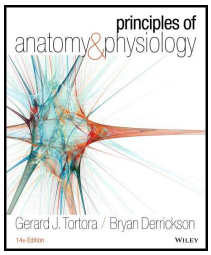


Principles of Anatomy and Physiology

14th Edition

CHAPTER 3
The Cellular Level of Organization

Introduction

The purpose of the chapter is to:

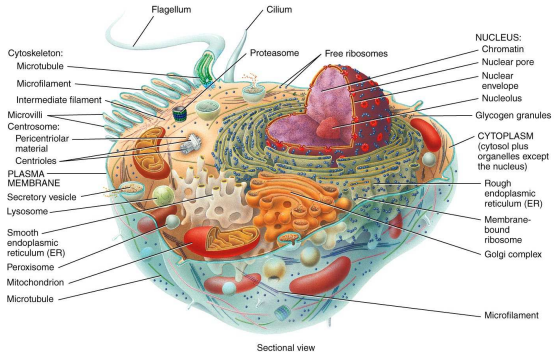
1. Introduce the parts of a cell
2. Discuss the importance of the plasma membrane
3. Discuss the components of the cytoplasm
4. Compare and contrast mitosis and meiosis
5. Understand the effects aging has on the cell

Parts of a Cell

The cell can be subdivided into 3 parts:

1. Plasma (cell) membrane
2. Cytoplasm
   - Cytosol
   - Organelles
3. Nucleus
   - Chromosomes
   - Genes

Parts of a Cell



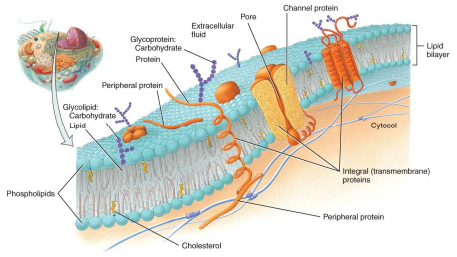
Parts of a Cell

The cell can be subdivided into 3 parts:

1. Plasma (cell) membrane
2. Cytoplasm
   - Cytosol
   - Organelles
3. Nucleus
   - Chromosomes
   - Genes

The Plasma Membrane

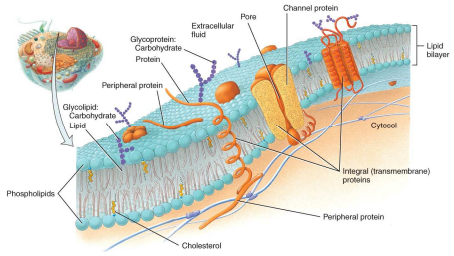
The plasma membrane is a flexible yet sturdy barrier that surrounds and contains the cytoplasm of the cell



Membrane Proteins

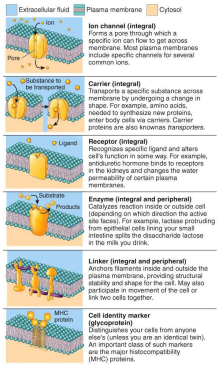
Two types of membrane proteins are

- Integral (also called transmembrane) proteins
- Peripheral proteins



Functions of Membrane Proteins

- Membrane proteins can serve a variety of functions
- The different proteins help determine many of the functions of the cell membrane



Membrane Fluidity

Membranes are fluid structures because most of the membrane lipids and many of the membrane proteins move easily in the bilayer

- Membrane lipids and proteins are mobile in their own half of the bilayer

Cholesterol serves to stabilize the membrane and reduce membrane fluidity

Membrane Permeability

Plasma membranes are selectively permeable

- The lipid bilayer is always permeable to small, nonpolar, uncharged molecules
- Transmembrane proteins that act as channels or transporters increase the permeability of the membrane
- Macromolecules are only able to pass through the plasma membrane by vesicular transport

Gradients Across the Plasma Membrane

A *concentration gradient* is the difference in the concentration of a chemical between one side of the plasma membrane and the other

An *electrical gradient* is the difference in concentration of ions between one side of the plasma membrane and the other

Together, these gradients make up an *electrochemical gradient*

Transport Across the Plasma Membrane

Transport processes that move substances across the cell membrane are:

- Passive processes
  - Simple diffusion
  - Facilitated diffusion
  - Osmosis
- Active processes
  - Active transport
  - Vesicular transport

Transport Processes

Interactions Animation:

- Transport Across the Plasma Membrane

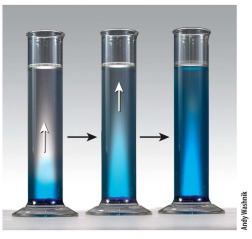
You must be connected to the Internet and in Slideshow Mode to run this animation.

Passive Processes

Simple Diffusion

Diffusion is influenced by:

1. Steepness of the concentration gradient
2. Temperature
3. Mass of diffusion substance
4. Surface area
5. Diffusion distance



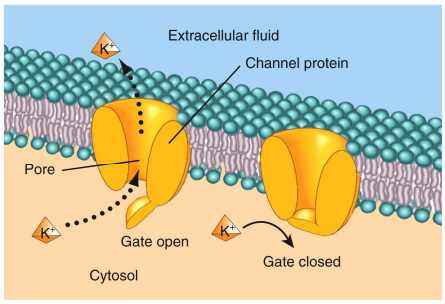
Facilitated Diffusion

Transmembrane proteins help solutes that are too polar or too highly charged move through the lipid bilayer

The processes involved are:

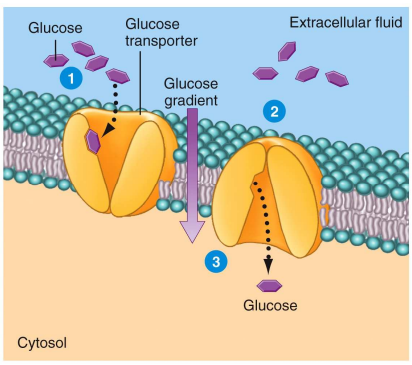
- Channel mediated facilitated diffusion
- Carrier mediated facilitated diffusion

Channel Mediated Facilitated Diffusion

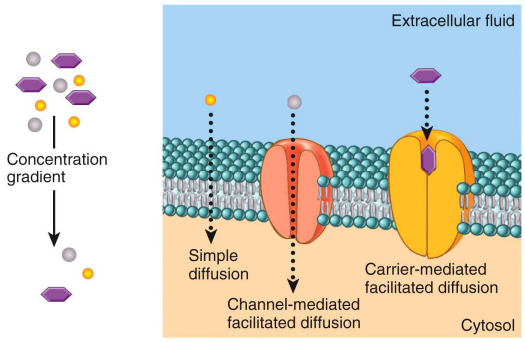


Details of the K^+ channel

Carrier Mediated Facilitated Diffusion

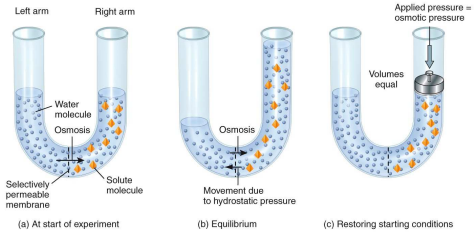


Diffusion: A Comparison



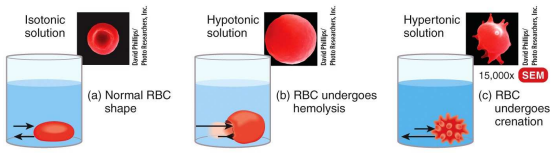
Osmosis

The net movement of a solvent through a selectively permeable membrane from an area of high concentration to an area of low concentration



Tonicity

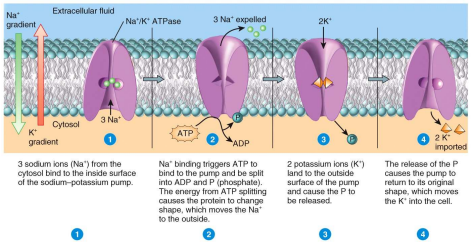
Tonicity of a solution relates to how the solution influences the shape of body cells



Active Processes

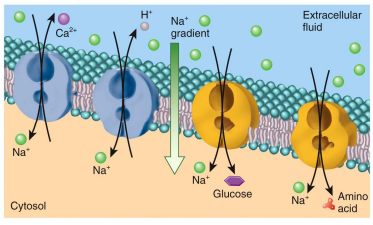
Primary Active Transport

Energy derived from ATP changes the shape of a transporter protein which pumps a substance across a plasma membrane against its concentration gradient



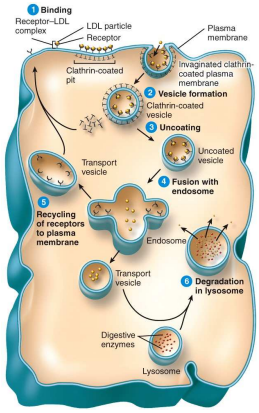
Secondary Active Transport

Energy stored (in a hydrogen or sodium concentration gradient) is used to drive other substances against their own concentration gradients

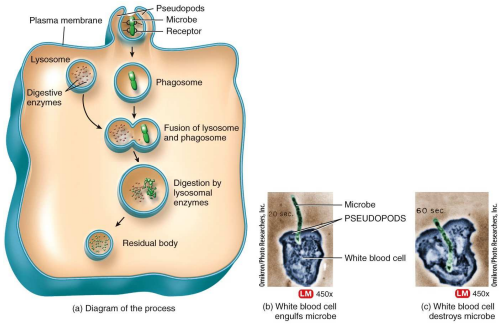


(a) Antiporters (b) Symporters

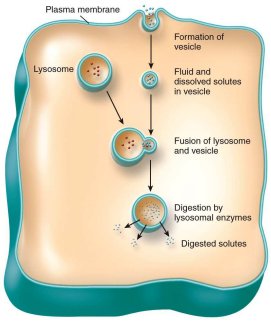
Active Transport in Vesicles: Receptor-mediated Endocytosis



Active Transport in Vesicles: Phagocytosis



Active Transport in Vesicles: Bulk Phase Endocytosis (Pinocytosis)



Active Transport in Vesicles: Exocytosis & Transcytosis

Exocytosis – membrane-enclosed secretory vesicles fuse with the plasma membrane and release their contents into the extracellular fluid

Transcytosis – a combination of endocytosis and exocytosis used to move substances from one side of a cell, across it, and out the other side

A Comparison of Transport Types

TABLE 3.1
Transport of Materials into and out of Cells

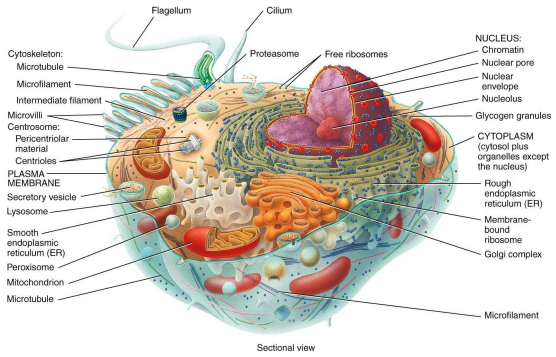
TRANSPORT PROCESS	DESCRIPTION	SUBSTANCES TRANSPORTED
PASSIVE PROCESSES	Movement of substances down a concentration gradient until equilibrium is reached; do not require cellular energy in the form of ATP.	
Diffusion	Movement of molecules or ions down a concentration gradient due to their kinetic energy until they reach equilibrium.	
Simple diffusion	Passive movement of a substance down its concentration gradient through the lipid bilayer of the plasma membrane without the help of membrane transport proteins.	Nonpolar, hydrophobic solutes: oxygen, carbon dioxide, and nitrogen gases; fatty acids; steroids; and fat-soluble vitamins. Polar molecules such as water, urea, and small alcohols.
Facilitated diffusion	Passive movement of a substance down its concentration gradient through the lipid bilayer by transmembrane proteins that function as channels or carriers.	Polar or charged solutes: glucose; fructose; galactose; some vitamins; and ions such as K^+, Cl^-, Na^+, and Ca^{2+}.
Osmosis	Passive movement of water molecules across a selectively permeable membrane from an area of higher to lower water concentration until equilibrium is reached.	Solvent: water in living systems.

A Comparison of Transport Types

TABLE 3.1
Transport of Materials into and out of Cells

TRANSPORT PROCESS	DESCRIPTION	SUBSTANCES TRANSPORTED
ACTIVE PROCESSES	Movement of substances against a concentration gradient; requires cellular energy in the form of ATP.	
Active Transport	Active process in which a cell expends energy to move a substance across the membrane against its concentration gradient by transmembrane proteins that function as carriers.	Polar or charged solutes.
Primary active transport	Active process in which a substance moves across the membrane against its concentration gradient by pumps (carriers) that use energy supplied by hydrolysis of ATP.	Na^+, K^+, Ca^{2+}, H^+, I^-, Cl^-, and other ions.
Secondary active transport	Coupled active transport of two substances across the membrane using energy supplied by a Na^+ or H^+ concentration gradient maintained by primary active transport pumps. Antiporters move Na^+ (or H^+) and another substance in opposite directions across the membrane; symporters move Na^+ (or H^+) and another substance in the same direction across the membrane.	Antiport: Ca^{2+}, H^+ out of cells. Symport: glucose, amino acids into cells.
Transport in Vesicles	Active process in which substances move into or out of cells in vesicles that bud from plasma membrane; requires energy supplied by ATP.	
Endocytosis	Movement of substances into a cell in vesicles.	
Receptor-mediated endocytosis	Ligand–receptor complexes trigger infolding of a clathrin-coated pit that forms a vesicle containing ligands.	Ligands: transferrin, low-density lipoproteins (LDLs), some vitamins, certain hormones, and antibodies.
Phagocytosis	"Cell eating"; movement of a solid particle into a cell after pseudopods engulf it to form a phagosome.	Bacteria, viruses, and aged or dead cells.
Bulk-phase endocytosis	"Cell drinking"; movement of extracellular fluid into a cell by infolding of plasma membrane to form a vesicle.	Solutes in extracellular fluid.
Exocytosis	Movement of substances out of a cell in secretory vesicles that fuse with the plasma membrane and release their contents into the extracellular fluid.	Neurotransmitters, hormones, and digestive enzymes.
Transcytosis	Movement of a substance through a cell as a result of endocytosis on one side and exocytosis on the opposite side.	Substances, such as antibodies, across endothelial cells. This is a common route for substances to pass between blood plasma and interstitial fluid.

Parts of a Cell: Cytoplasm



Sectional view

Cytoplasm

Cytosol is also known as the intracellular fluid portion of the cytoplasm

Organelles are the specialized structures that have specific shapes and perform specific functions

TABLE 3.2

Cell Parts and Their Functions

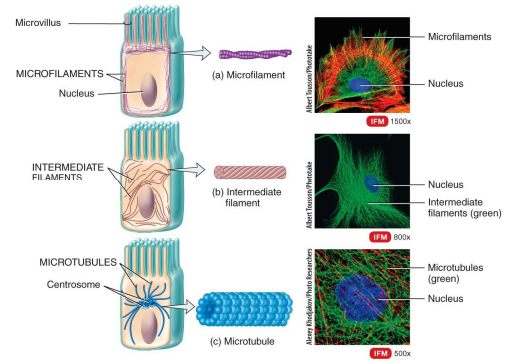
PART	DESCRIPTION	FUNCTIONS
PLASMA MEMBRANE	Fluid mosaic lipid bilayer (phospholipids, cholesterol, and glycolipids) studded with proteins; surrounds cytoplasm.	Protects cellular contents; makes contact with other cells; contains channels, transporters, receptors, enzymes, cell-identity markers, and linker proteins; mediates entry and exit of substances.
CYTOPLASM	Cellular contents between plasma membrane and nucleus—cytosol and organelles.	Site of all intracellular activities except those occurring in the nucleus.
Cytosol	Composed of water, solutes, suspended particles, lipid droplets, and glycogen granules.	Fluid in which many of cell's metabolic reactions occur.
	The cytoskeleton is a network in the cytoplasm composed of three protein filaments: microfilaments, intermediate filaments, and microtubules.	The cytoskeleton maintains shape and general organization of cellular contents; responsible for cell movements.
Organelles	Specialized structures with characteristic shapes.	Each organelle has specific functions.
Centrosome	Pair of centrioles plus pericentriolar material.	The pericentriolar material contains tubulins, which are used for growth of the mitotic spindle and microtubule formation.
Cilia and flagella	Motile cell surface projections that contain 20 microtubules and a basal body.	Cilia: move fluids over cell's surface; flagella: move entire cell.
Ribosome	Composed of two subunits containing ribosomal RNA and proteins; may be free in cytosol or attached to rough ER.	Protein synthesis.

TABLE 3.2

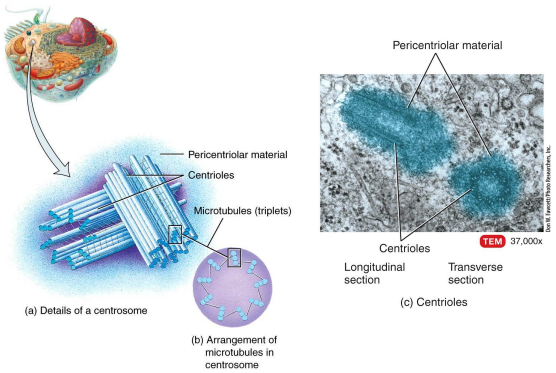
Cell Parts and Their Functions

PART	DESCRIPTION	FUNCTIONS
Endoplasmic reticulum (ER)	Membranous network of flattened sacs or tubules. Rough ER is covered by ribosomes and is attached to the nuclear envelope; smooth ER lacks ribosomes.	Rough ER: synthesizes glycoproteins and phospholipids that are transferred to cellular organelles, inserted into plasma membrane, or secreted during exocytosis; smooth ER: synthesizes fatty acids and steroids, inactivates or detoxifies drugs, removes phosphate group from glucose-6-phosphate, and stores and releases calcium ions in muscle cells.
Golgi complex	Consists of 3–20 flattened membranous sacs called cisternae; structurally and functionally divided into entry (*cis*) face, medial cisternae, and exit (*trans*) face.	Entry (*cis*) face accepts proteins from rough ER; medial cisternae form glycoproteins, glycolipids, and lipoproteins; exit (*trans*) face modifies molecules further, then sorts and packages them for transport to their destinations.
Lysosome	Vesicle formed from Golgi complex; contains digestive enzymes.	Fuses with and digests contents of endosomes, pinocytic vesicles, and phagosomes and transports final products of digestion into cytosol; digests worn-out organelles (autophagy), entire cells (autolysis), and extracellular materials.
Peroxisome	Vesicle containing oxidases (oxidative enzymes) and catalase (decomposes hydrogen peroxide); new peroxisomes bud from preexisting ones.	Oxidizes amino acids and fatty acids; detoxifies harmful substances, such as hydrogen peroxide and associated free radicals.
Proteasome	Tiny barrel-shaped structure that contains proteases (proteolytic enzymes).	Degrades unneeded, damaged, or faulty proteins by cutting them into small peptides.
Mitochondrion	Consists of an outer and an inner mitochondrial membrane, cristae, and matrix; new mitochondria form from preexisting ones.	Site of aerobic cellular respiration reactions that produce most of a cell's ATP. Plays an important early role in apoptosis.
NUCLEUS	Consists of a nuclear envelope with pores, nucleoli, and chromosomes, which exist as a tangled mass of chromatin in interphase cells.	Nuclear pores control the movement of substances between the nucleus and cytoplasm, nucleoli produce ribosomes, and chromosomes consist of genes that control cellular structure and direct cellular functions.

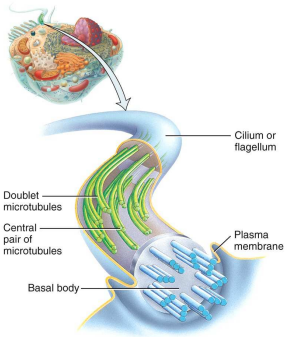
Cytoskeleton



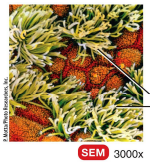
Centrosome/Centrioles



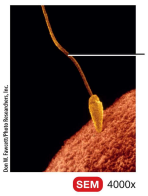
Cilia and Flagella



(a) Arrangement of microtubules in a cilium or flagellum

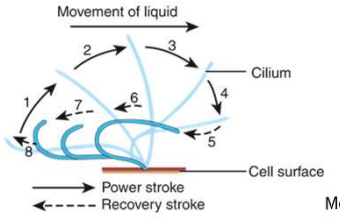


(b) Cilia lining the trachea

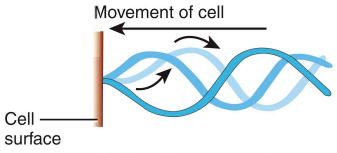


(c) Flagellum of a sperm cell

Cilia and Flagella

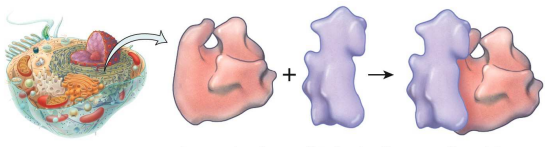


(d) Ciliary movement



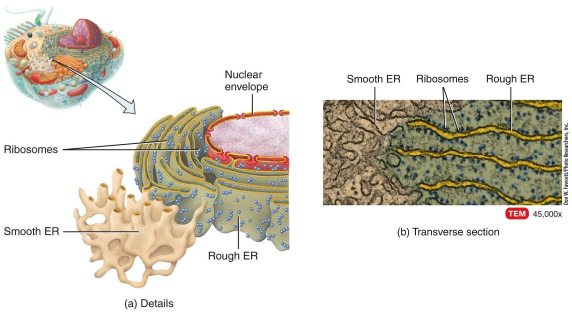
(e) Flagellar movement

Ribosomes

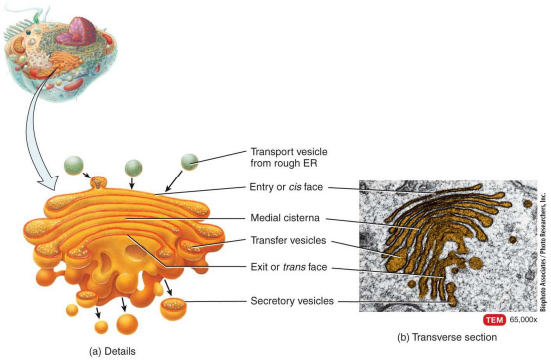


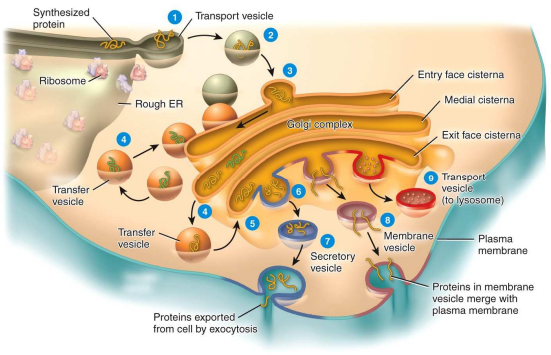
Details of ribosomal subunits

Endoplasmic Reticulum

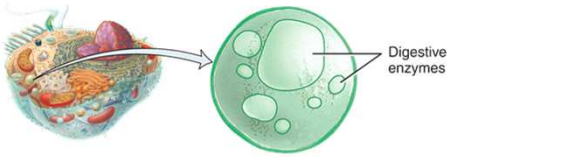


Golgi Complex

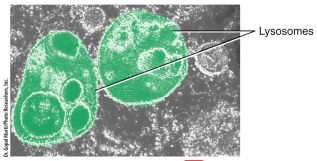




Lysosomes



(a) Lysosome



(b) Several lysosomes

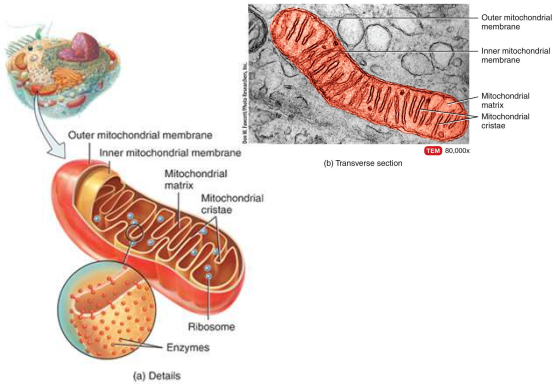
Peroxisomes

Peroxisomes are structures that are similar in shape to lysosomes, but are smaller and contain enzymes that use oxygen to oxidize (break down) organic substances

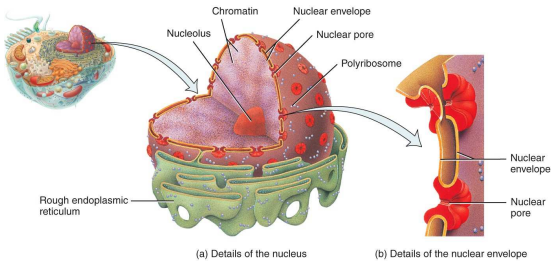
Proteasomes

Proteasomes are barrel-shaped structures that destroy unneeded, damaged, or faulty proteins by cutting long proteins into smaller peptides

Mitochondria

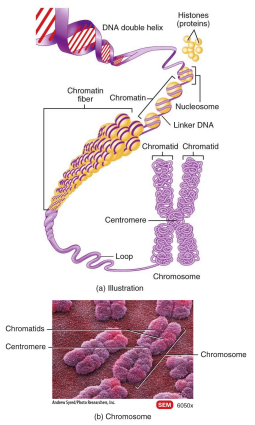


Nucleus

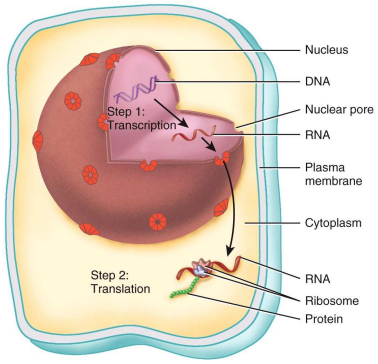


Nucleus

The nucleus contains the cell's hereditary units, called genes, which are arranged in chromosomes

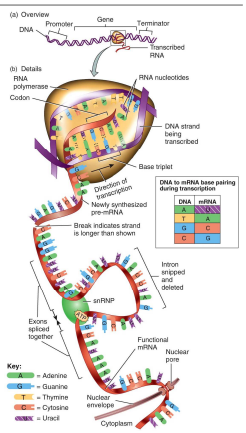


Gene Expression



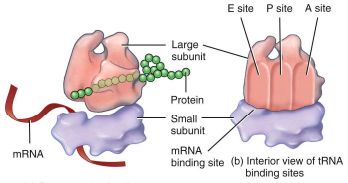
Protein Synthesis: Transcription

Transcription occurs in the nucleus and is the process by which genetic information encoded in DNA is copied onto a strand of RNA to direct protein synthesis



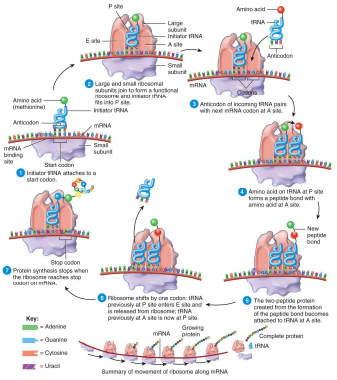
Protein Synthesis: Translation

Translation occurs in the nucleus and is the process of reading the mRNA nucleotide sequence to determine the amino acid sequence of the newly formed protein



(a) Components of a ribosome and their relationship to mRNA and protein during translation

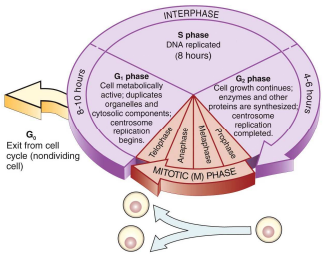
Protein Synthesis During Transcription



Cell Division

Cell division is a process by which cells reproduce themselves

- Cell cycle

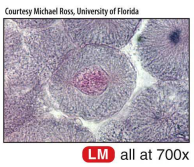


Interphase

G_1 phase

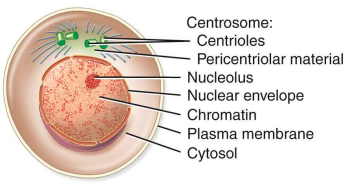
S

G_2 phase



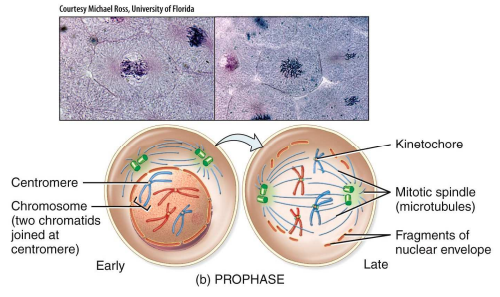
LM all at 700x

(a) INTERPHASE



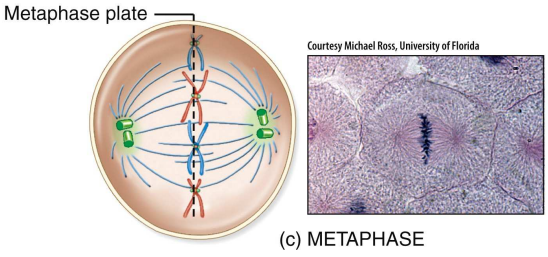
Mitotic Phase: Prophase

During prophase chromatin condenses into chromosomes



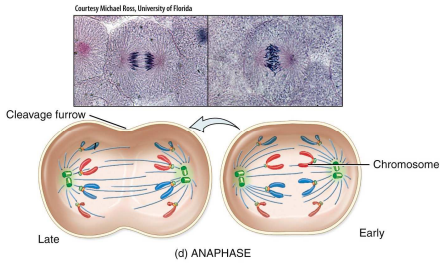
Mitotic Phase: Metaphase

During metaphase centromeres of chromosomes line up at the metaphase plate



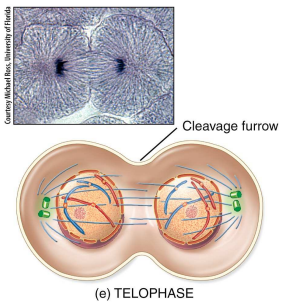
Mitotic Phase: Anaphase

During anaphase centromeres of chromosomes split and sister chromatids move toward opposite poles of the cell



Mitotic Phase: Telophase

During telophase the mitotic spindle dissolves, chromosomes regain their chromatin appearance, and a new nuclear membrane forms



Cytokinesis

During cytokinesis a cleavage furrow forms and eventually the cytoplasm of the parent cell fully splits

- When this is complete, interphase begins

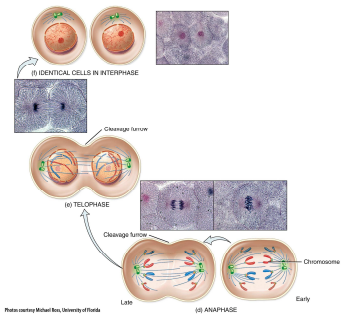


TABLE 3.3

Events of the Somatic Cell Cycle

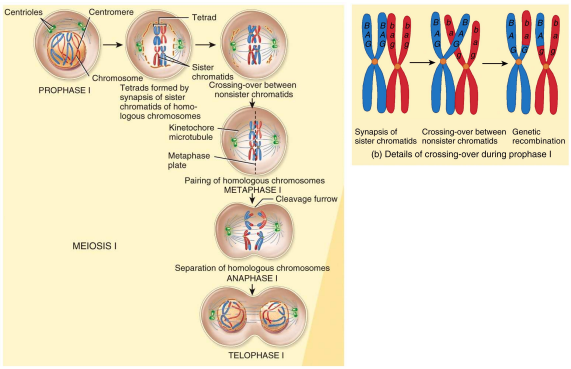
PHASE	ACTIVITY
Interphase	Period between cell divisions; chromosomes not visible under light microscope.
G_1 phase	Metabolically active cell duplicates most of its organelles and cytosolic components; replication of chromosomes begins. (Cells that remain in the G_1 phase for a very long time, and possibly never divide again, are said to be in the G_0 phase.)
S phase	Replication of DNA and centrosomes.
G_2 phase	Cell growth, enzyme and protein synthesis continue; replication of centrosomes complete.
Mitotic phase	Parent cell produces identical cells with identical chromosomes; chromosomes visible under light microscope.
Mitosis	Nuclear division; distribution of two sets of chromosomes into separate nuclei.
Prophase	Chromatin fibers condense into paired chromatids; nucleolus and nuclear envelope disappear; each centrosome moves to an opposite pole of the cell.
Metaphase	Centromeres of chromatid pairs line up at metaphase plate.
Anaphase	Centromeres split; identical sets of chromosomes move to opposite poles of cell.
Telophase	Nuclear envelopes and nucleoli reappear; chromosomes resume chromatin form; mitotic spindle disappears.
Cytokinesis	Cytoplasmic division; contractile ring forms cleavage furrow around center of cell, dividing cytoplasm into separate and equal portions.

Control of Cell Destiny

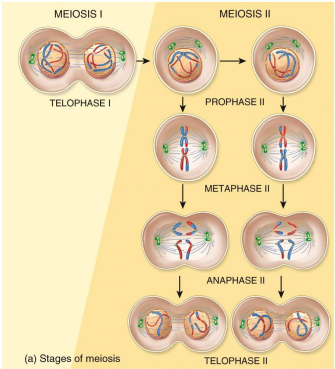
3 possible destinies:

1. Remain alive and functioning without dividing
2. Grow and divide
3. Die

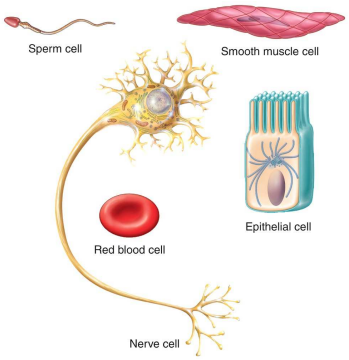
Reproductive Cell Division: Meiosis I



Reproductive Cell Division: Meiosis II



Cellular Diversity



Aging and Cells

As we age:

- Our cells gradually deteriorate in their ability function normally and in their ability to respond to environmental stresses
- The numbers of our body cells decreases
- We lose the integrity of the extracellular components of our tissues

Free radicals

End of Chapter 3