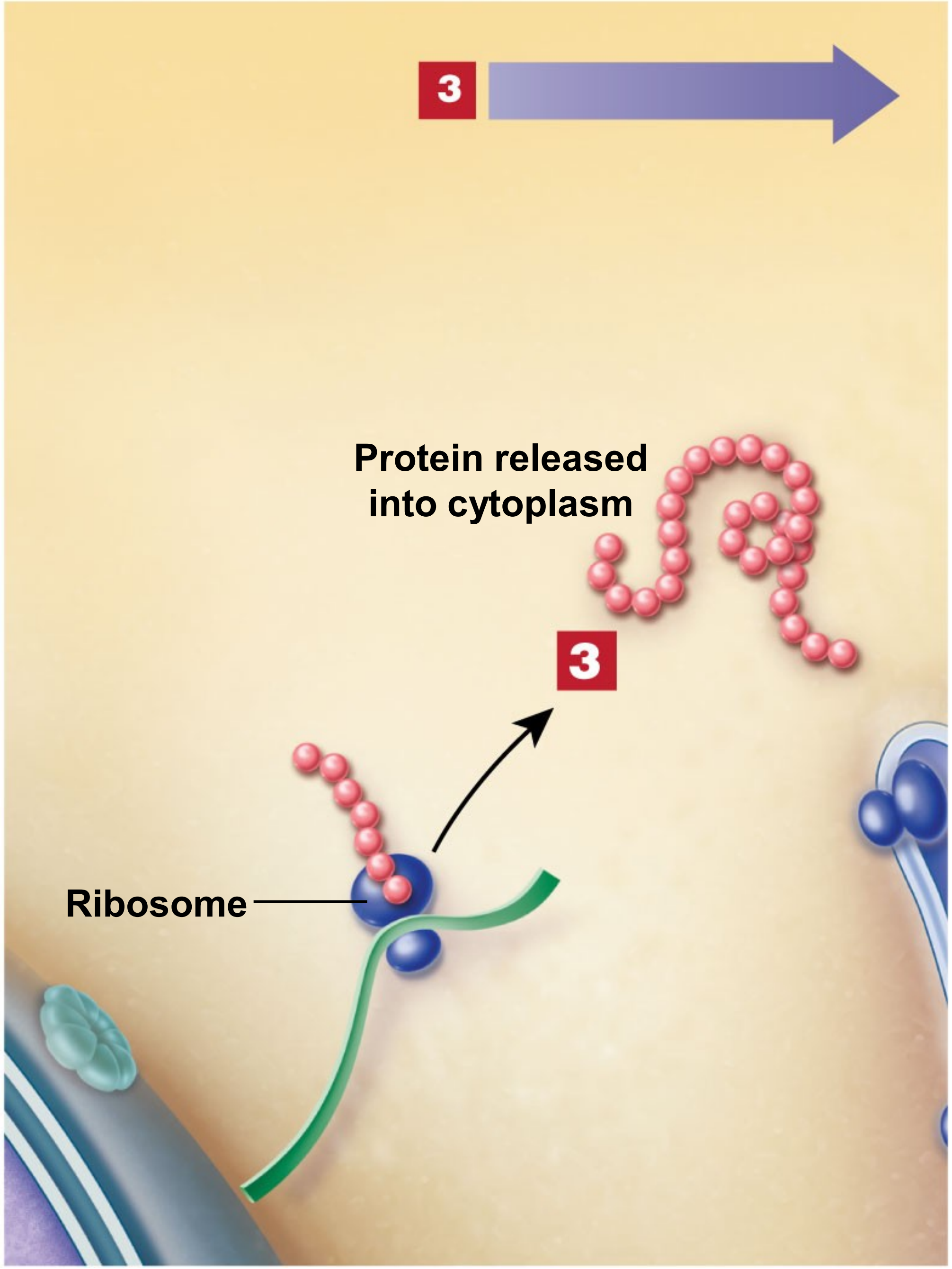


Figure 3-7 Protein Synthesis

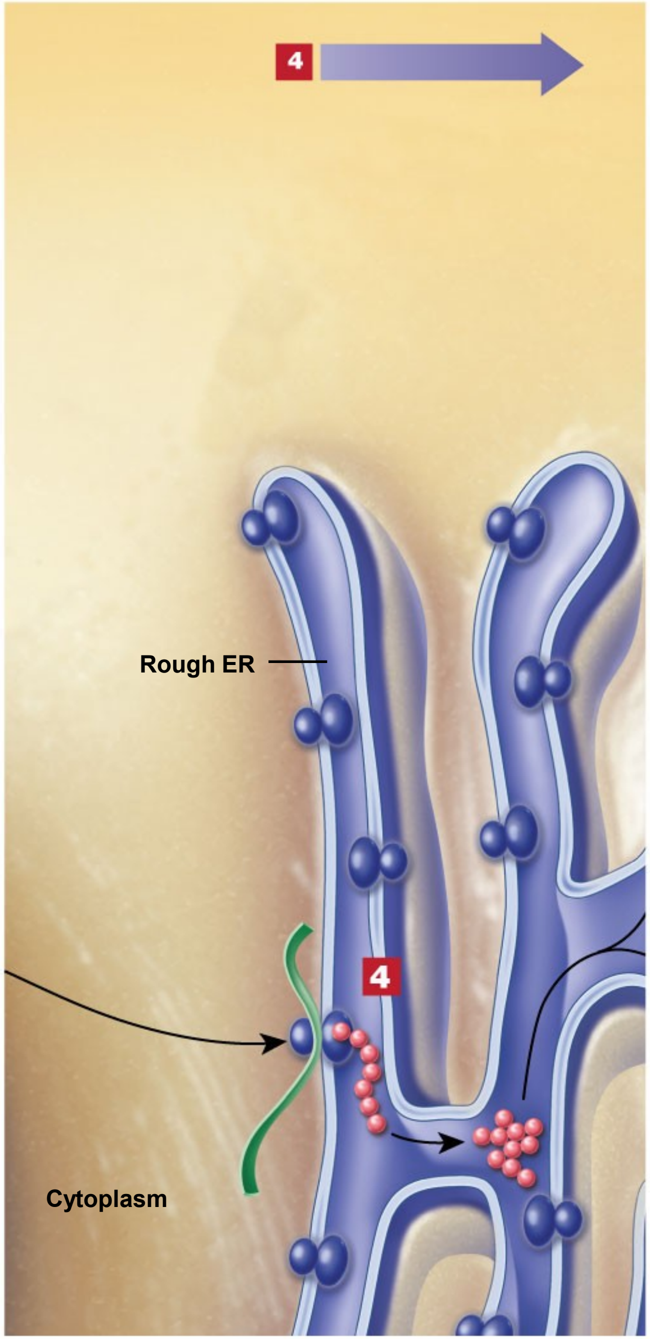


Figure 3-7 Protein Synthesis

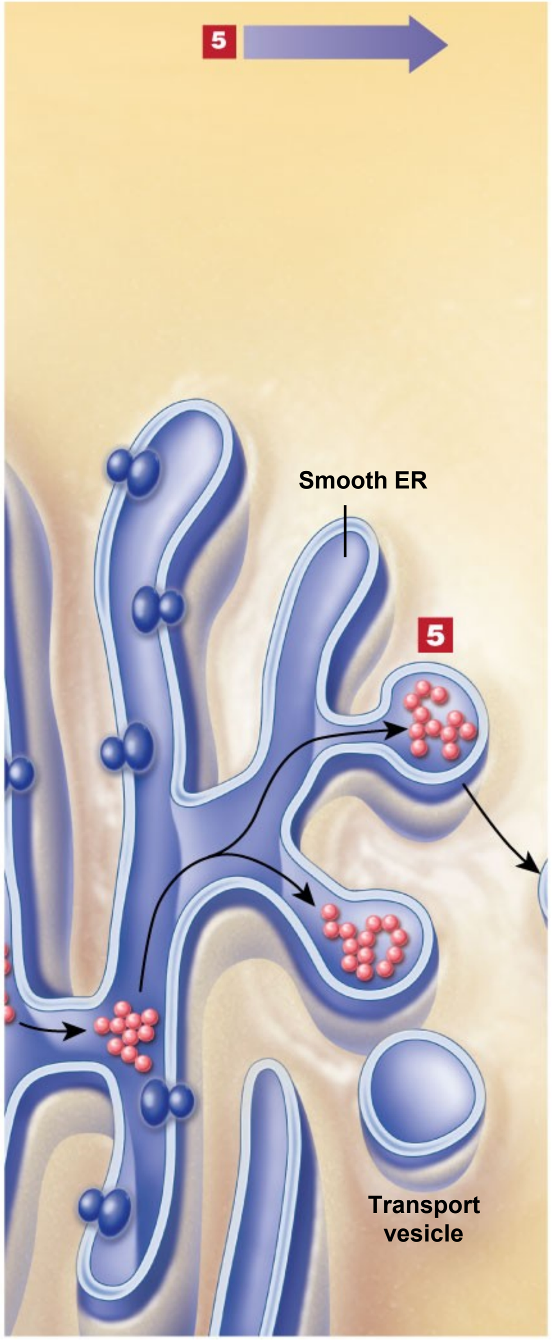
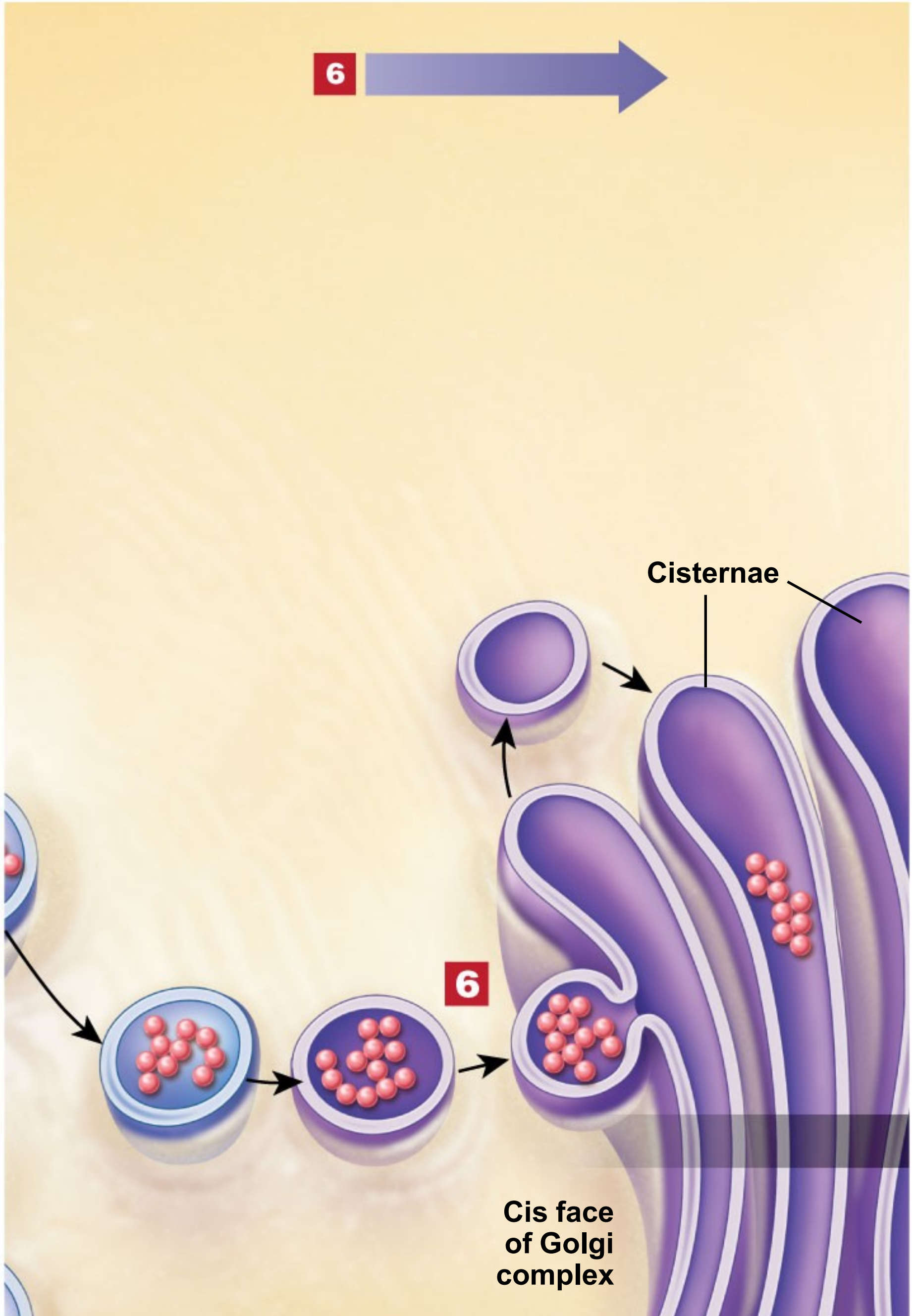


Figure 3-7 Protein Synthesis



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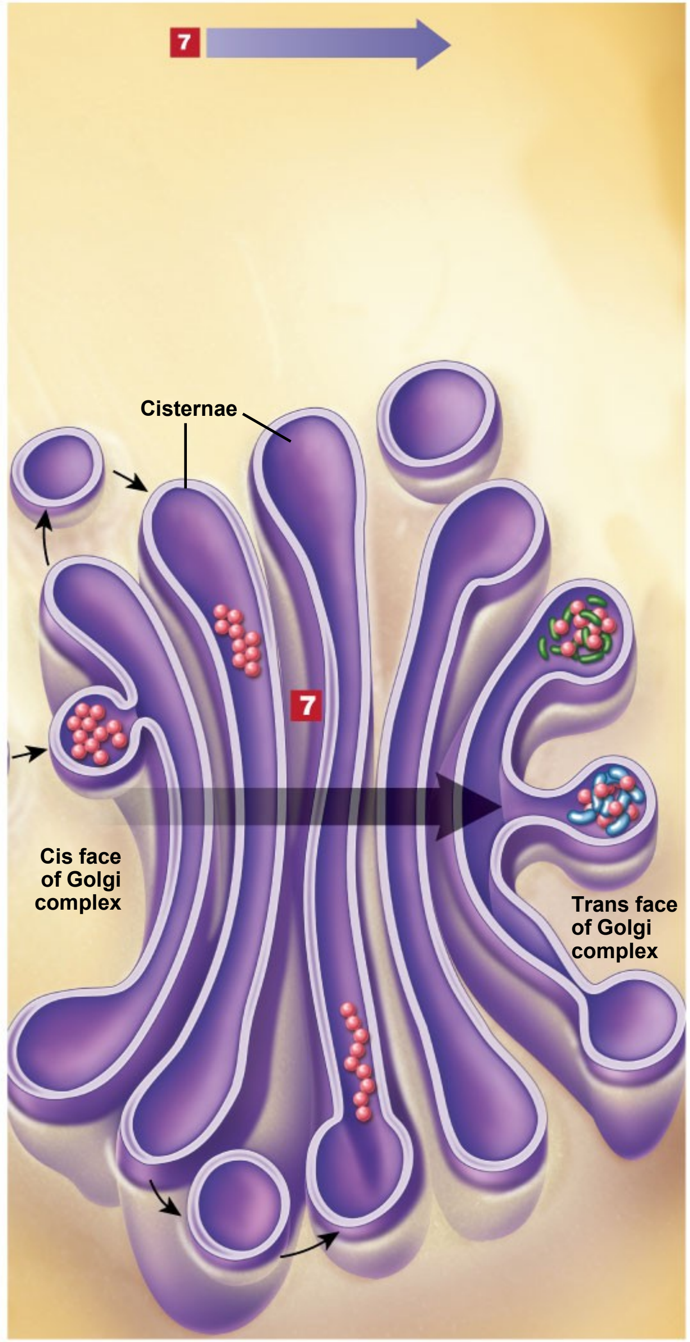


Figure 3-7 Protein Synthesis

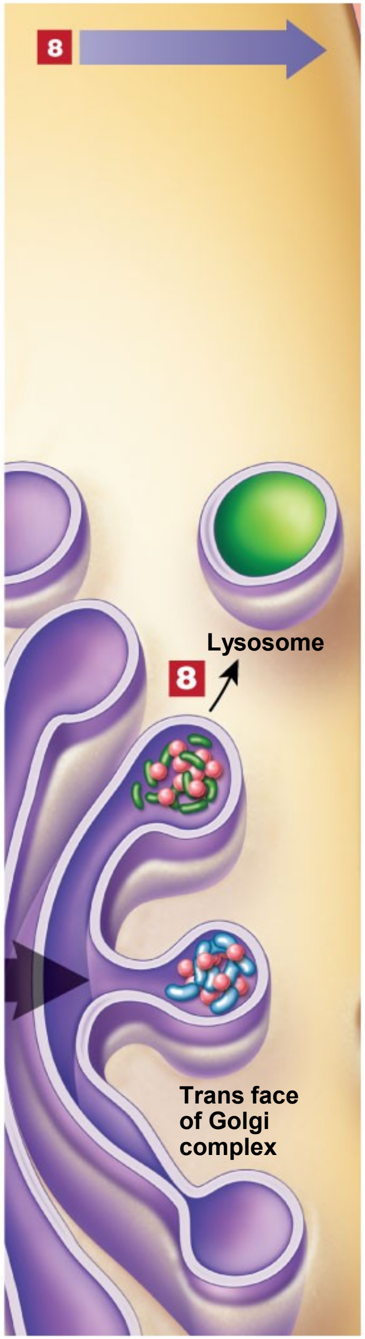
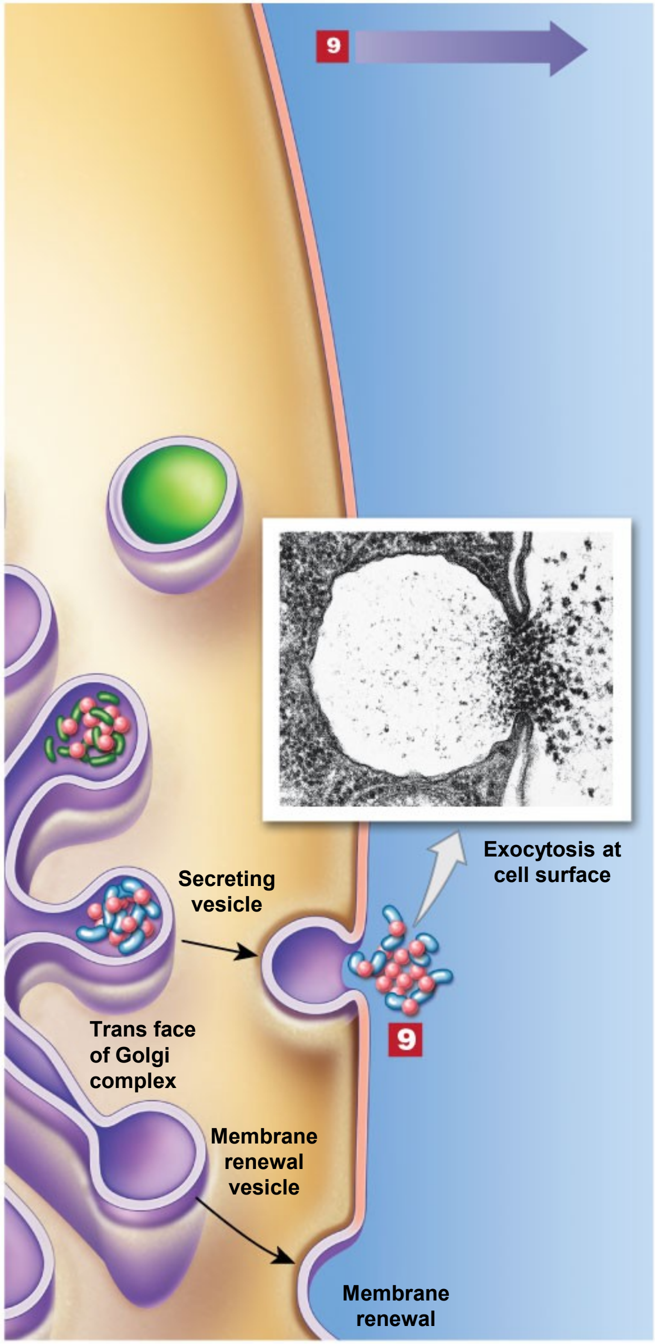


Figure 3-7 Protein Synthesis



3-2 Organelles and the Cytoplasm

- **Lysosomes**
  - Powerful enzyme-containing vesicles
    - *Lyso-* = dissolve, *soma* = body
  - *Primary lysosome*
    - Formed by Golgi apparatus and inactive enzymes
  - *Secondary lysosome*
    - Lysosome fused with damaged organelle
    - Digestive enzymes activated
    - Toxic chemicals isolated

3-2 Organelles and the Cytoplasm

- Lysosomes
  - Functions
    1. Clean up inside cells
    2. **Autolysis**

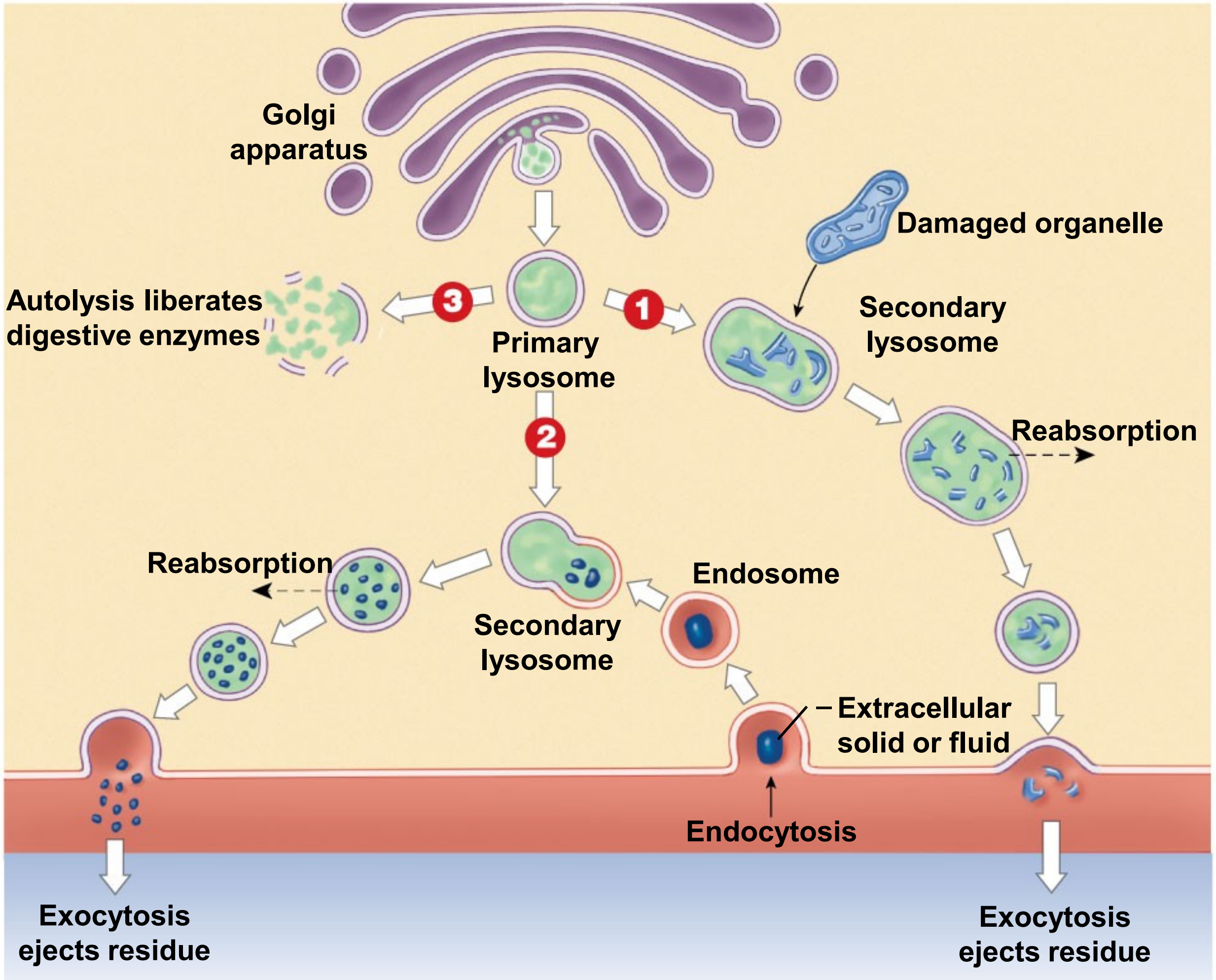
3-2 Organelles and the Cytoplasm

- Clean Up inside Cells
  - Break down large molecules
  - Attack bacteria
  - Recycle damaged organelles
  - Eject wastes by exocytosis

3-2 Organelles and the Cytoplasm

- **Autolysis**
  - *Auto-* = self, *lysis* = break
  - Self-destruction of damaged cells
    - Lysosome membranes break down
    - Digestive enzymes released
    - Cell decomposes
    - Cellular materials recycle

Figure 3-8 Lysosome Functions



Activation of lysosomes occurs when:

1. A primary lysosome fuses with the membrane of another organelle, such as a mitochondrion
2. A primary lysosome fuses with an endosome containing fluid or solid materials from outside the cell
3. The lysosomal membrane breaks down during autolysis following injury to, or death of, the cell

3-2 Organelles and the Cytoplasm

- **Peroxisomes**
  - Are enzyme-containing vesicles
    - Break down fatty acids, organic compounds
    - Produce hydrogen peroxide (H_2O_2)
    - Replicate by division

3-2 Organelles and the Cytoplasm

- **Membrane Flow**
  - A continuous exchange of membrane parts by vesicles
    - All membranous organelles (except mitochondria)
    - Allows adaptation and change

3-2 Organelles and the Cytoplasm

- **Mitochondria**
  - Have smooth outer membrane and inner membrane with numerous folds (**cristae**)
  - **Matrix**
    - Fluid around cristae
  - *Mitochondrion* takes chemical energy from food (glucose)
    - Produces energy molecule ATP

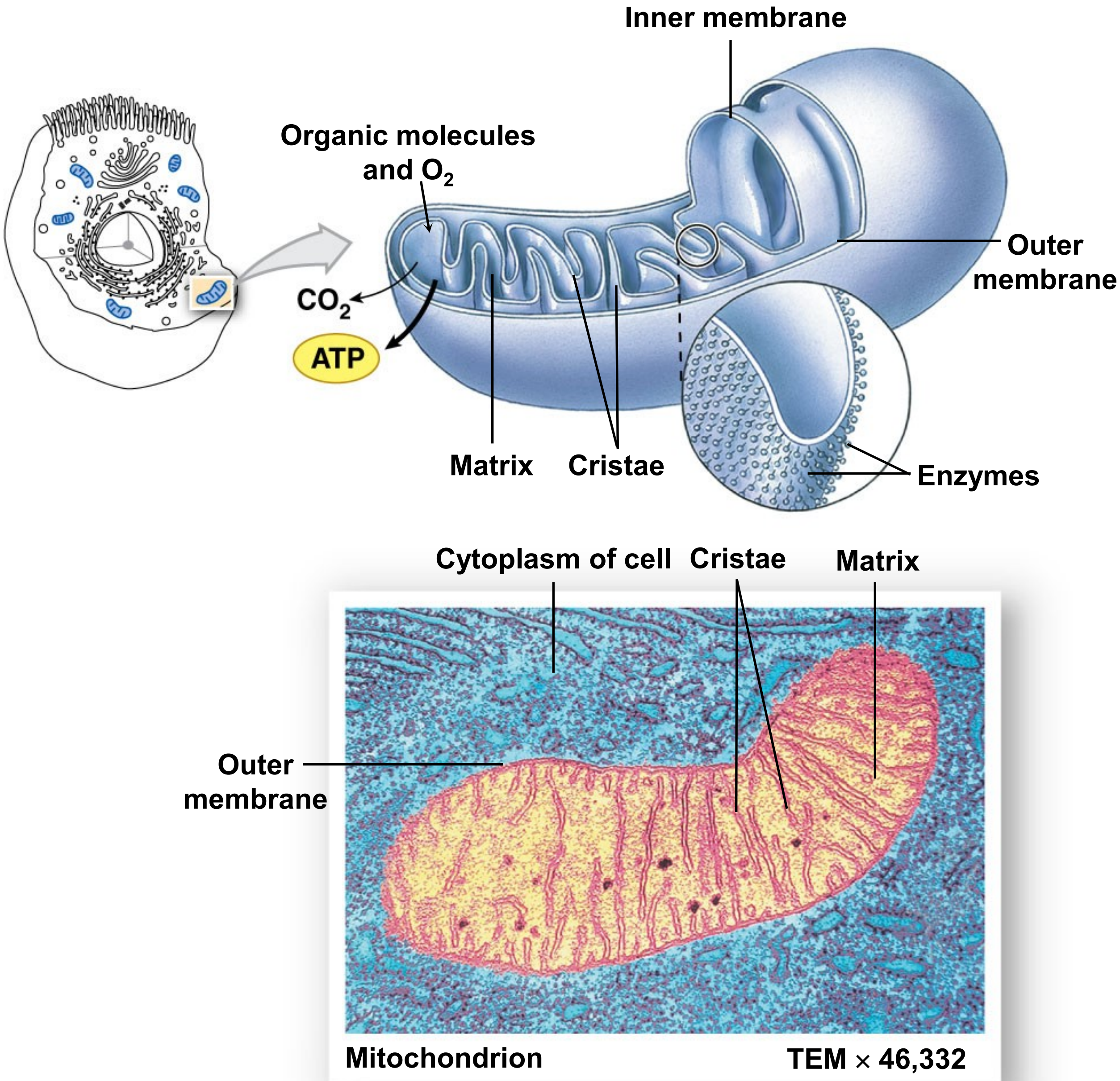
3-2 Organelles and the Cytoplasm

- Mitochondrial Energy Production
  - **Glycolysis**
    - Glucose to pyruvic acid (in cytosol)
  - Citric acid cycle (also known as the *Krebs cycle* and the *tricarboxylic acid cycle* or *TCA cycle*)
    - Pyruvic acid to CO_2 (in matrix)
  - Electron transport chain
    - Inner mitochondrial membrane

3-2 Organelles and the Cytoplasm

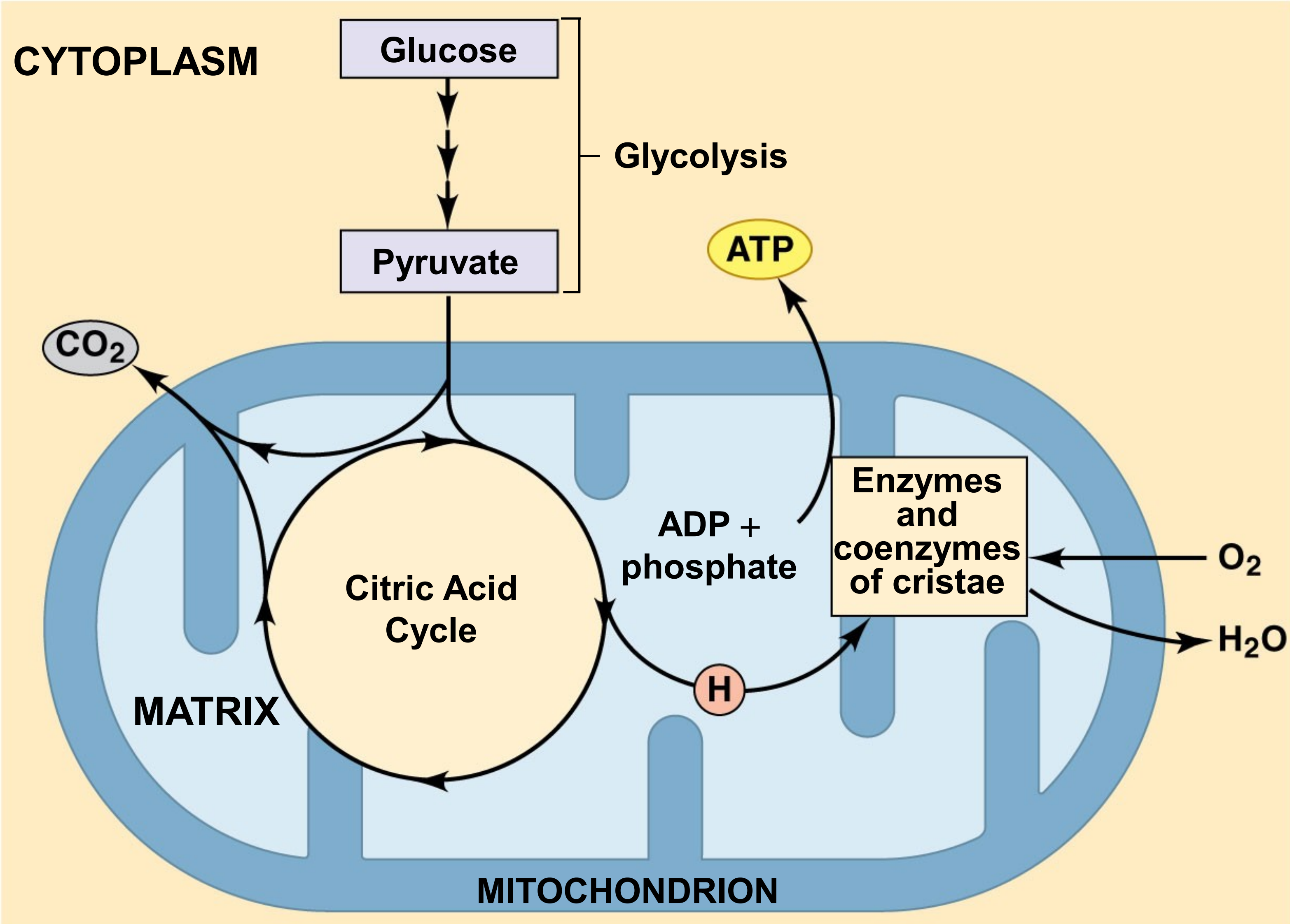
- Mitochondrial Energy Production
  - Called **aerobic metabolism** (cellular respiration)
    - Mitochondria use oxygen to break down food and produce ATP
    - Glucose + oxygen + ADP $\rightarrow$ carbon dioxide + water + ATP

Figure 3-9a Mitochondria



a Shown here is the three-dimensional organization and a color-enhanced TEM of a typical mitochondrion in section.

Figure 3-9b Mitochondria

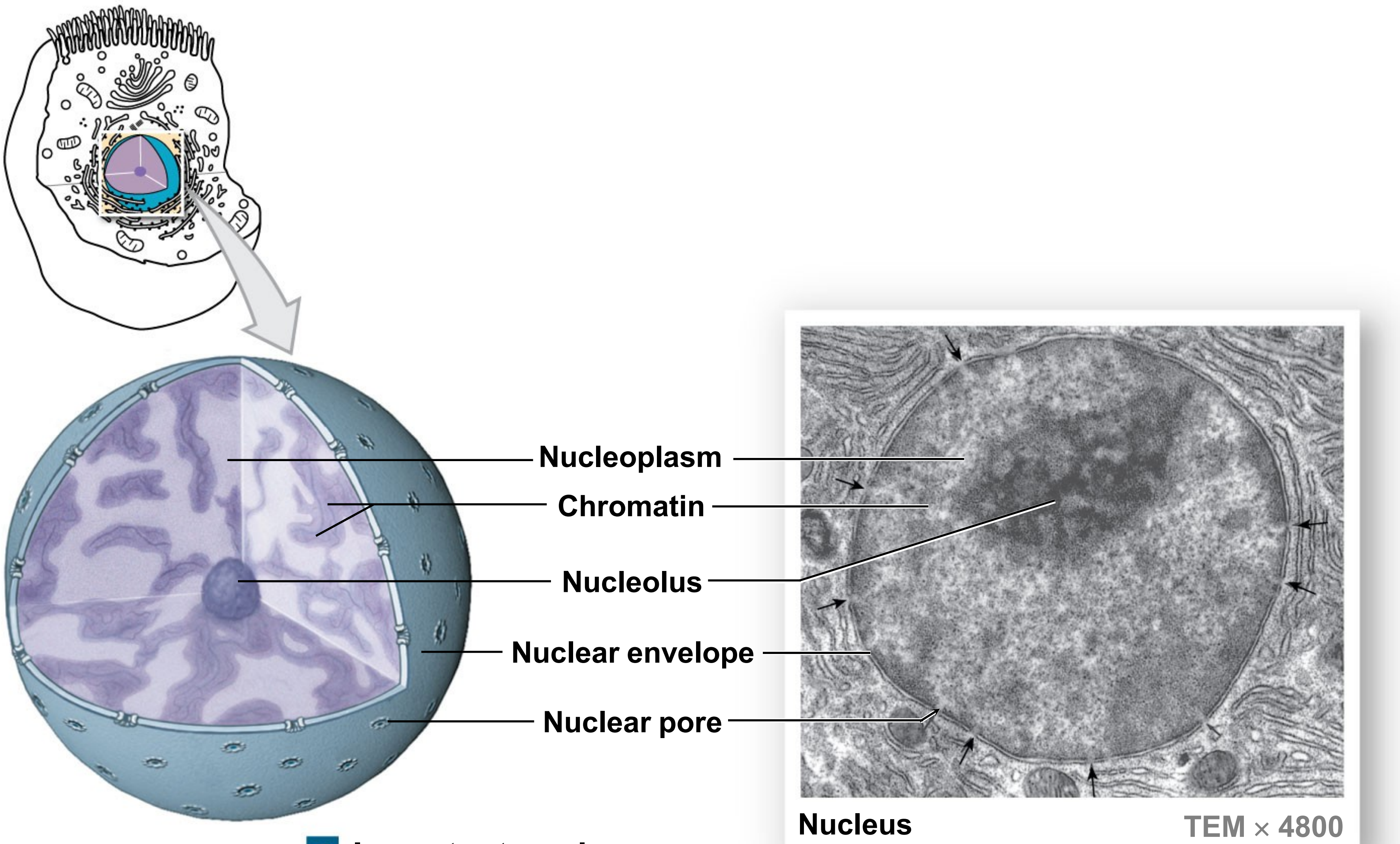


b This is an overview of the role of mitochondria in energy production. Mitochondria absorb short carbon chains (such as pyruvate) and oxygen and generate carbon dioxide and ATP.

3-3 Cell Nucleus

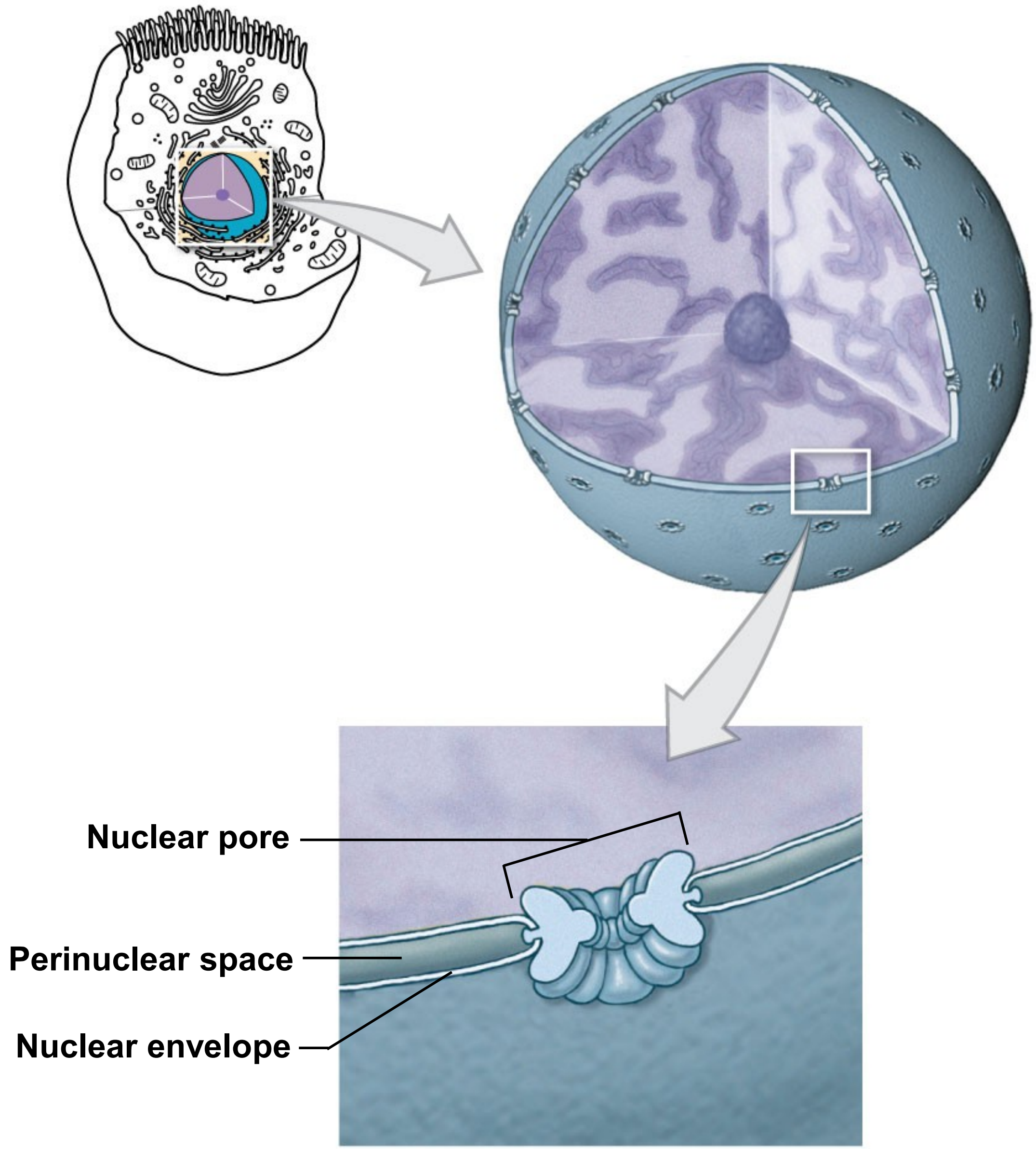
- **Nucleus**
  - Largest organelle
  - The cell's control center
  - **Nuclear envelope**
    - Double membrane around the nucleus
  - **Perinuclear space**
    - Between the two layers of the nuclear envelope
  - **Nuclear pores**
    - Communication passages

Figure 3-10a The Nucleus

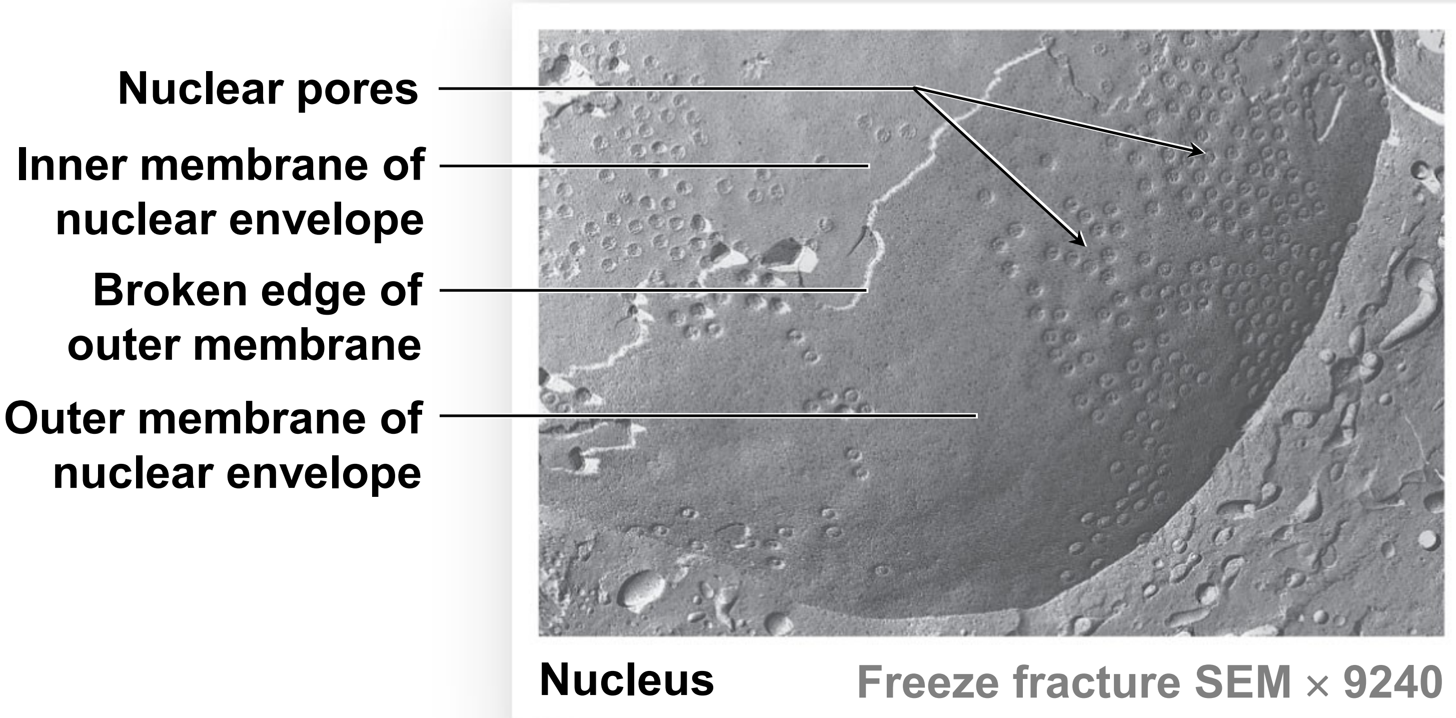


a Important nuclear structures are shown here.

Figure 3-10b The Nucleus



b A nuclear pore is a large protein complex that spans the nuclear envelope.



c This cell was frozen and then broken apart to make its internal structures visible. The technique, called *freeze fracture* or *freeze-etching*, provides a unique perspective on the internal organization of cells. The nuclear envelope and nuclear pores are visible. The fracturing process broke away part of the outer membrane of the nuclear envelope, and the cut edge of the nucleus can be seen.

3-3 Cell Nucleus

- Contents of the Nucleus
  - DNA
    - All information to build and run organisms
  - *Nucleoplasm*
    - Fluid containing ions, enzymes, nucleotides, and some RNA
  - **Nuclear matrix**
    - Support filaments

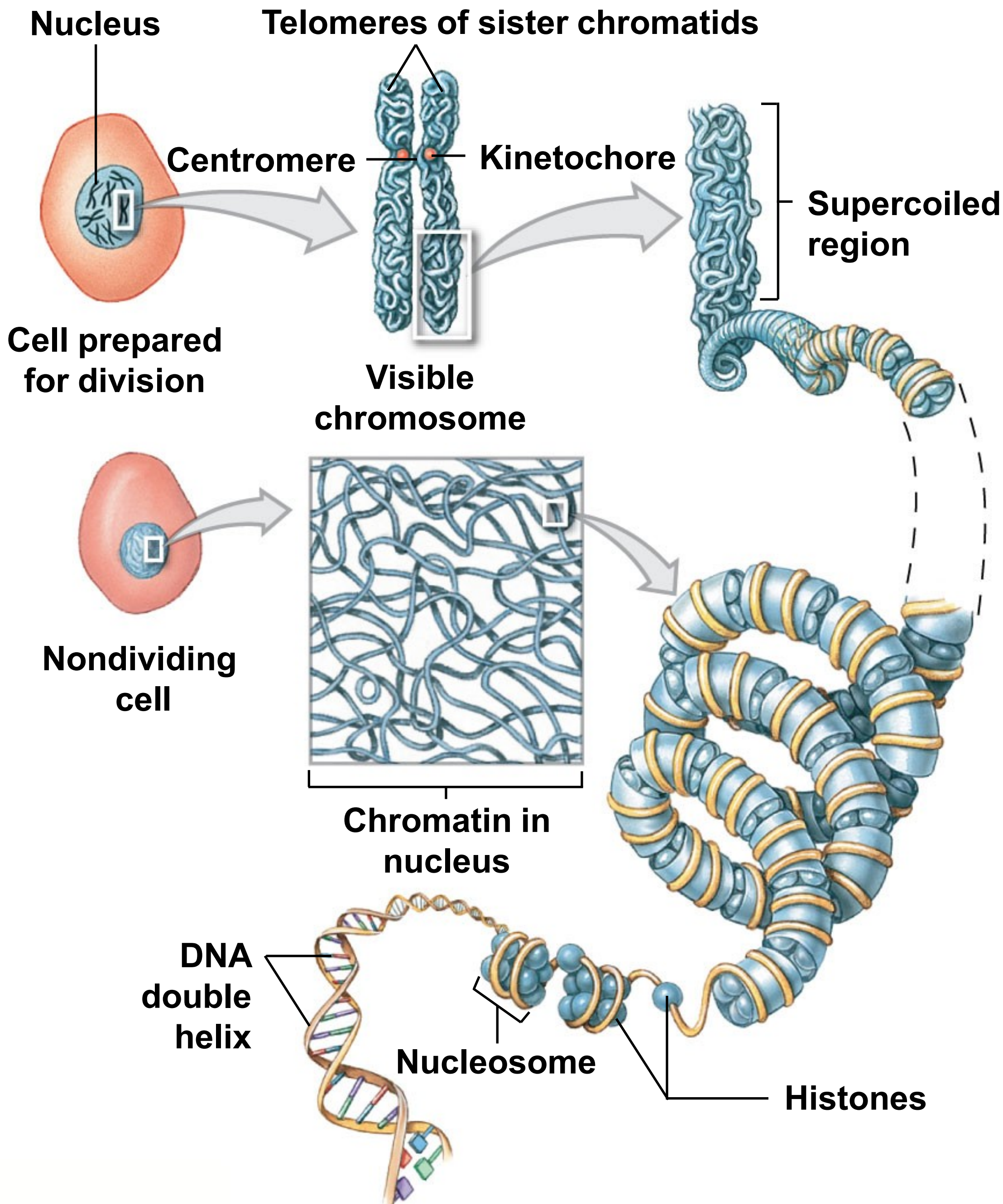
3-3 Cell Nucleus

- Contents of the Nucleus
  - **Nucleoli**
    - Are related to protein production
    - Are made of RNA, enzymes, and **histones**
    - Synthesize rRNA and ribosomal subunits
  - **Nucleosomes**
    - DNA coiled around histones

3-3 Cell Nucleus

- Contents of the Nucleus
  - **Chromatin**
    - Loosely coiled DNA (cells not dividing)
  - **Chromosomes**
    - Tightly coiled DNA (cells dividing)

Figure 3-11 The Organization of DNA within the Nucleus



3-3 Cell Nucleus

- Information Storage in the Nucleus
  - DNA
    - Instructions for every protein in the body
  - **Gene**
    - DNA instructions for one protein
  - **Genetic code**
    - The chemical language of DNA instructions
      - Sequence of bases (A, T, C, G)
    - Triplet code
      - 3 bases = 1 amino acid

3-4 Protein Synthesis

- The Role of Gene Activation in Protein Synthesis
  - The nucleus contains chromosomes
  - Chromosomes contain DNA
  - DNA stores genetic instructions for proteins
  - Proteins determine cell structure and function

3-4 Protein Synthesis

- The Role of Gene Activation in Protein Synthesis
  - **Gene activation** – uncoiling DNA to use it
    - Promoter
    - Terminator
  - **Transcription**
    - Copies instructions from DNA to mRNA (in nucleus)
    - **RNA polymerase** produces **messenger RNA (mRNA)**

3-4 Protein Synthesis

- The Role of Gene Activation in Protein Synthesis
  - Translation
    - Ribosome reads code from mRNA (in cytoplasm)
    - Assembles amino acids into polypeptide chain
  - Processing
    - RER and Golgi apparatus produce protein

3-4 Protein Synthesis

- The Transcription of mRNA
  - A gene is *transcribed* to mRNA in three steps
    1. **Gene activation**
    2. **DNA to mRNA**
    3. **RNA processing**

3-4 Protein Synthesis

- **Step 1: Gene activation**
  - Uncoils DNA, removes histones
  - Start (promoter) and stop codes on DNA mark location of gene
    - **Coding strand** is code for protein
    - **Template strand** is used by RNA polymerase molecule

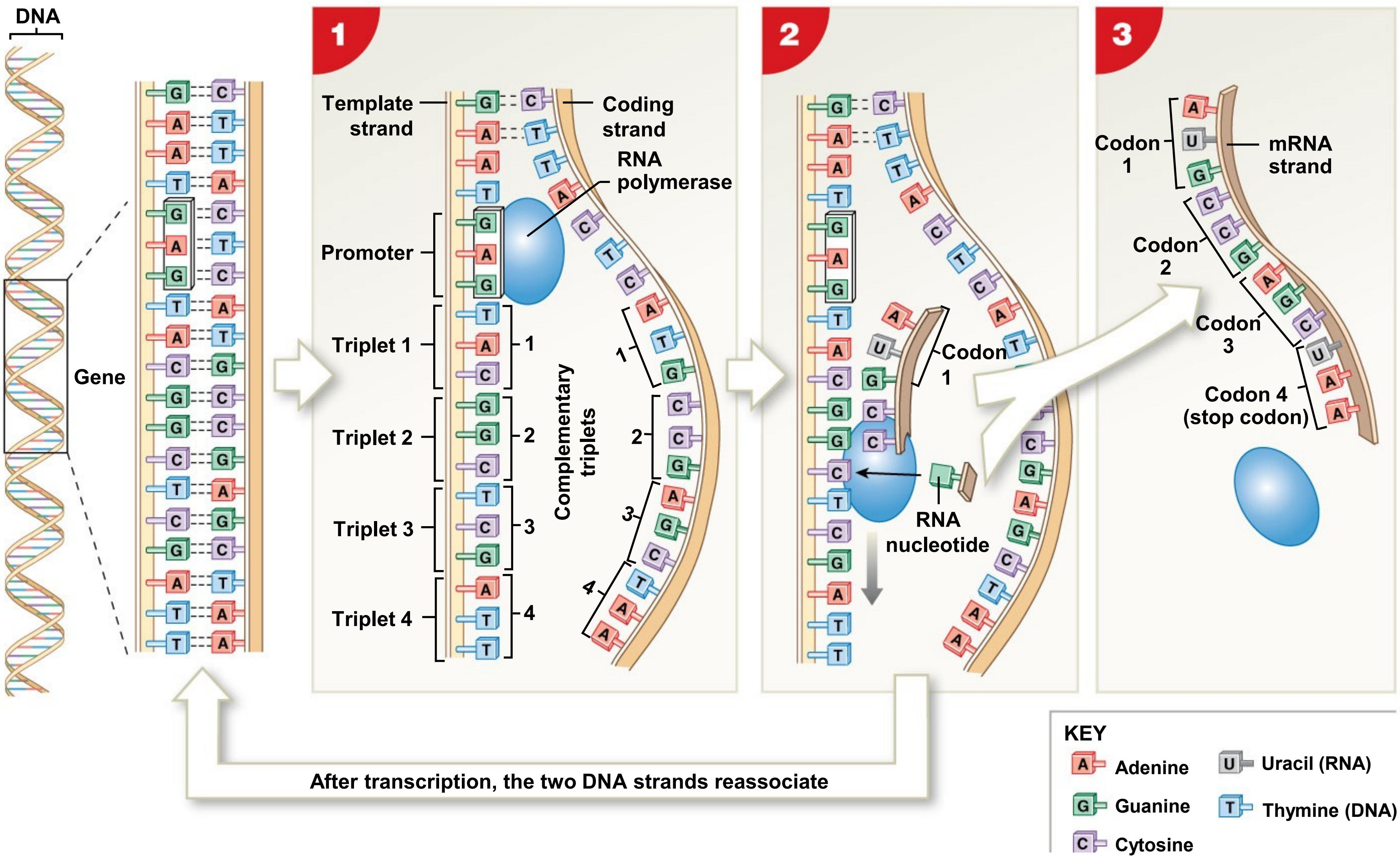
3-4 Protein Synthesis

- **Step 2: DNA to mRNA**
  - Enzyme RNA polymerase transcribes DNA
    - Binds to promoter (*start*) sequence
    - Reads DNA code for gene
    - Binds nucleotides to form messenger RNA (mRNA)
    - mRNA duplicates DNA coding strand, uracil replaces thymine

3-4 Protein Synthesis

- **Step 3: RNA processing**
  - At *stop* signal, mRNA detaches from DNA molecule
    - Code is edited (**RNA processing**)
    - Unnecessary codes (**introns**) removed
    - Good codes (**exons**) spliced together
    - Triplet of three nucleotides (**codon**) represents one amino acid

Figure 3-12 mRNA Transcription



3-4 Protein Synthesis

- **Translation**
  - mRNA moves:
    - From the nucleus through a nuclear pore
  - mRNA moves:
    - To a ribosome in cytoplasm surrounded by amino acids
  - mRNA binds to ribosomal subunits
    - tRNA delivers amino acids to mRNA

3-4 Protein Synthesis

- **Translation**
  - tRNA **anticodon** binds to mRNA codon
    - 1 mRNA codon *translates* to 1 amino acid
  - Enzymes join amino acids with peptide bonds
    - Polypeptide chain has specific *sequence* of amino acids
  - At *stop codon*, components separate

Figure 3-13 The Process of Translation

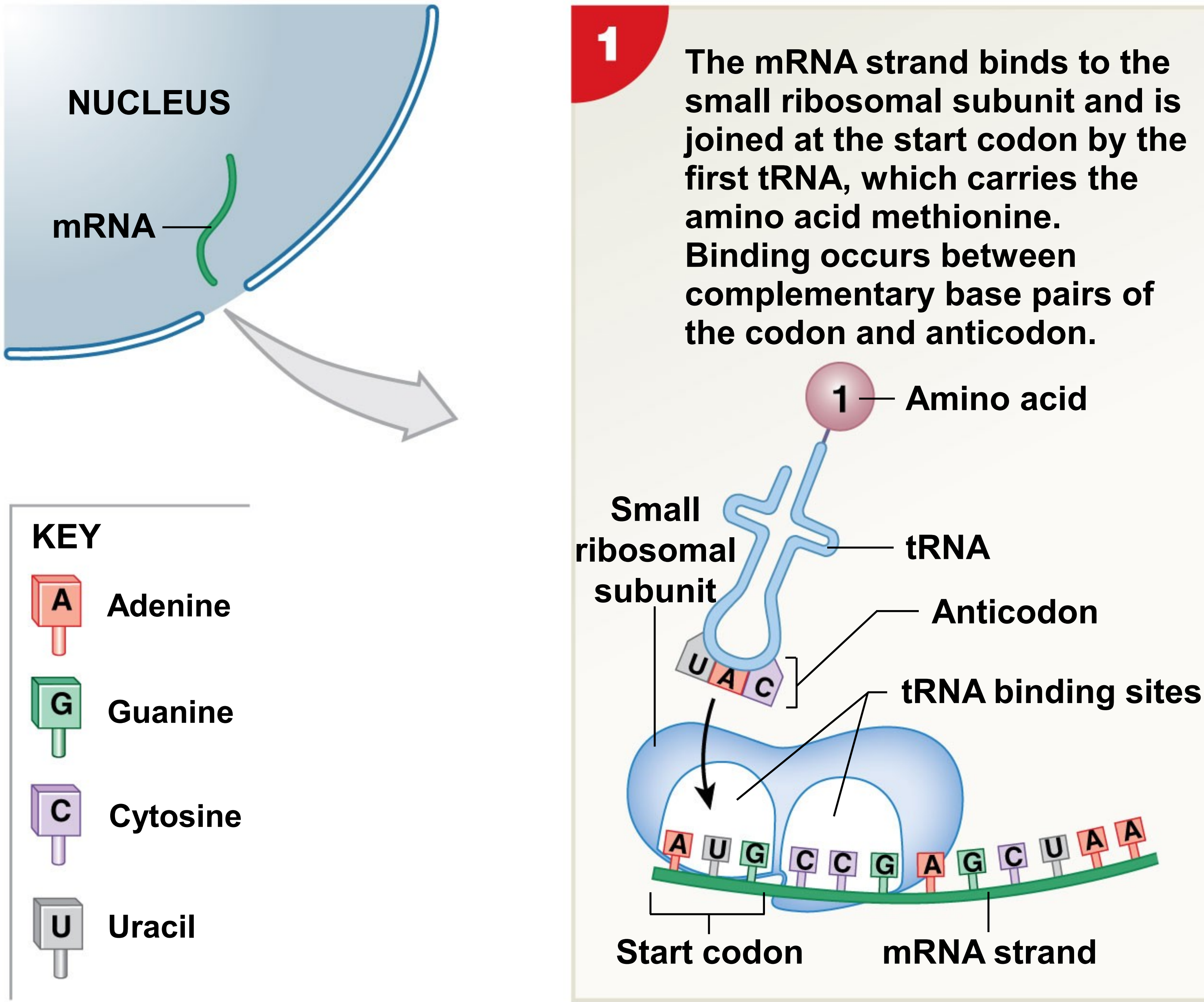


Figure 3-13 The Process of Translation

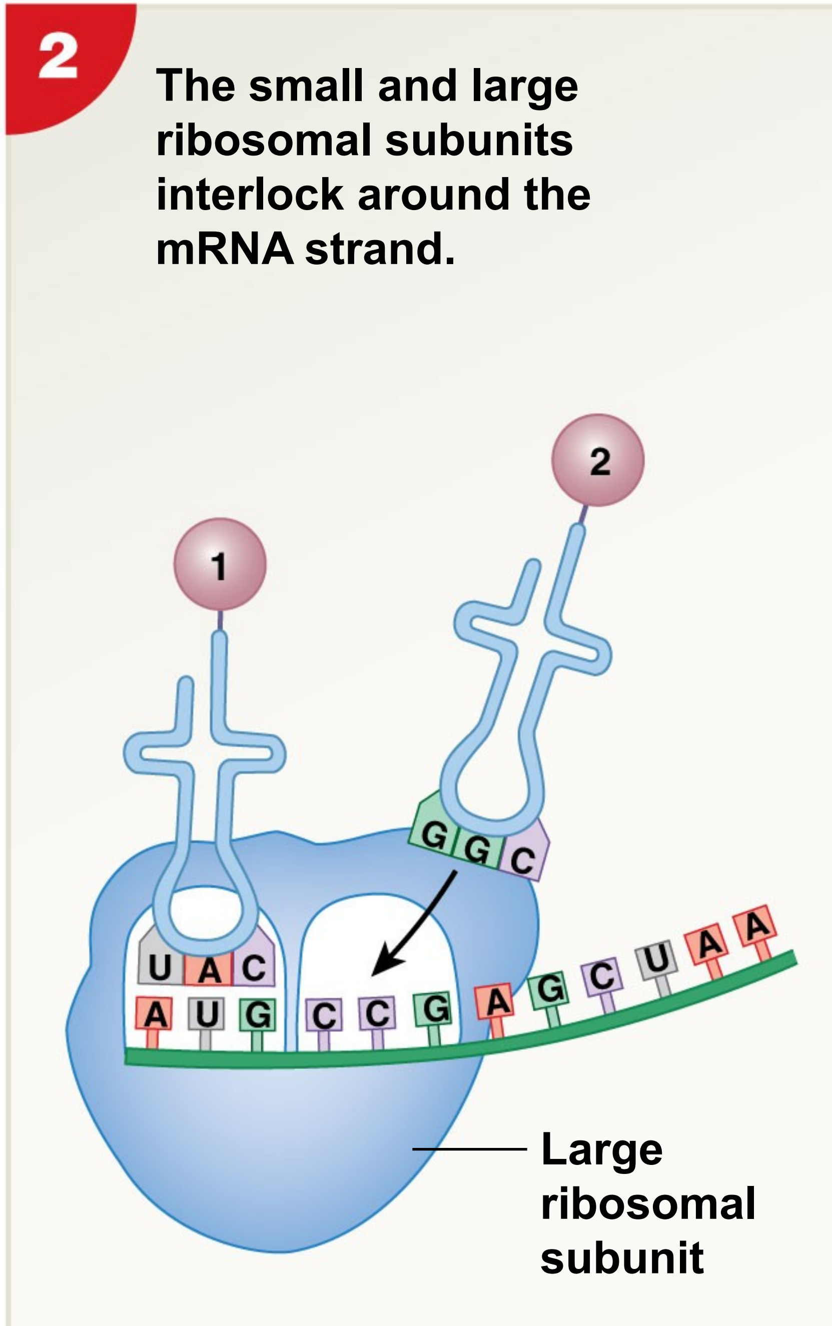


Figure 3-13 The Process of Translation

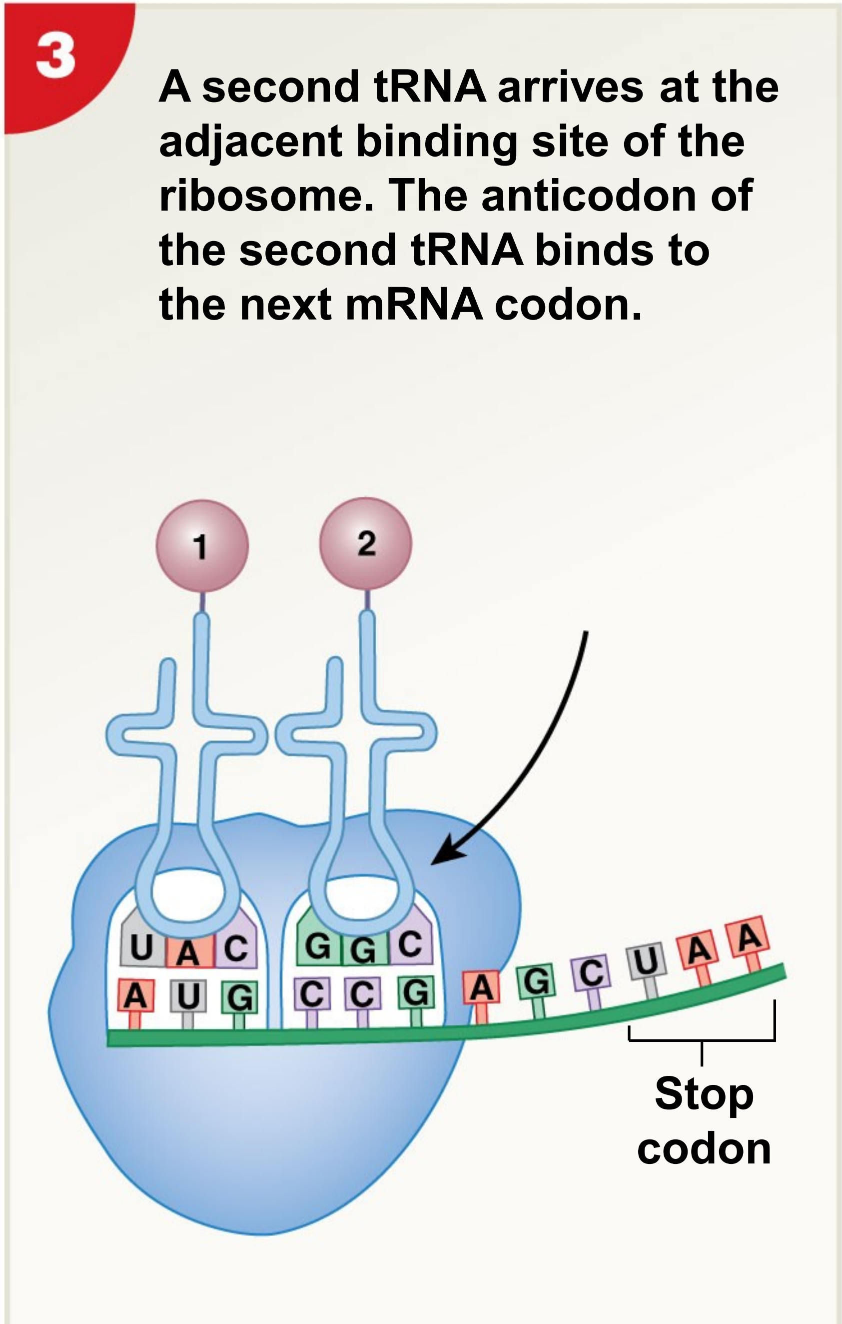


Figure 3-13 The Process of Translation

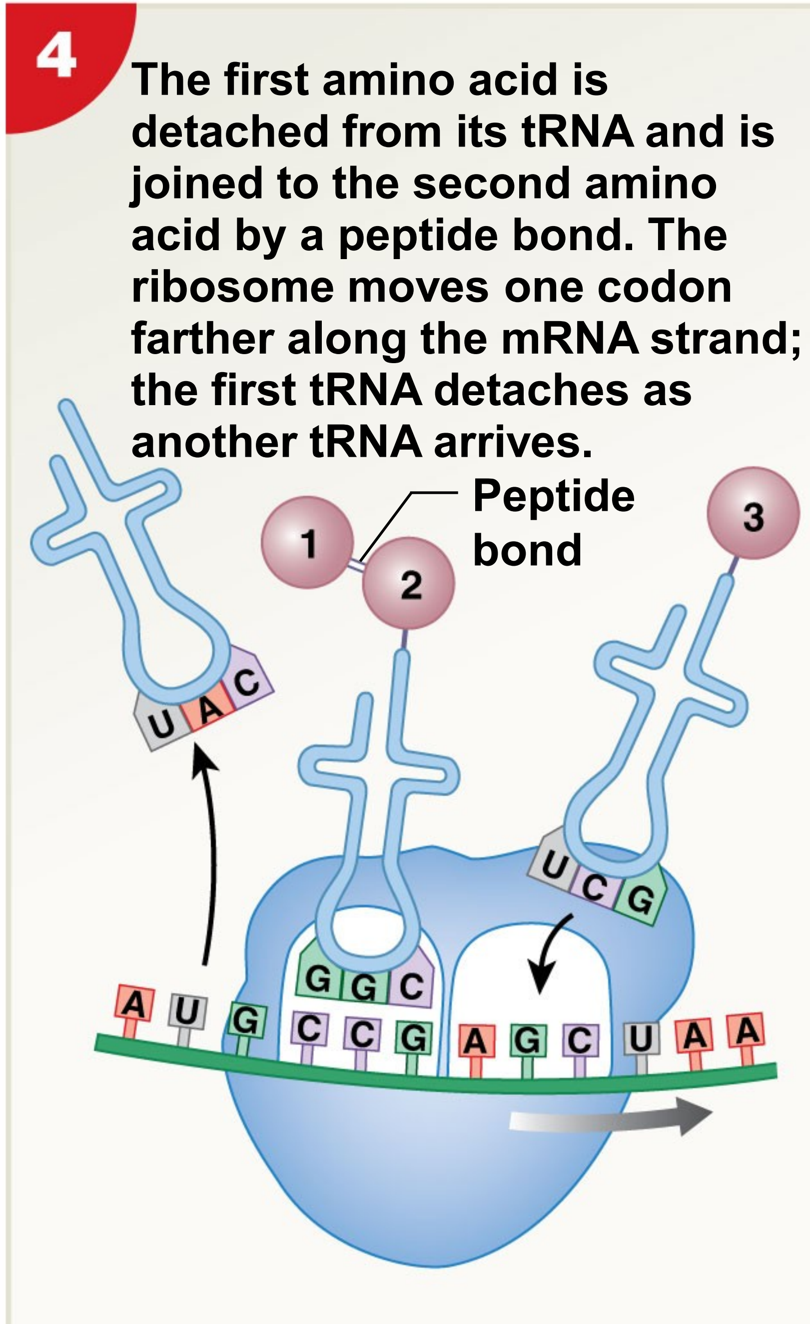


Figure 3-13 The Process of Translation

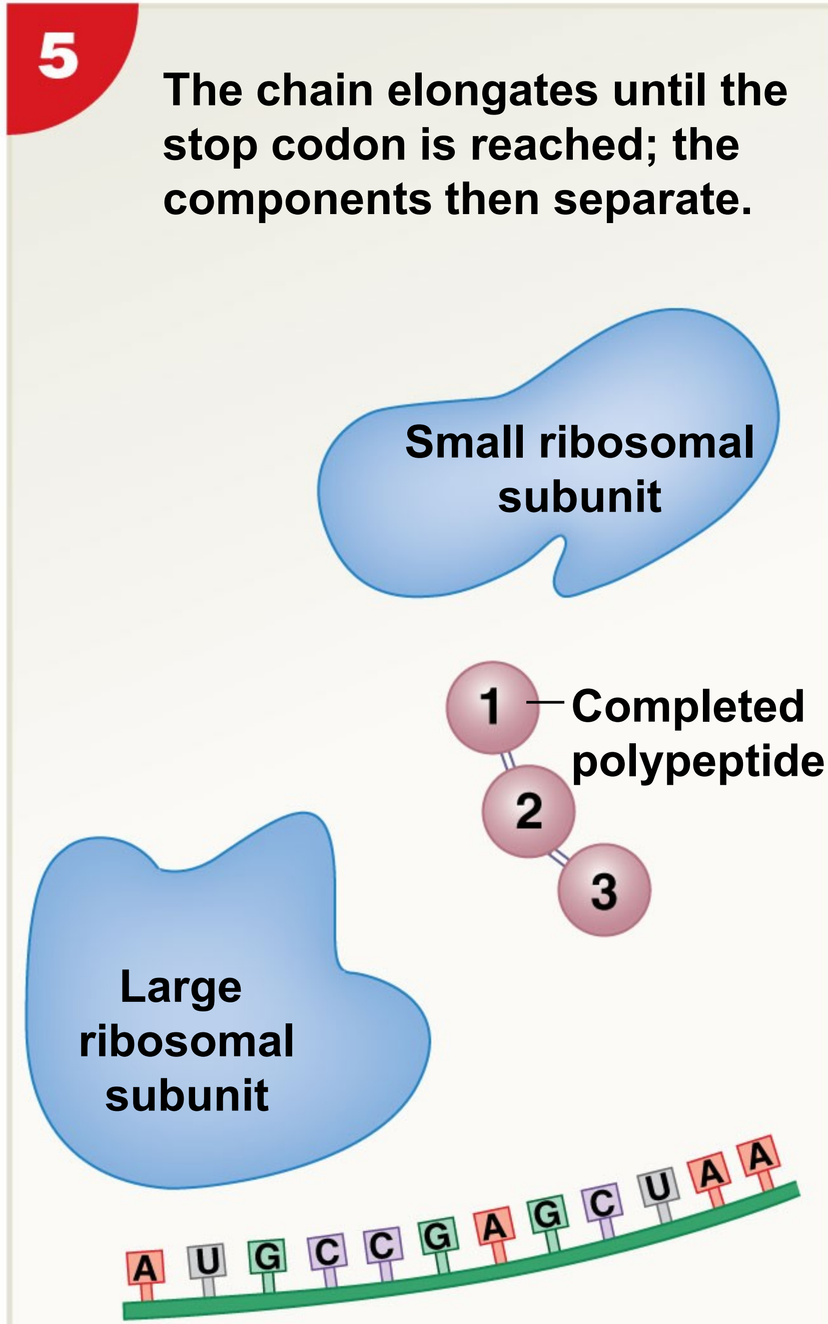


Table 3-1 Examples of the Triplet Code

Table 3–1 Examples of the Triplet Code

DNA Triplets				
Template Strand	Coding Strand	mRNA Codon	tRNA Anticodon	Amino Acid
AAA	TTT	UUU	AAA	Phenylalanine
AAT	TTA	UUA	AAU	Leucine
ACA	TGT	UGU	ACA	Cysteine
CAA	GTT	GUU	CAA	Valine
TAC	ATG	AUG	UAC	Methionine
TCG	AGC	AGC	UCG	Serine
GGC	CCG	CCG	GGC	Proline
CGG	GCC	GCC	CGG	Alanine

3-4 Protein Synthesis

- How the Nucleus Controls Cell Structure and Function
  1. *Direct* control through synthesis of:
     - Structural proteins
     - Secretions (environmental response)
  2. *Indirect* control over metabolism through enzymes

3-5 Diffusion and Osmosis

- Membrane Transport
  - The plasma (cell) membrane is a barrier, but:
    - Nutrients must get in
    - Products and wastes must get out
  - **Permeability** determines what moves in and out of a cell, and a membrane that:
    - Lets nothing in or out is **impermeable**
    - Lets anything pass is **freely permeable**
    - Restricts movement is **selectively permeable**

3-5 Diffusion and Osmosis

- Membrane Transport
  - Plasma membrane is **selectively permeable**
    - Allows some materials to move freely
    - Restricts other materials
  - Selective permeability restricts materials based on:
    - Size
    - Electrical charge
    - Molecular shape
    - Lipid solubility

3-5 Diffusion and Osmosis

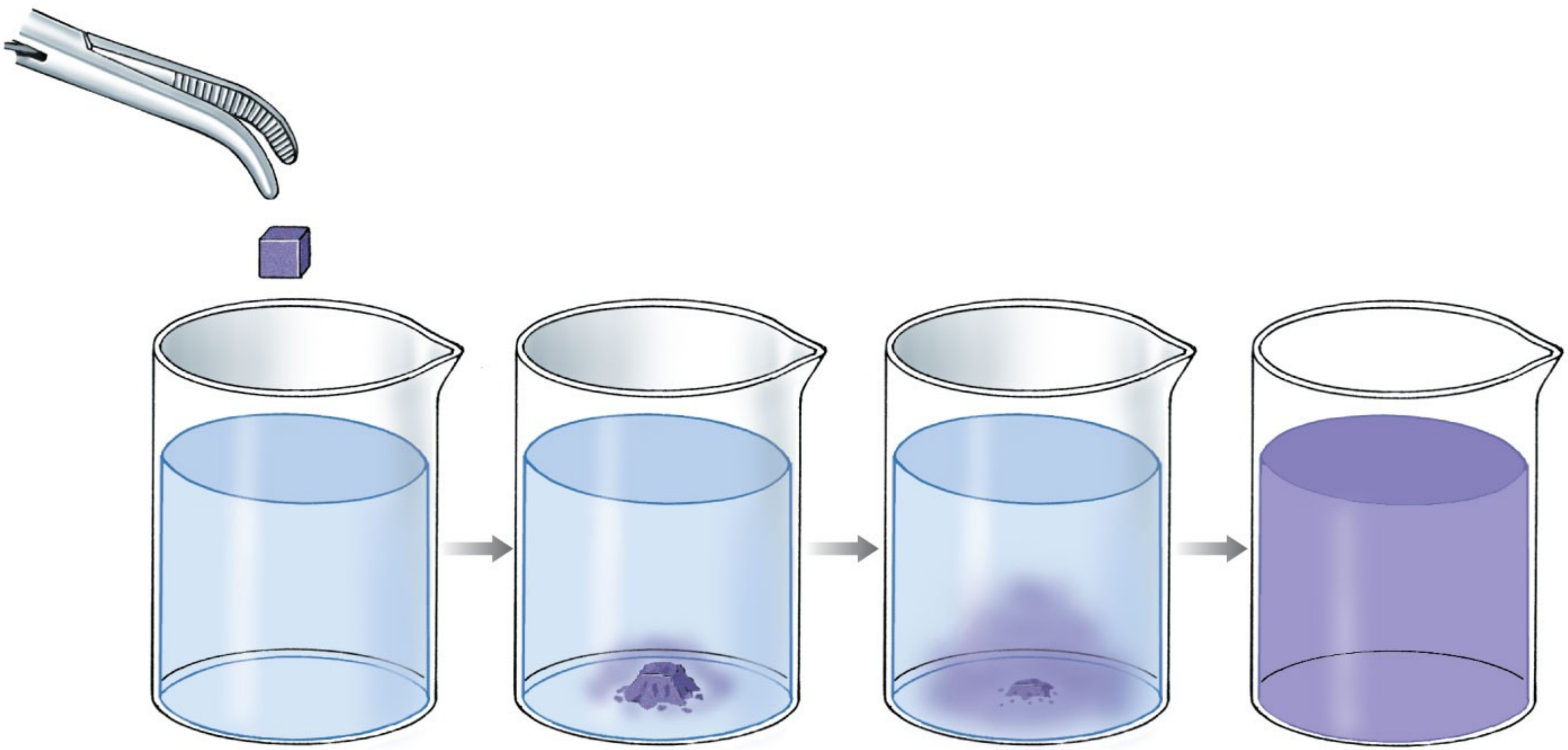
- Membrane Transport
  - Transport through a plasma membrane can be:
    - *Active* (requiring energy and ATP)
    - *Passive* (no energy required)
  - Diffusion (passive)
  - Carrier-mediated transport (passive or active)
  - Vesicular transport (active)

3-5 Diffusion and Osmosis

- Diffusion
  - All molecules are constantly in motion
  - Molecules in solution move randomly
  - Random motion causes mixing
  - Concentration is the amount of solute in a solvent
  - **Concentration gradient**
    - More solute in one part of a solvent than another

PLAY ANIMATION Membrane Transport: Diffusion

Figure 3-14 Diffusion



3-5 Diffusion and Osmosis

- Factors Influencing Diffusion
  - *Distance* the particle has to move
  - *Molecule Size*
    - Smaller is faster
  - *Temperature*
    - More heat, faster motion
  - *Concentration Gradient*
    - The difference between high and low concentrations
  - *Electrical Forces*
    - Opposites attract, like charges repel

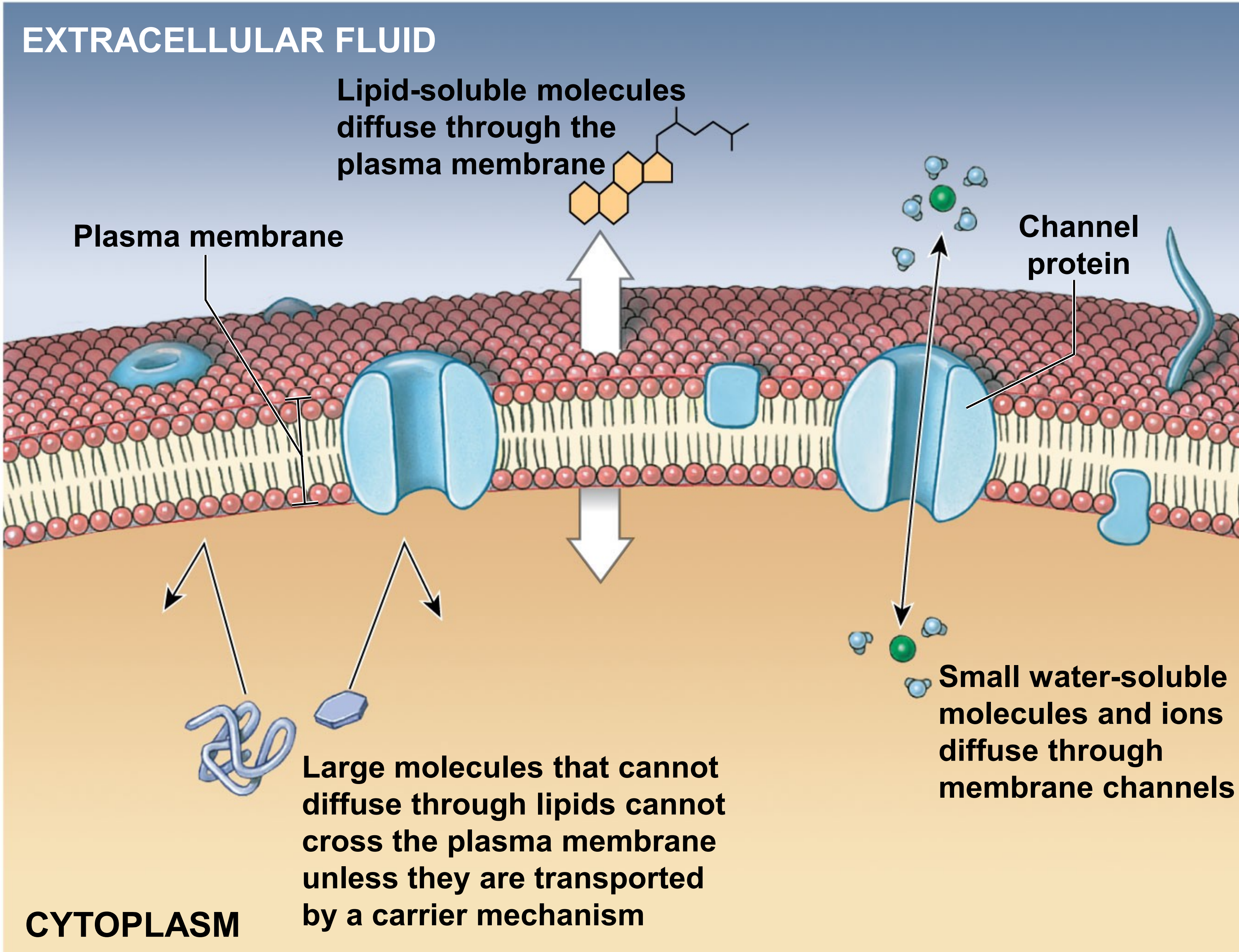
3-5 Diffusion and Osmosis

- Diffusion across Plasma Membranes
  - Can be simple or channel mediated
    - Materials that diffuse through plasma membrane by **simple diffusion**
      - Lipid-soluble compounds (alcohols, fatty acids, and steroids)
      - Dissolved gases (oxygen and carbon dioxide)

3-5 Diffusion and Osmosis

- Diffusion across Plasma Membranes
  - **Channel-mediated diffusion**
    - Water-soluble compounds and ions
  - Factors in channel-mediated diffusion
    - Size
    - Charge
    - Interaction with the channel – **leak channels**

Figure 3-15 Diffusion across the Plasma Membrane



3-5 Diffusion and Osmosis

- Osmosis: A Special Case of Diffusion
  - **Osmosis** is the diffusion of water across the cell membrane
    - More solute molecules, lower concentration of water molecules
    - Membrane must be freely permeable to water, selectively permeable to solutes
    - Water molecules diffuse across membrane toward solution with more solutes
    - Volume increases on the side with more solutes

Figure 3-16 Osmosis

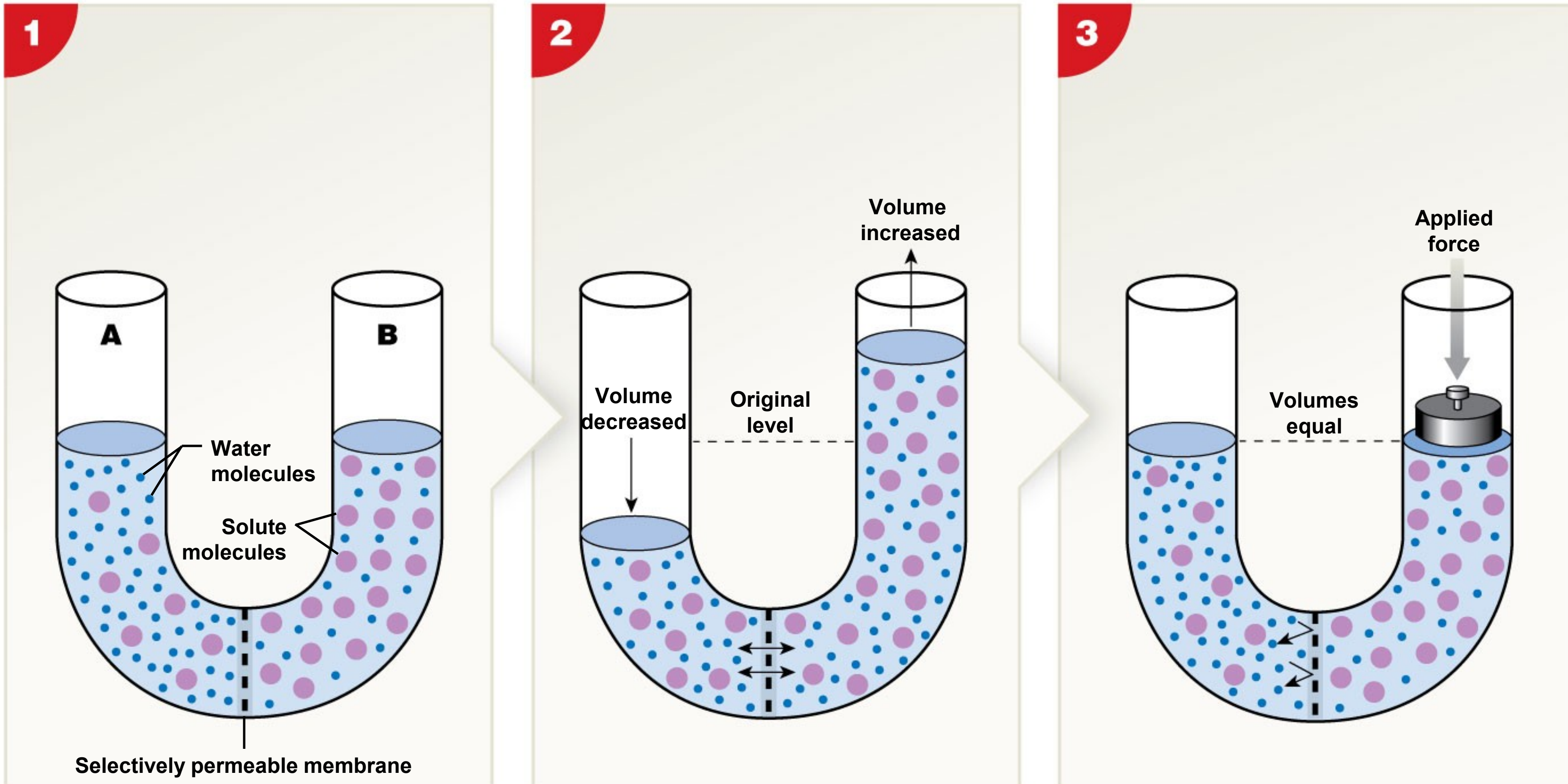


Figure 3-16 Osmosis

1

Two solutions containing different solute concentrations are separated by a selectively permeable membrane. Water molecules (small blue dots) begin to cross the membrane toward solution B, the solution with the higher concentration of solutes (large pink dots)

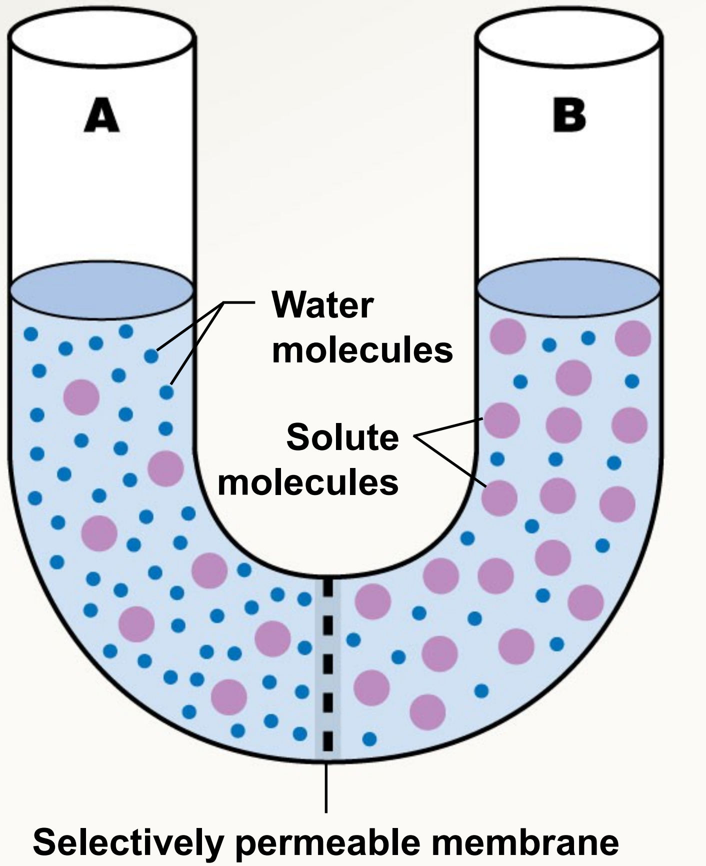


Figure 3-16 Osmosis

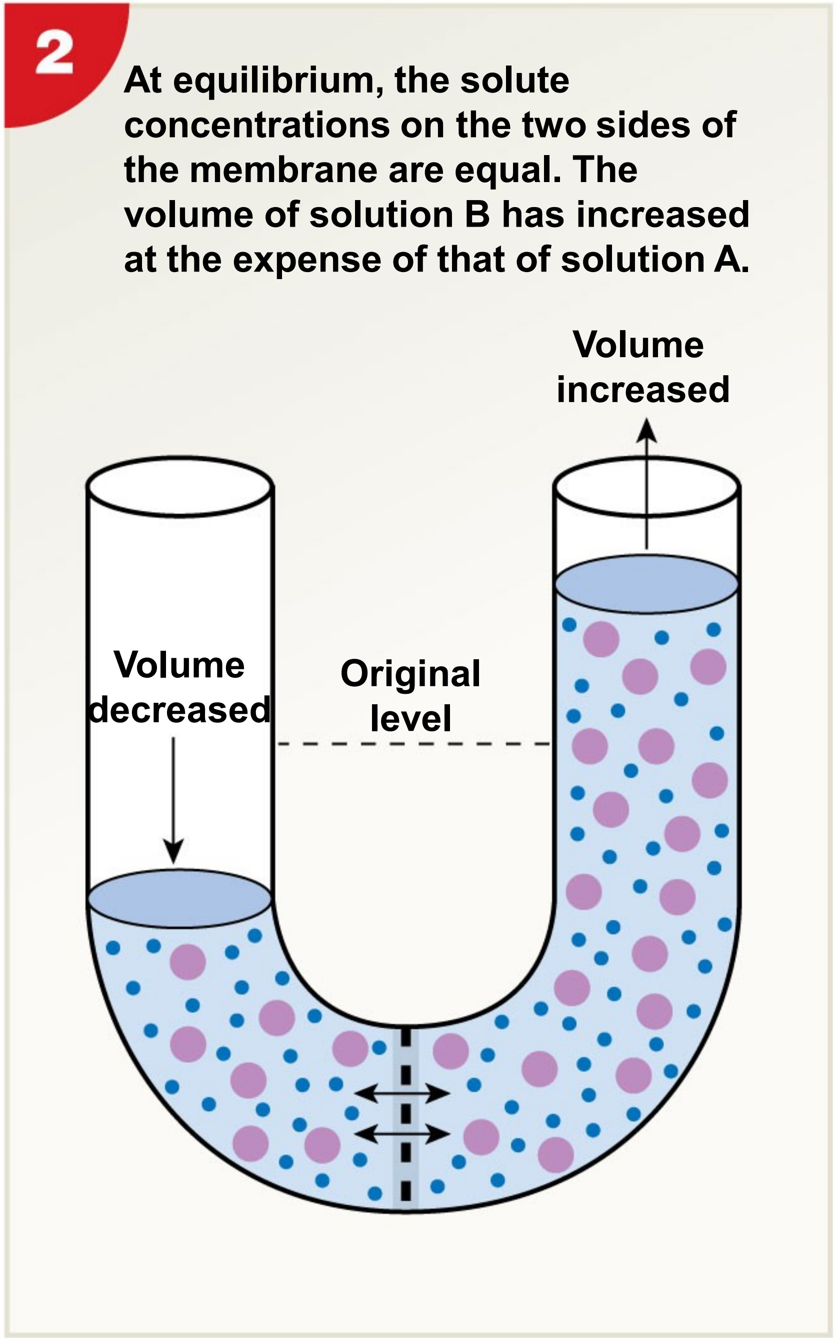
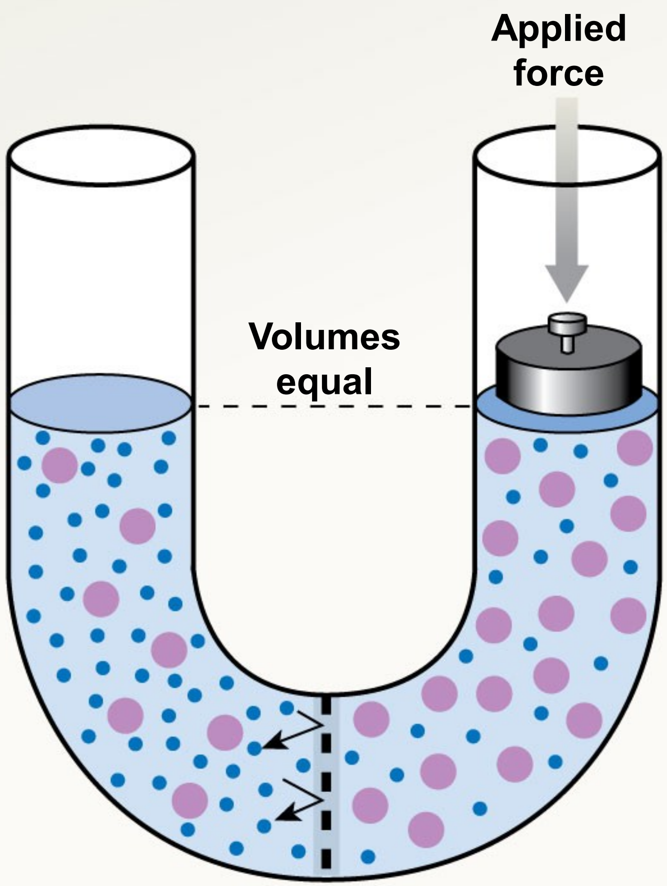


Figure 3-16 Osmosis

3

Osmosis can be prevented by resisting the change in volume. The osmotic pressure of solution B is equal to the amount of hydrostatic pressure required to stop the osmotic flow.



3-5 Diffusion and Osmosis

- Osmosis: A Special Case of Diffusion
  - **Osmotic pressure**
    - Is the force of a concentration gradient of water
    - Equals the force (**hydrostatic pressure**) needed to block osmosis

3-5 Diffusion and Osmosis

- Osmolarity and Tonicity
  - The osmotic effect of a solute on a cell
    - Two fluids may have equal **osmolarity**, but different **tonicity**
  - **Isotonic** (*iso-* = same, *tonos* = tension)
    - A solution that does not cause osmotic flow of water in or out of a cell
  - **Hypotonic** (*hypo-* = below)
    - Has less solutes and loses water through osmosis
  - **Hypertonic** (*hyper-* = above)
    - Has more solutes and gains water by osmosis

3-5 Diffusion and Osmosis

- Osmolarity and Tonicity
  - A cell in a hypotonic solution:
    - Gains water
    - Ruptures (**hemolysis** of red blood cells)
  - A cell in a hypertonic solution:
    - Loses water
    - Shrinks (**crenation** of red blood cells)

Figure 3-17 Osmotic Flow across a Plasma Membrane

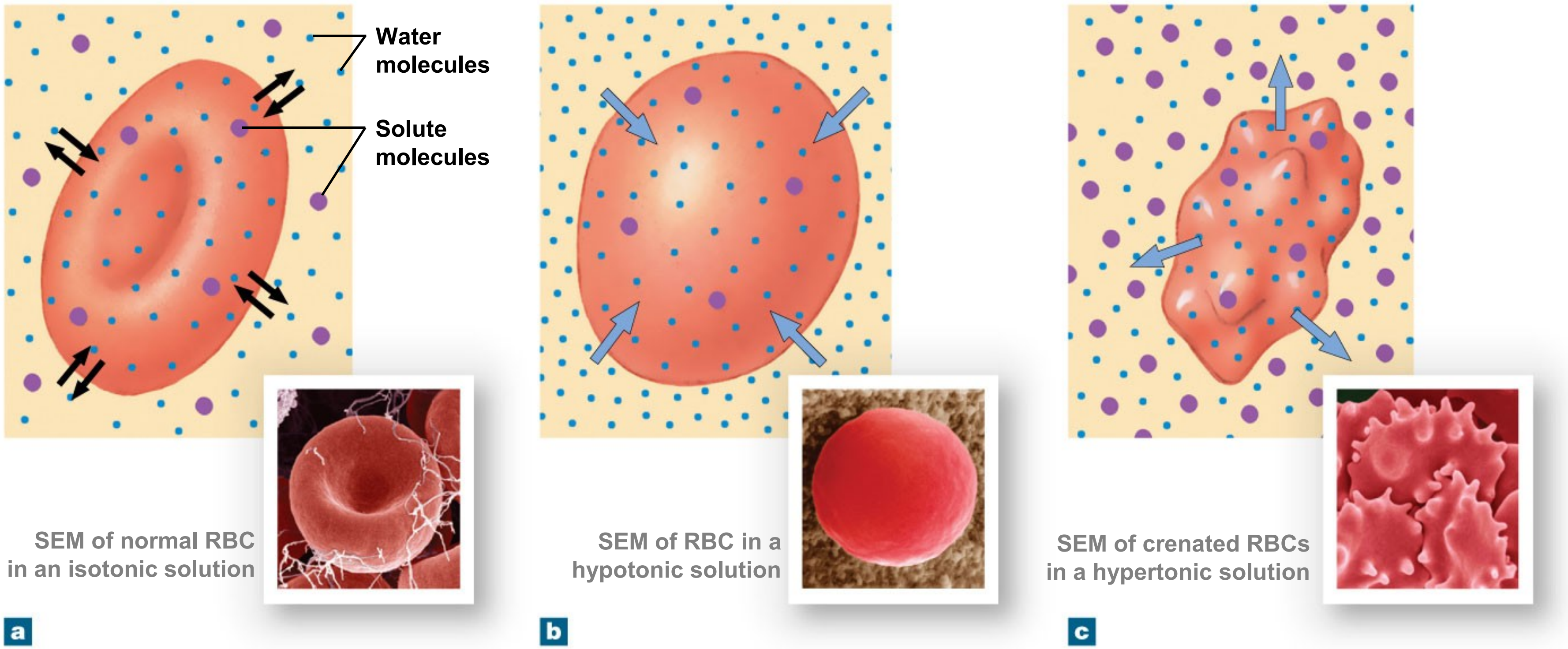
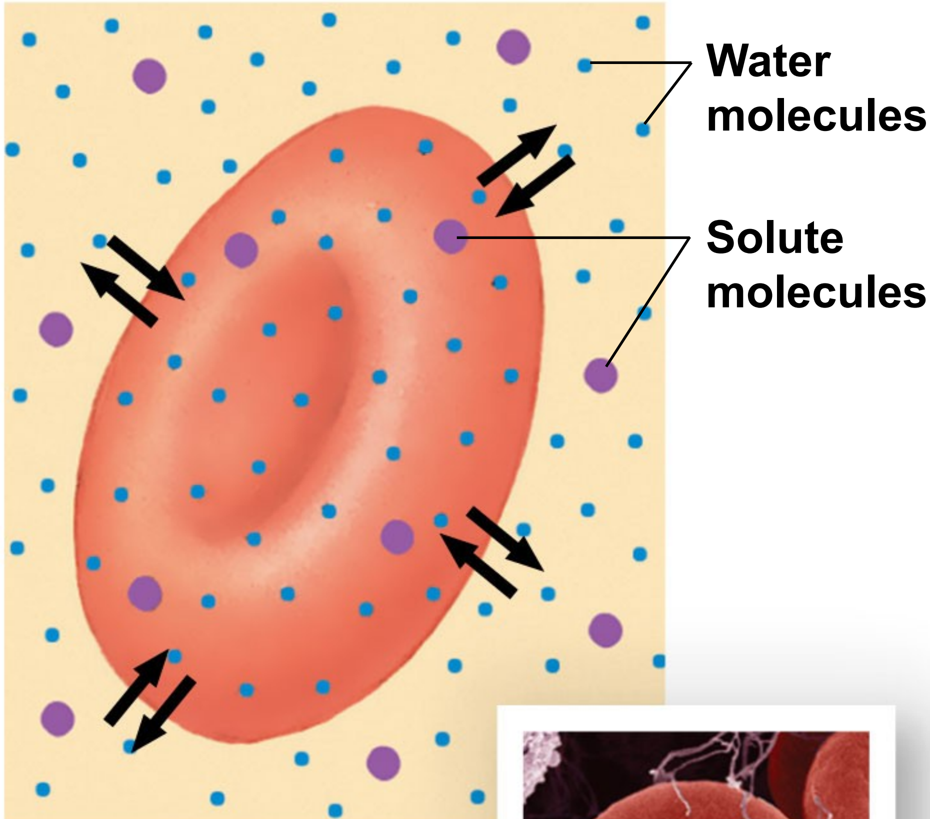
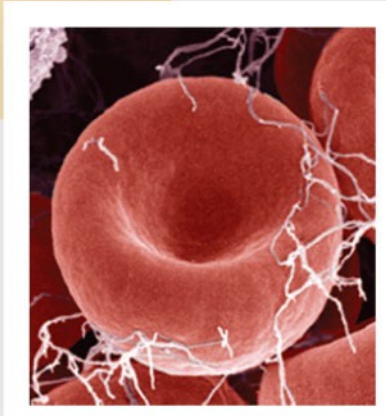


Figure 3-17a Osmotic Flow across a Plasma Membrane

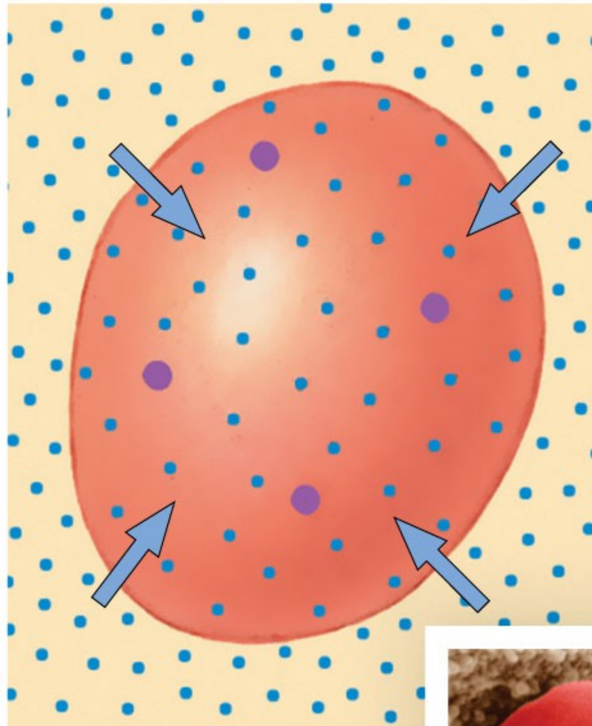


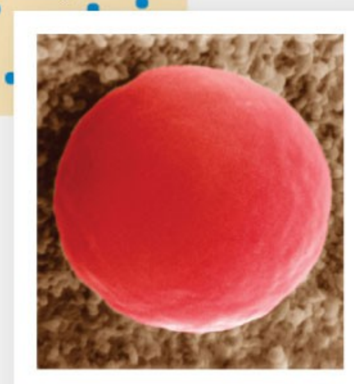


SEM of normal RBC in an isotonic solution

a In an isotonic saline solution, no osmotic flow occurs, and these red blood cells appear normal.

Figure 3-17b Osmotic Flow across a Plasma Membrane

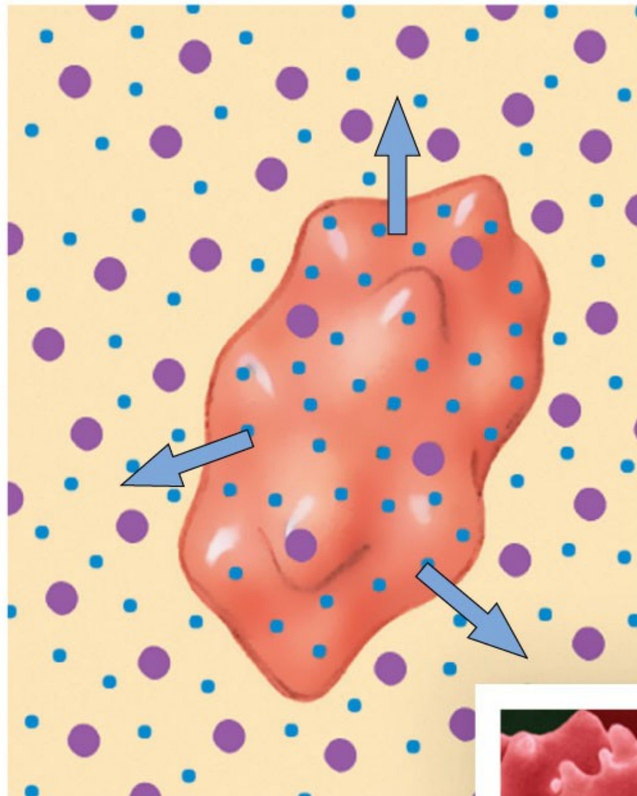


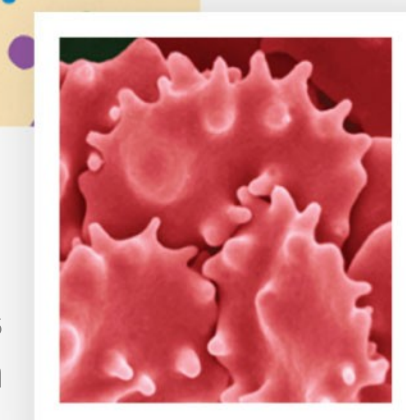


SEM of RBC in a hypotonic solution

b Immersion in a hypotonic saline solution results in the osmotic flow of water into the cells. The swelling may continue until the plasma membrane ruptures, or lyses.

Figure 3-17c Osmotic Flow across a Plasma Membrane





SEM of crenated RBCs in a hypertonic solution

c Exposure to a hypertonic solution results in the movement of water out of the cell. The red blood cells shrivel and become crenated.

3-6 Carriers and Vesicles

- **Carrier-Mediated Transport**
  - Of ions and organic substrates
    - Characteristics
      - *Specificity*
        - One transport protein, one set of substrates
      - *Saturation Limits*
        - Rate depends on transport proteins, not substrate
      - *Regulation*
        - Cofactors such as hormones

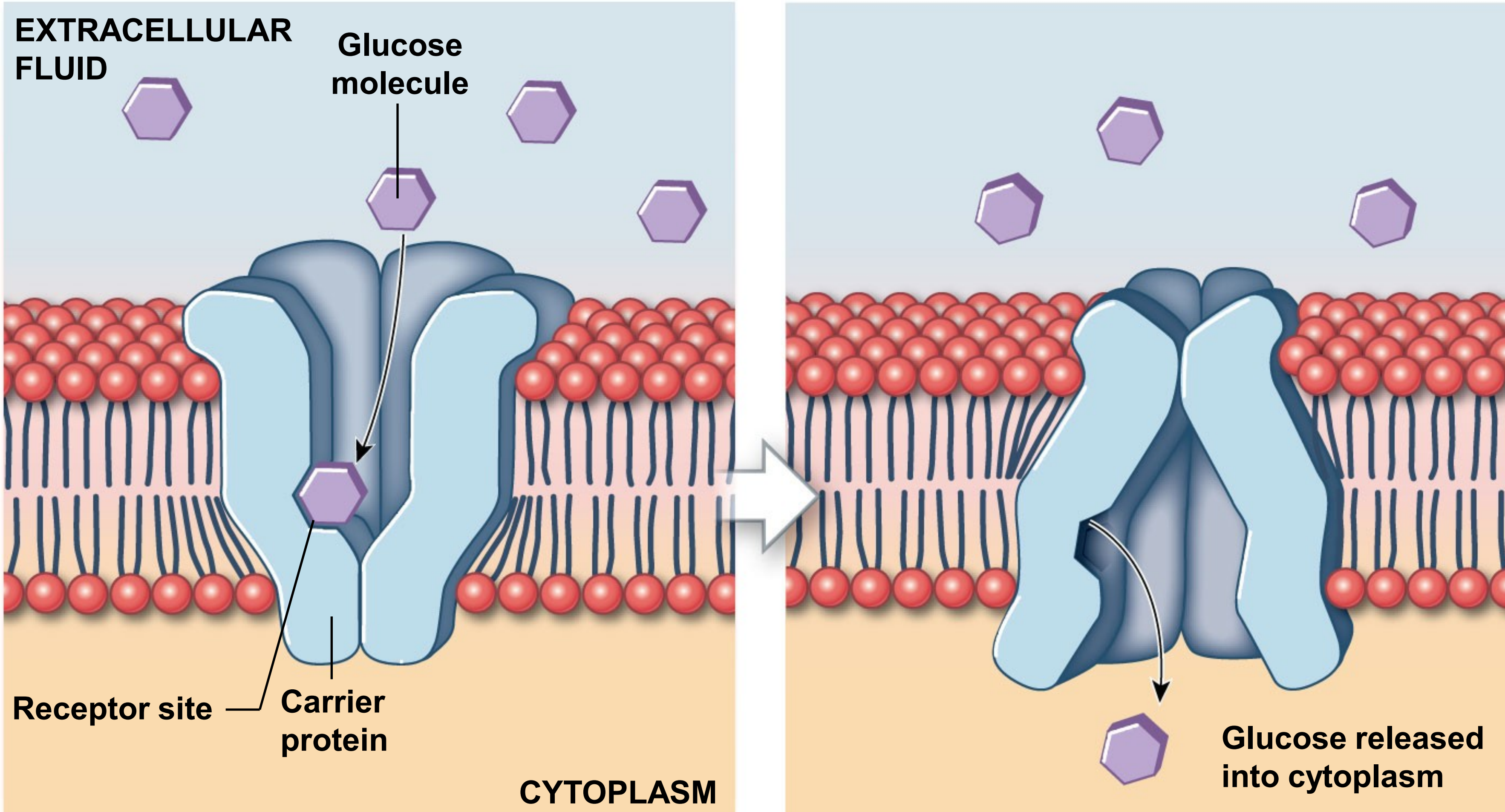
3-6 Carriers and Vesicles

- Carrier-Mediated Transport
  - **Cotransport**
    - Two substances move in the same direction at the same time
  - **Countertransport**
    - One substance moves in while another moves out

3-6 Carriers and Vesicles

- Carrier-Mediated Transport
  - **Facilitated Diffusion**
    - Passive
    - Carrier proteins transport molecules too large to fit through channel proteins (glucose, amino acids)
      - Molecule binds to **receptor site** on carrier protein
      - Protein changes shape, molecules pass through
      - Receptor site is specific to certain molecules

Figure 3-18 Facilitated Diffusion



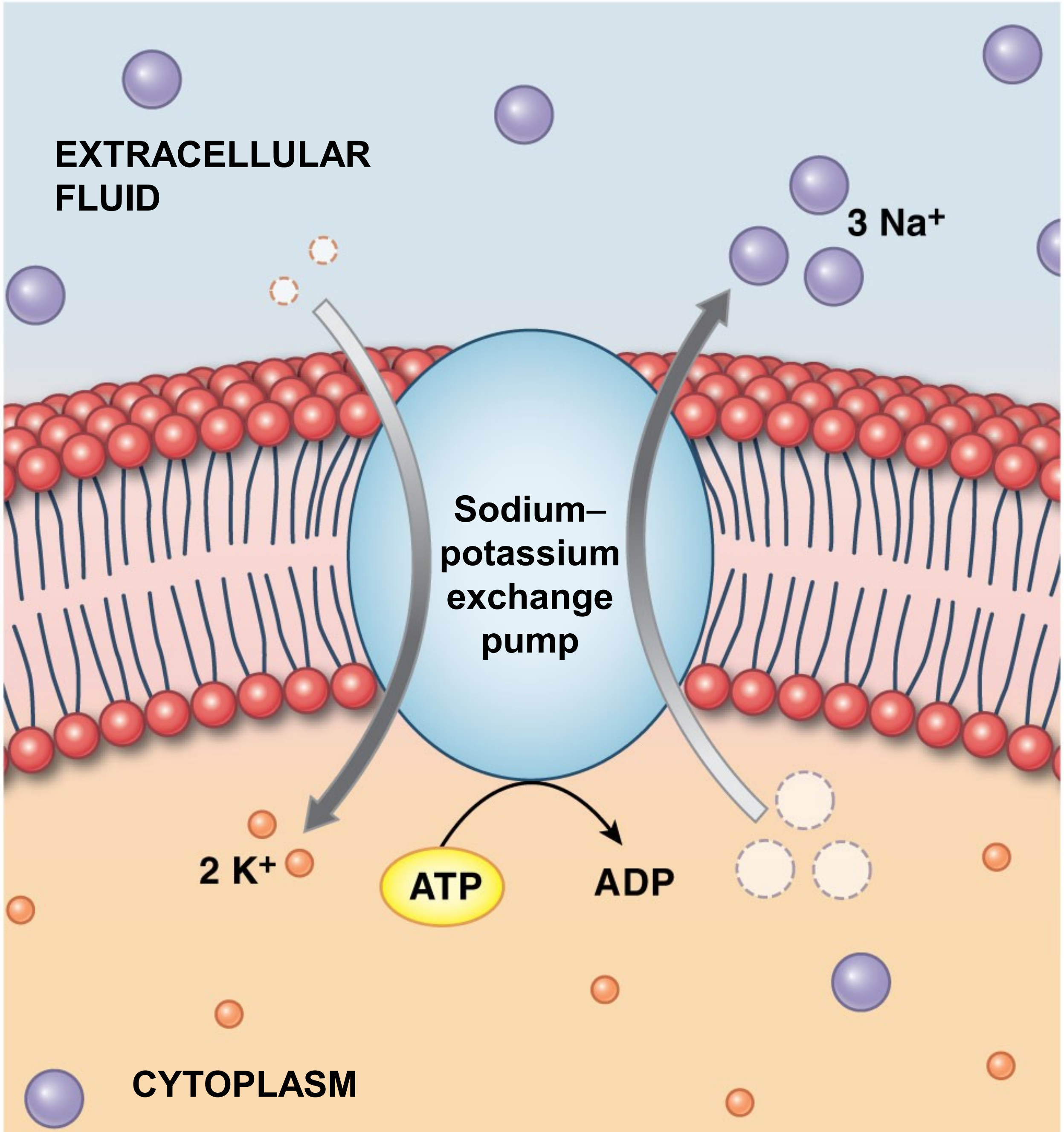
3-6 Carriers and Vesicles

- Carrier-Mediated Transport
  - Active Transport (Primary or Secondary)
    - Active transport proteins
      - Move substrates against concentration gradient
      - Require energy, such as ATP
      - **Ion pumps** move ions (Na^+, K^+, Ca^{2+}, Mg^{2+})
      - **Exchange pump** countertransports two ions at the same time

3-6 Carriers and Vesicles

- Carrier-Mediated Transport
  - Primary Active Transport
    - **Sodium–potassium exchange pump**
      - Active transport, carrier mediated
        - Sodium ions (Na^+) out, potassium ions (K^+) in
        - 1 ATP moves 3 Na^+ and 2 K^+

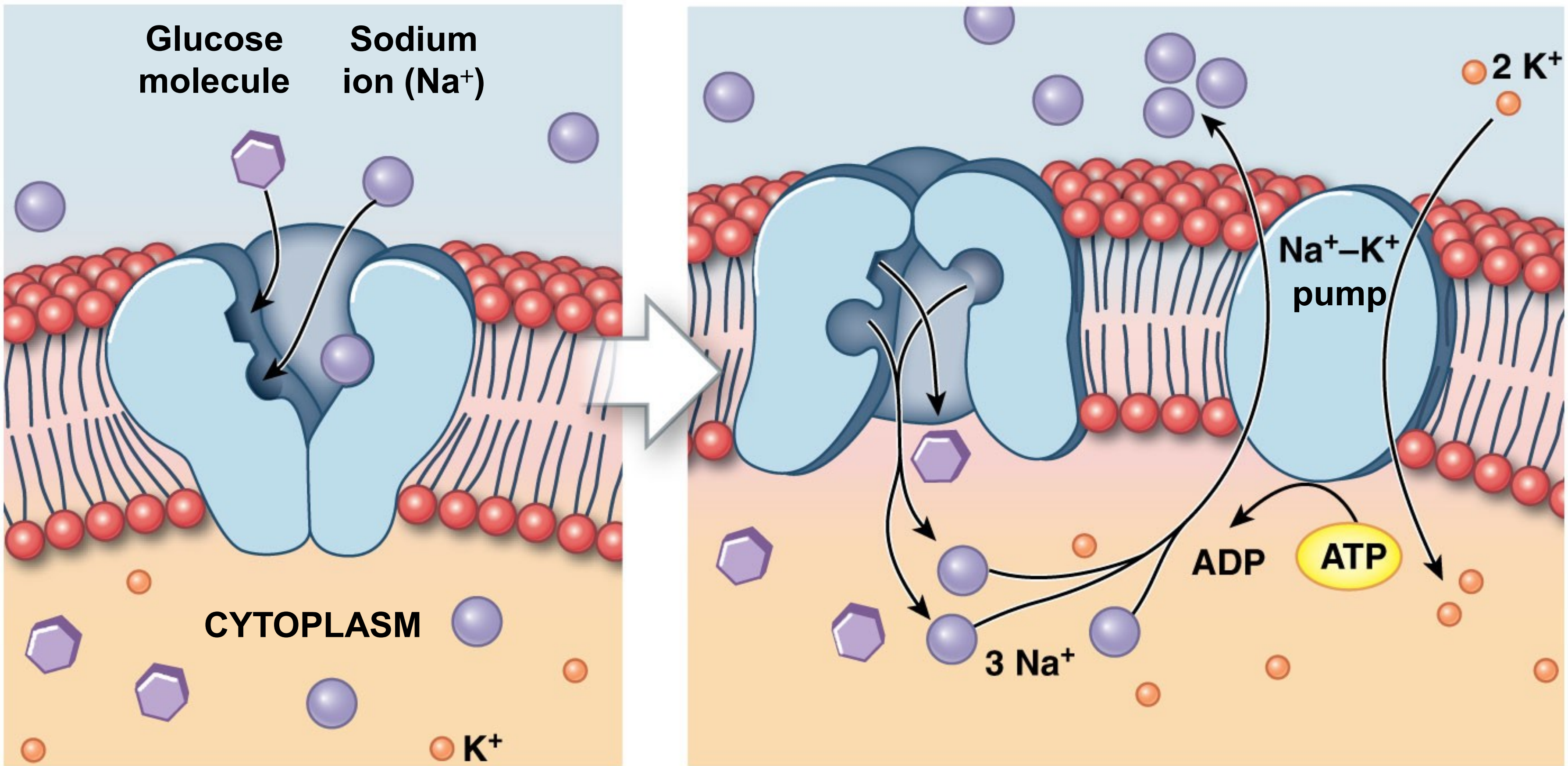
Figure 3-19 The Sodium-Potassium Exchange Pump



3-6 Carriers and Vesicles

- Carrier-Mediated Transport
  - **Secondary Active Transport**
    - Na^+ concentration gradient drives glucose transport
    - ATP energy pumps Na^+ back out

Figure 3-20 Secondary Active Transport



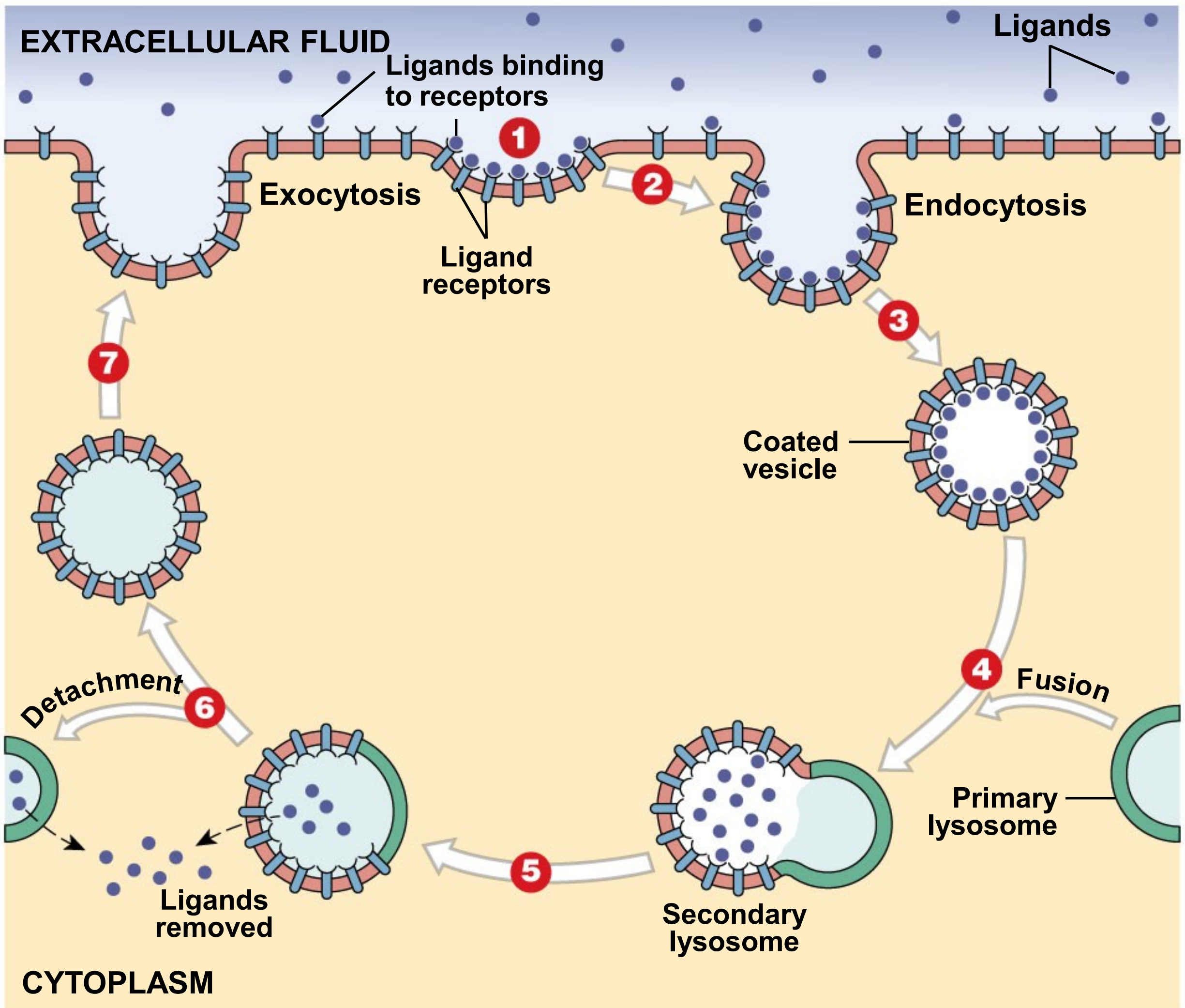
3-6 Carriers and Vesicles

- **Vesicular Transport** (*Bulk Transport*)
  - Materials move into or out of cell in **vesicles**
    - **Endocytosis** (*endo-* = inside) is active transport using ATP
      - *Receptor mediated*
      - *Pinocytosis*
      - *Phagocytosis*

3-6 Carriers and Vesicles

- Endocytosis
  - **Receptor-mediated endocytosis**
    - Receptors (glycoproteins) bind target molecules (**ligands**)
    - **Coated vesicle (**endosome) carries ligands and receptors into the cell

Figure 3-21 Receptor-Mediated Endocytosis



Receptor-Mediated Endocytosis

1. Target molecules (ligands) bind to receptors in plasma membrane.
2. Areas coated with ligands form deep pockets in plasma membrane surface.
3. Pockets pinch off, forming endosomes known as coated vesicles.
4. Coated vesicles fuse with primary lysosomes to form secondary lysosomes.
5. Ligands are removed and absorbed into the cytoplasm.
6. The lysosomal and endosomal membranes separate.
7. The endosome fuses with the plasma membrane, and the receptors are again available for ligand binding.

3-6 Carriers and Vesicles

- Endocytosis
  - **Pinocytosis**
    - Endosomes “drink” extracellular fluid
  - **Phagocytosis**
    - **Pseudopodia** (*pseudo-* = false, *pod-* = foot)
    - Engulf large objects in **phagosomes**
- **Exocytosis** (*exo-* = outside)
  - Granules or droplets are released from the cell

Figure 3-22a Pinocytosis and Phagocytosis

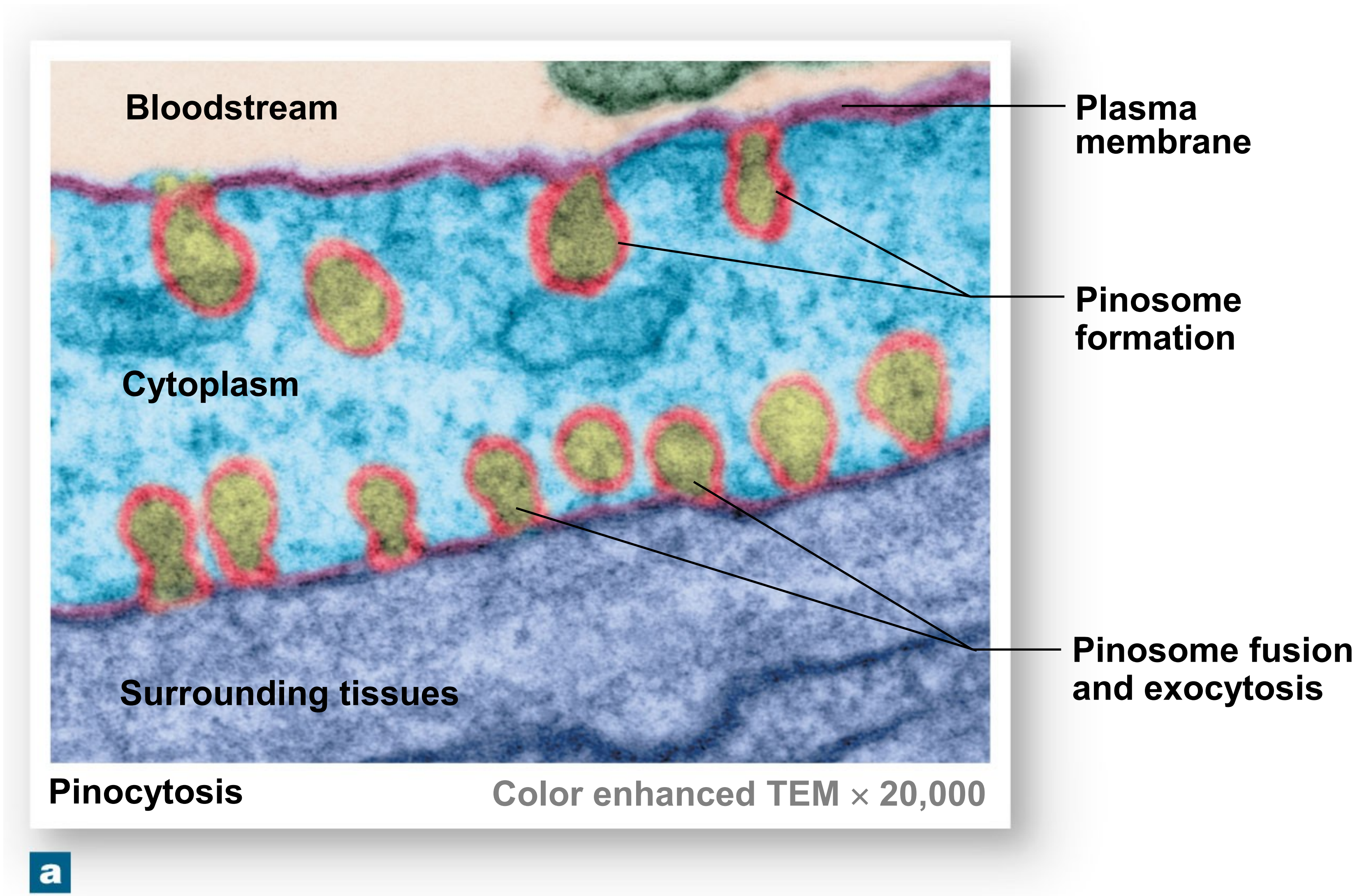


Figure 3-22b Pinocytosis and Phagocytosis

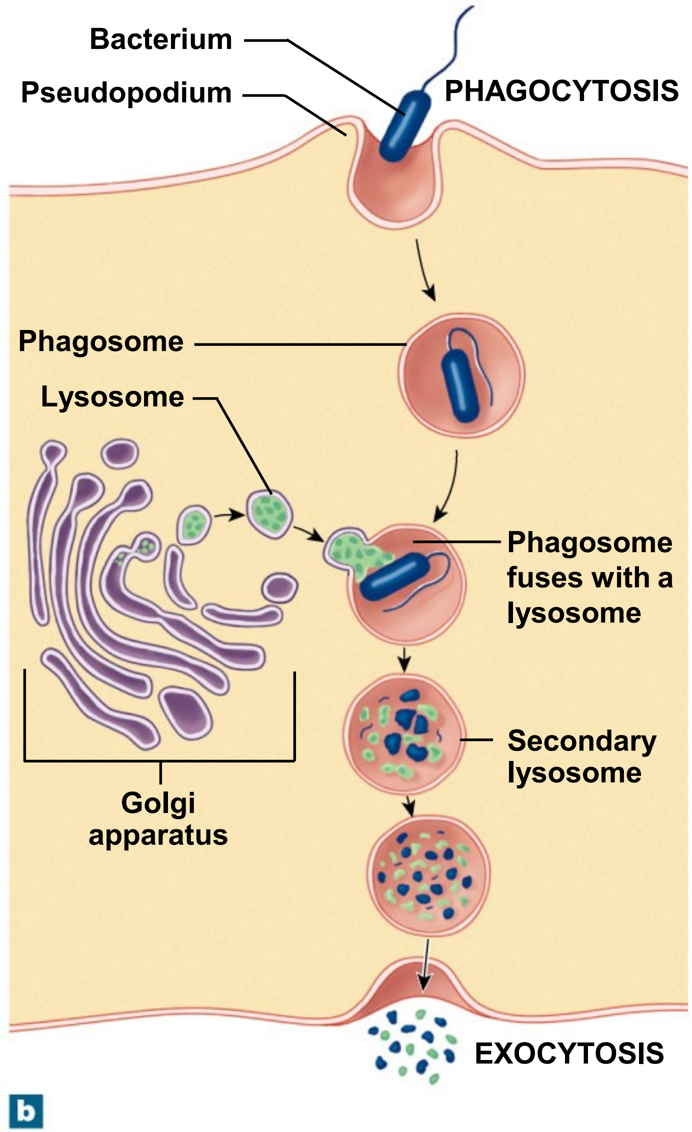


Table 3-2 Mechanisms Involved in Movement across Plasma Membranes

Mechanism	Process	Factors Affecting Rate	Substances Involved (Sites)
Diffusion (includes simple diffusion and channel-mediated diffusion)	Molecular movement of solutes; direction determined by relative concentrations	Size of concentration gradient; size of molecules; electrical charge; lipid solubility, temperature; additional factors apply to channel-mediated diffusion	Small inorganic ions; most gases and lipid-soluble materials (all cells)
Osmosis	Movement of water molecules toward solution containing relatively higher solute concentration; requires selectively permeable membrane	Concentration gradient; opposing osmotic or hydrostatic pressure; number of aquaporins (water channels)	Water only (all cells)
Carrier-Mediated Transport			
Facilitated diffusion	Carrier proteins passively transport solutes across a membrane down a concentration gradient	Size of gradient, temperature, and availability of carrier protein	Glucose and amino acids (all cells, but several different regulatory mechanisms exist)
Active transport	Carrier proteins actively transport solutes across a membrane, often against a concentration gradient	Availability of carrier, substrates, and ATP	Na^+, K^+, Ca^{2+}, Mg^{2+} (all cells); other solutes by specialized cells
Secondary active transport	Carrier proteins passively transport two solutes, with one (normally Na^+) moving down its concentration gradient; the cell must later expend ATP to eject the Na^+	Availability of carrier, substrates, and ATP	Glucose and amino acids (specialized cells); iodide
Vesicular Transport			
Endocytosis	Creation of membranous vesicles containing fluid or solid material	Stimulus and mechanics incompletely understood; requires ATP	Fluids, nutrients (all cells); debris, pathogens (specialized cells)
Exocytosis	Fusion of vesicles containing fluids or solids (or both) with the plasma membrane	Stimulus and mechanics incompletely understood; requires ATP	Fluids, debris (all cells)

3-7 Transmembrane Potential

- Transmembrane Potential
  - Charges are separated creating a **potential difference**
  - Unequal charge across the plasma membrane is **transmembrane potential**
  - **Resting potential** ranges from –10 mV to –100 mV, depending on cell type

3-8 Cell Life Cycle

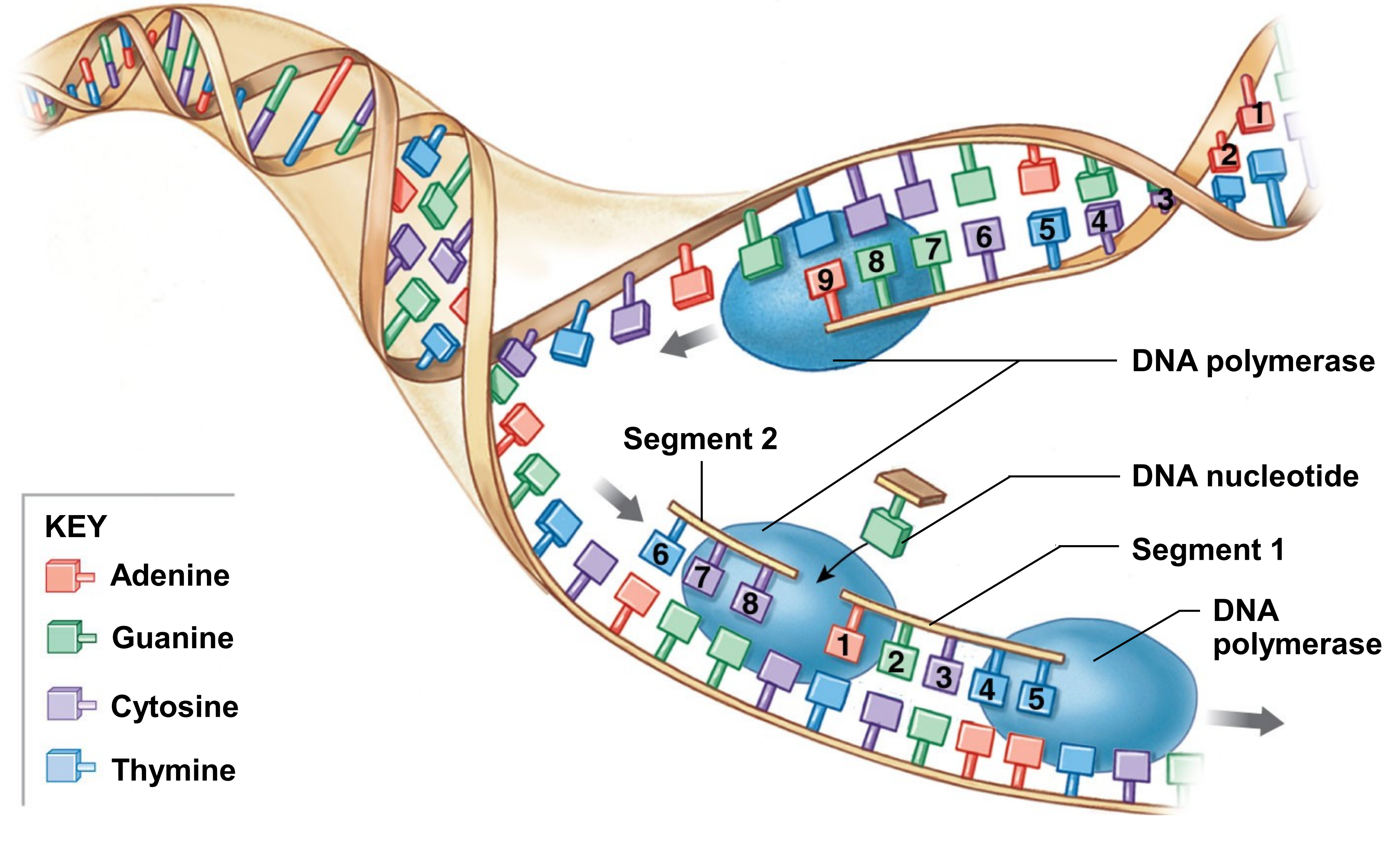
- Cell Life Cycle
  - Most of a cell's life is spent in a nondividing state (interphase)
  - Body (somatic) cells divide in three stages
    - **DNA replication** duplicates genetic material exactly
    - **Mitosis** divides genetic material equally
    - Cytokinesis divides cytoplasm and organelles into two **daughter cells**

3-8 Cell Life Cycle

- DNA Replication
  - *Helicases* unwind the DNA strands
  - **DNA polymerase**
    1. Promotes bonding between the nitrogenous bases of the DNA strand and complementary DNA nucleotides dissolved in the nucleoplasm
    2. Links the nucleotides by covalent bonds
  - DNA polymerase works in one direction
  - **Ligases** piece together sections of DNA

PLAY A&P FLIX: DNA Replication

Figure 3-23 DNA Replication



3-8 Cell Life Cycle

- **Interphase**
  - The nondividing period
    - **G-zero (G_0) phase** — specialized cell functions only
    - **G_1 phase** — cell growth, organelle duplication, protein synthesis
    - **S phase** — DNA replication and histone synthesis
    - **G_2 phase** — finishes protein synthesis and centriole replication

Figure 3-24 Stages of a Cell's Life Cycle: Interphase

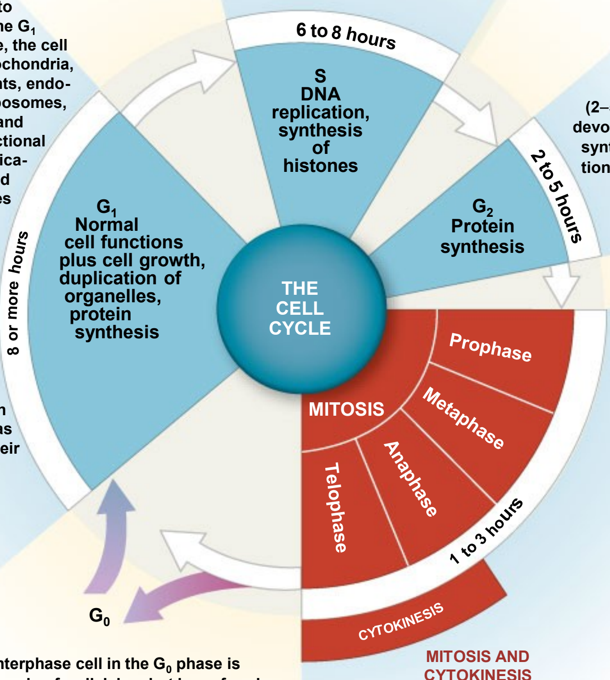
INTERPHASE

Most cells spend only a small part of their time actively engaged in cell division. Somatic cells spend the majority of their functional lives in a state known as interphase. During interphase, a cell perfoms all its normal functions and, if necessary, prepares for cell division.

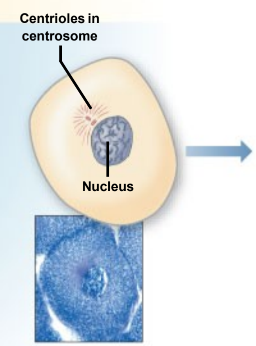
A cell that is ready to divide first enters the G_1 phase. In this phase, the cell makes enough mitochondria, cytoskeletal elements, endoplasmic reticula, ribosomes, Golgi membranes, and cytosol for two functional cells. Centriole replication begins in G_1 and commonly continues until G_2. In cells dividing at top speed, G_1 may last just 8–12 hours. Such cells pour all their energy into mitosis, and all other activities cease. If G_1 lasts for days, weeks, or months, preparation for mitosis occurs as the cells perform their normal functions.

When the activities of G_1 have been completed, the cell enters the S phase. Over the next 6–8 hours, the cell duplicates its chromosomes. This involves DNA replication and the synthesis of histones and other proteins in the nucleus.

Once DNA replication has ended, there is a brief (2–5-hour) G_2 phase devoted to last-minute protein synthesis and to the completion of centriole replication.



An interphase cell in the G_0 phase is not preparing for division, but is performing all of the other functions appropriate for that particular cell type. Some mature cells, such as skeletal muscle cells and most neurons, remain in G_0 indefinitely and never divide. In contrast, stem cells, which divide repeatedly with very brief interphase periods, never enter G_0.



Interphase

During interphase, the DNA strands are loosely coiled and chromosomes cannot be seen.

Figure 3-24 Stages of a Cell's Life Cycle: Interphase

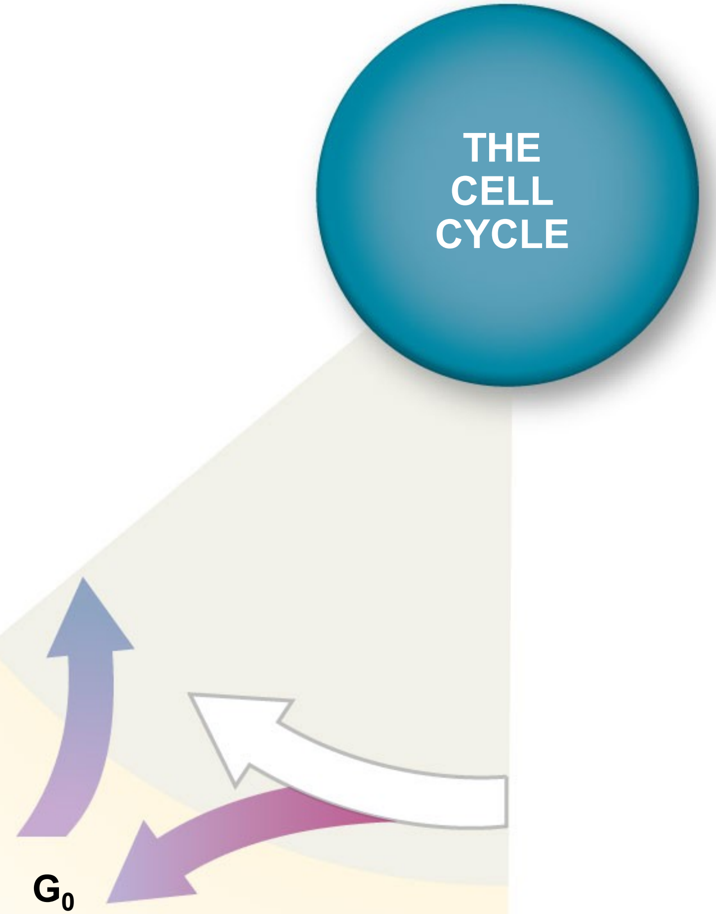


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Figure 3-24 Stages of a Cell's Life Cycle: Interphase

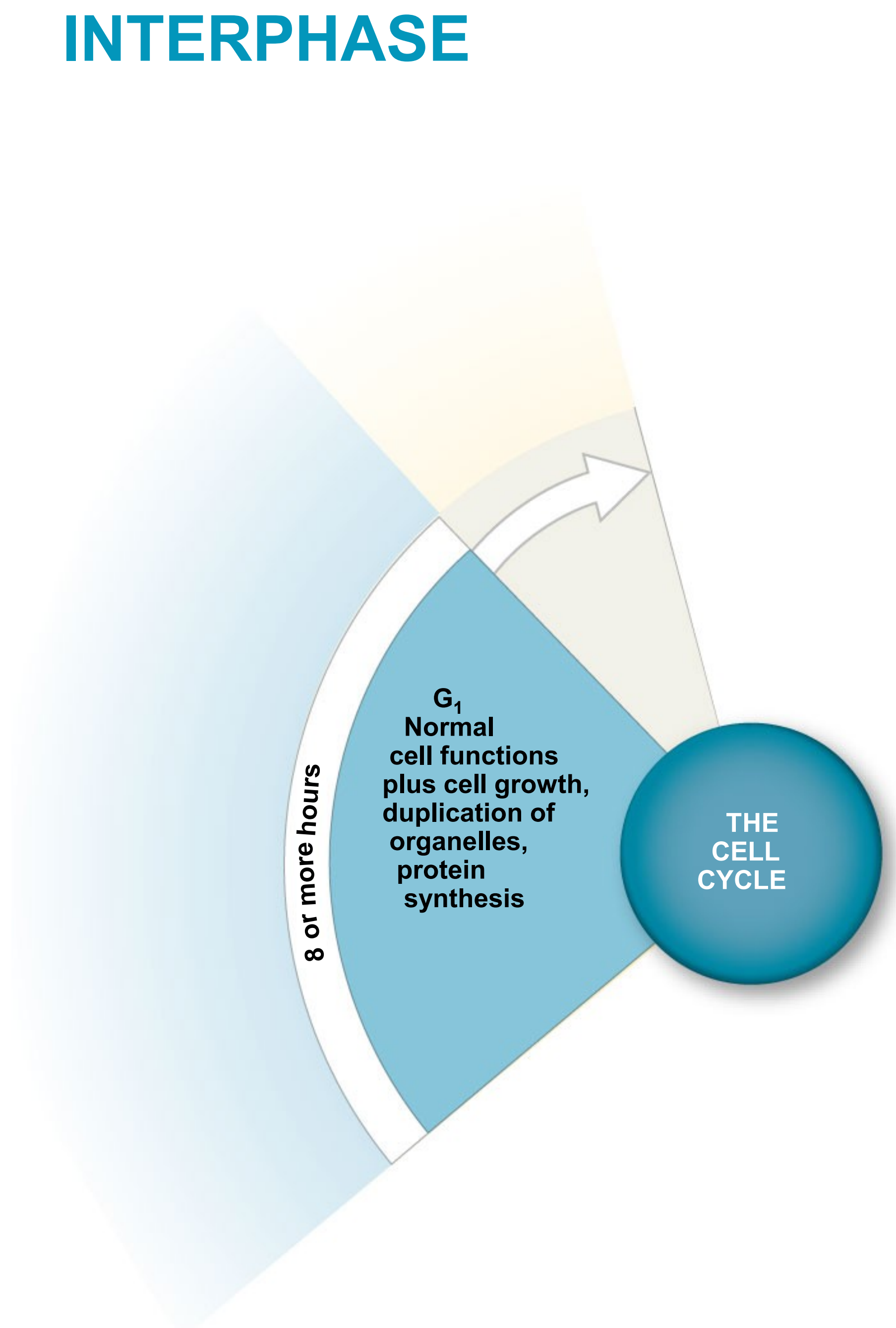


Figure 3-24 Stages of a Cell's Life Cycle: Interphase

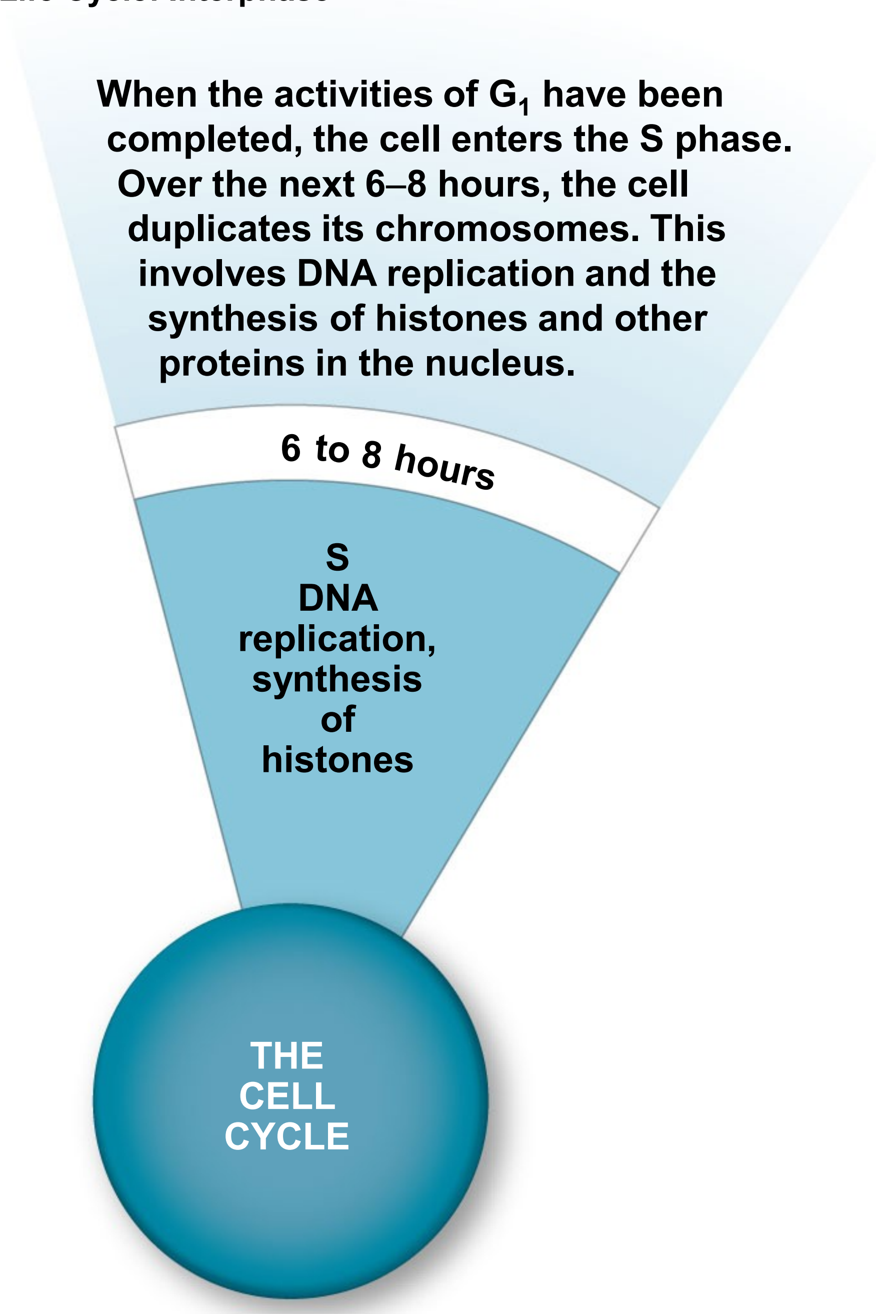
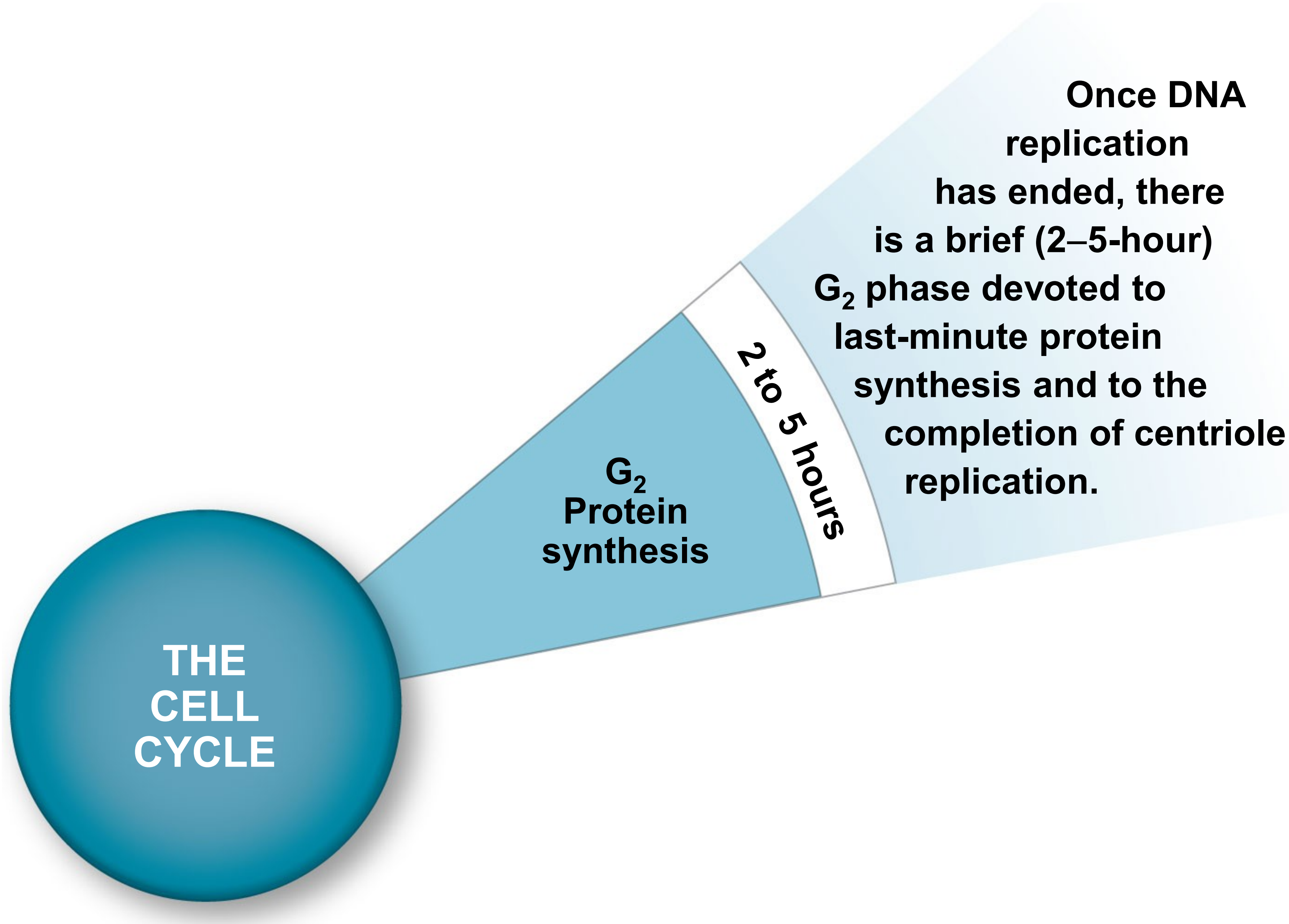


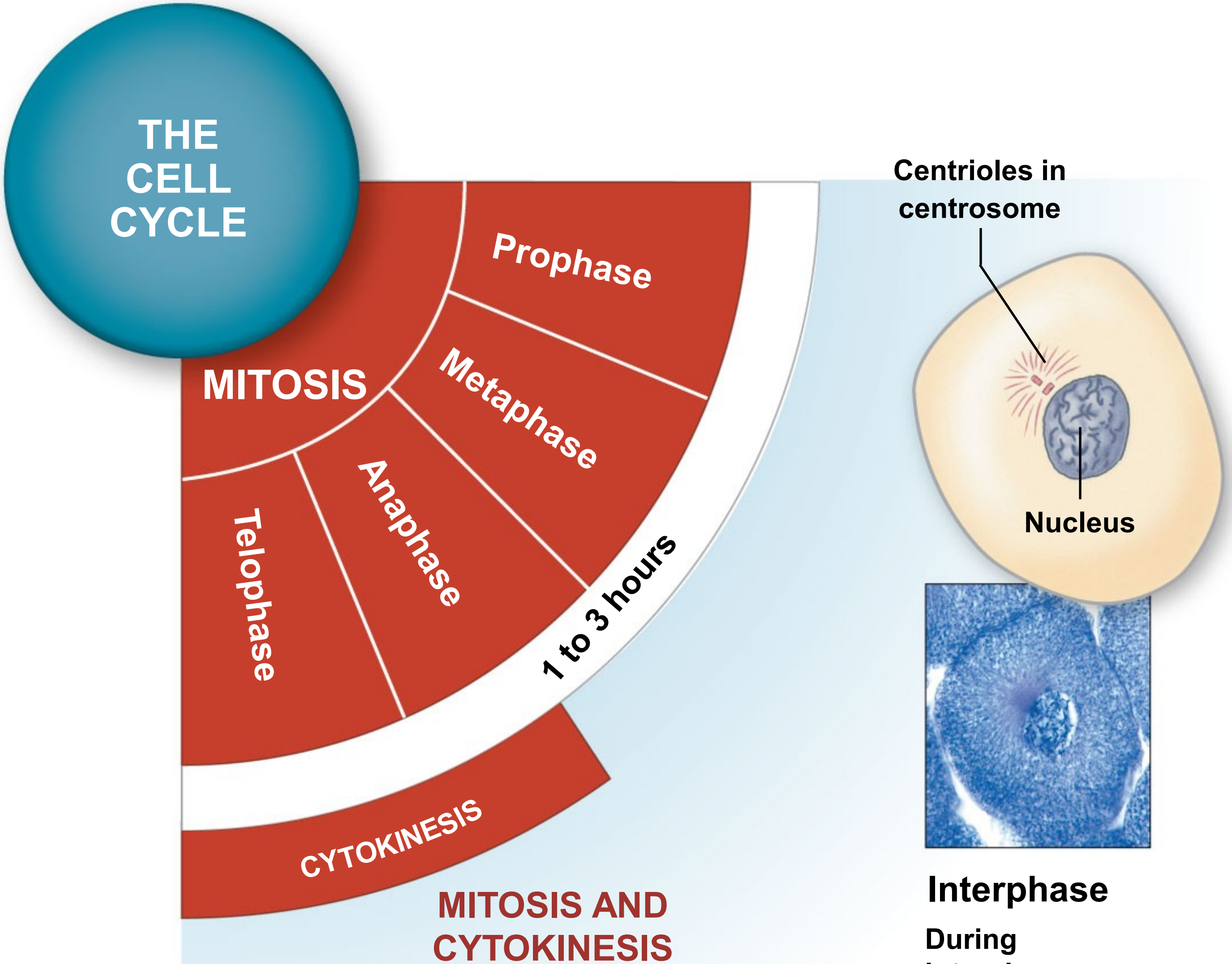
Figure 3-24 Stages of a Cell's Life Cycle: Interphase



3-8 Cell Life Cycle

- **Mitosis**
  - Divides duplicated DNA into two sets of **chromosomes**
    - DNA coils tightly into **chromatids**
    - Chromatids connect at a **centromere**
    - Protein complex around centromere is **kinetochore**

Figure 3-24 Stages of a Cell's Life Cycle: Interphase



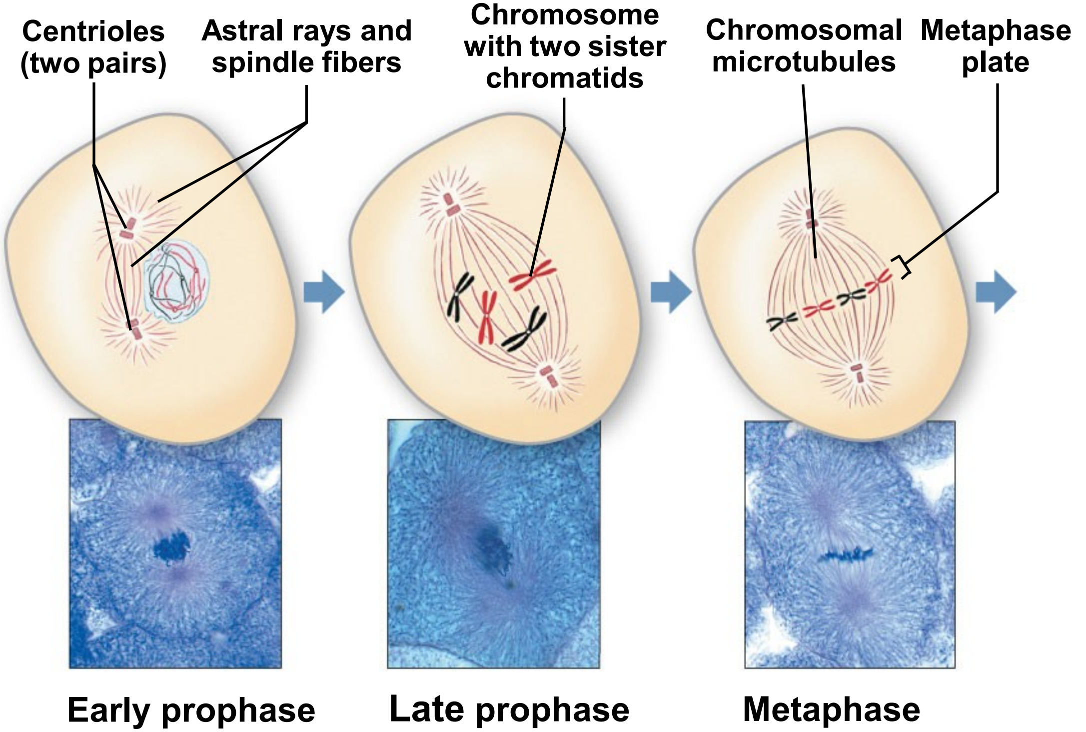
Interphase

During interphase, the DNA strands are loosely coiled and chromosomes cannot be seen.

3-8 Cell Life Cycle

- Mitosis
  - **Prophase**
    - Nucleoli disappear
    - Centriole pairs move to cell poles
    - Microtubules (**spindle fibers**) extend between centriole pairs
    - Nuclear envelope disappears
    - Spindle fibers attach to **kinetochore**
  - **Metaphase**
    - Chromosomes align in a central plane (metaphase plate)

Figure 3-24 Stages of a Cell's Life Cycle: Mitosis and Cytokinesis

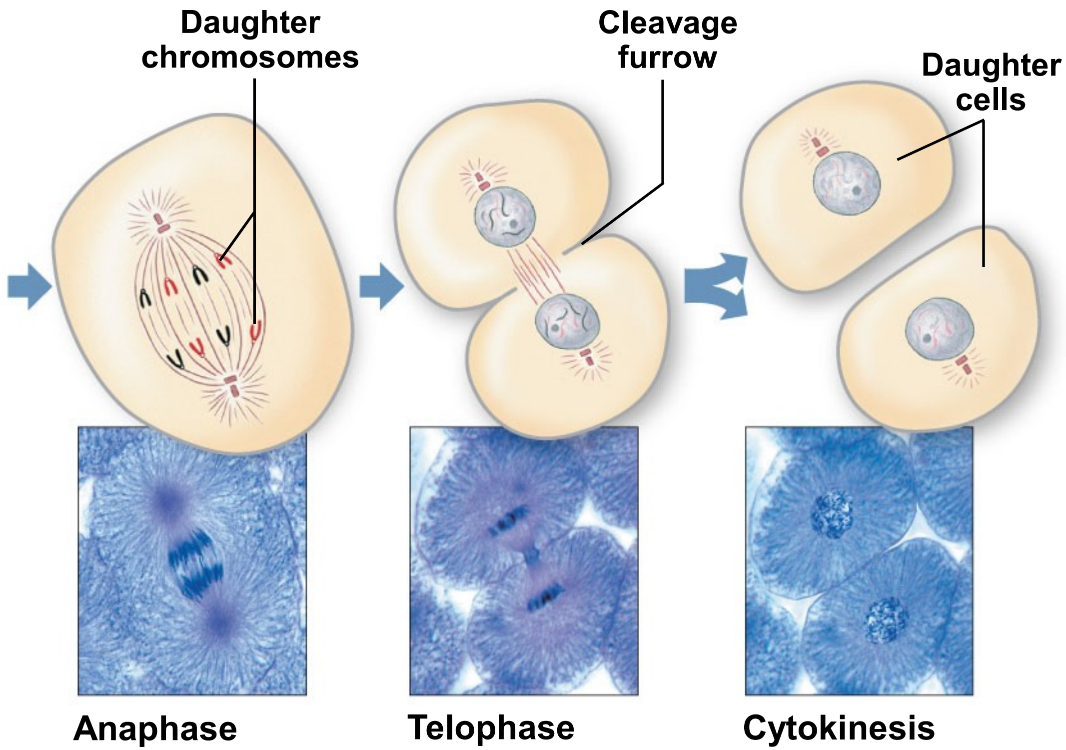


3-8 Cell Life Cycle

- Mitosis
  - **Anaphase**
    - Microtubules pull chromosomes apart
    - **Daughter chromosomes** group near centrioles
  - **Telophase**
    - Nuclear membranes re-form
    - Chromosomes uncoil
    - Nucleoli reappear
    - Cell has two complete nuclei

PLAY A&P FLIX: Mitosis

Figure 3-24 Stages of a Cell's Life Cycle: Mitosis and Cytokinesis



3-8 Cell Life Cycle

- **Cytokinesis**
  - Division of the cytoplasm
    - Cleavage furrow around metaphase plate
    - Membrane closes, producing daughter cells

Figure 3-24 Stages of a Cell's Life Cycle: Mitosis and Cytokinesis

3-8 Cell Life Cycle

- The Mitotic Rate and Energy Use
  - Rate of cell division
    - Slower **mitotic rate** means longer cell life
    - Cell division requires energy (ATP)
  - Muscle cells, neurons rarely divide
  - Exposed cells (skin and digestive tract) live only days or hours – replenished by **stem cells**

3-9 Regulation of the Cell Life Cycle

- Cell Division
  - Normally, cell division balances cell loss
  - Increased cell division
    - Internal factors (**M-phase promoting factor, MPF**)
    - Extracellular chemical factors (**growth factors**)
  - Decreased cell division
    - *Repressor genes* (faulty repressors cause cancers)
    - Worn out **telomeres** (terminal DNA segments)

Table 3-3 Chemical Factors Affecting Cell Division

Table 3–3 Chemical Factors Affecting Cell Division

Factor	Sources	Effects	Targets
M-phase promoting factor (maturation-promoting factor)	Forms within cytoplasm from Cdc2 and cyclin	Initiates mitosis	Regulatory mechanism active in all dividing cells
Growth hormone	Anterior lobe of the pituitary gland	Stimulation of growth, cell division, differentiation	All cells, especially in epithelial and connective tissues
Prolactin	Anterior lobe of the pituitary gland	Stimulation of cell growth, division, development	Gland and duct cells of mammary glands
Nerve growth factor (NGF)	Salivary glands; other sources suspected	Stimulation of nerve cell repair and development	Neurons and neuroglia
Epidermal growth factor (EGF)	Duodenal glands; other sources suspected	Stimulation of stem cell divisions and epithelial repairs	Epidermis
Fibroblast growth factor (FGF)	Unknown	Division and differentiation of fibroblasts and related cells	Connective tissues
Erythropoietin	Kidneys (primary source)	Stimulation of stem cell divisions and maturation of red blood cells	Bone marrow
Thymosins and related compounds	Thymus	Stimulation of division and differentiation of lymphocytes (especially T cells)	Thymus and other lymphoid tissues and organs
Chalones	Many tissues	Inhibition of cell division	Cells in the immediate area

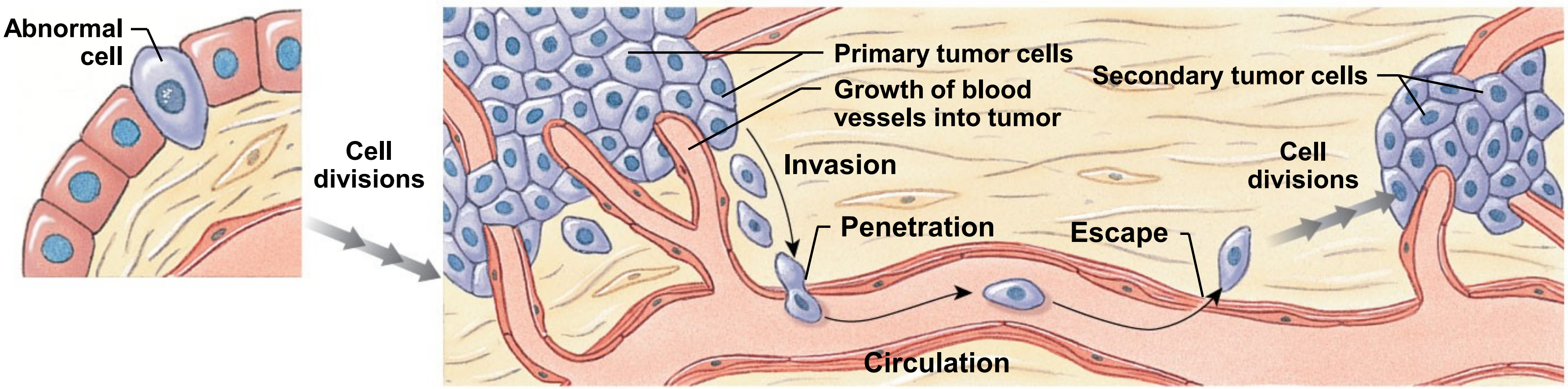
3-10 Cell Division and Cancer

- Cancer Develops in Steps
  - Abnormal cell
  - Primary tumor
  - Metastasis
  - Secondary tumor

3-10 Cell Division and Cancer

- **Tumor** (*Neoplasm*)
  - Enlarged mass of cells
  - Abnormal cell growth and division
  - *Benign tumor*
    - Contained, not life threatening unless large
  - *Malignant tumor*
    - Spreads into surrounding tissues (**invasion**)
    - Starts new tumors (**metastasis**)

Figure 3-25 The Development of Cancer



3-11 Differentiation

- Differentiation
  - All cells carry complete DNA instructions for all body functions
  - Cells specialize or **differentiate**
    - To form tissues (liver cells, fat cells, and neurons)
    - By turning *off* all genes not needed by that cell
  - All body cells, except sex cells, contain the same 46 chromosomes
  - Differentiation depends on which genes are active and which are inactive