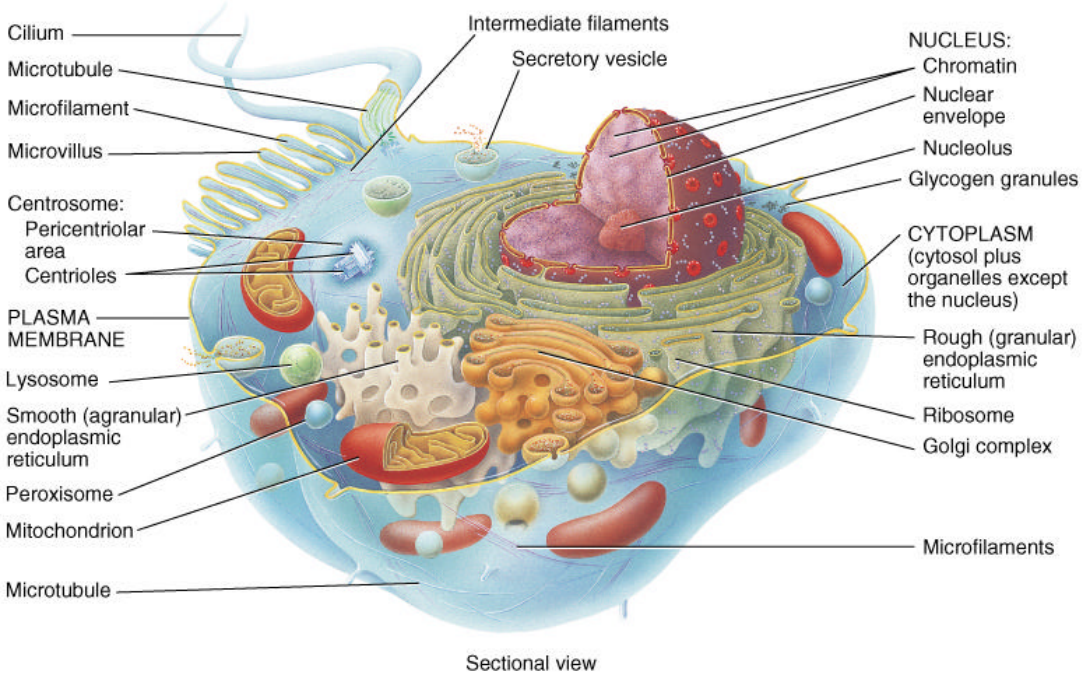
The Cellular Level of Organization

- Basic, living, structural and functional unit of the body
  - compartmentalization of chemical reactions within specialized structures
  - regulate inflow & outflow of materials
  - use genetic material to direct cell activities
- Cytology = study of cellular structure
- Cell physiology = study of cellular function

Generalized Cell Structures

- Plasma membrane = cell membrane
- Nucleus = genetic material of cell
- Cytoplasm = everything between the membrane and the nucleus
  - cytosol = intracellular fluid
  - organelles = subcellular structures with specific functions

The Typical Cell



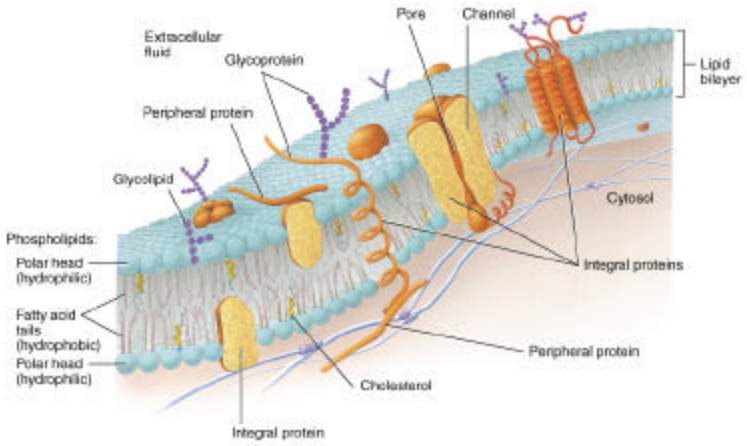
Sectional view

- Not all cells contain all of these organelles.

Plasma Membrane

- Flexible but sturdy barrier that surround cytoplasm of cell
- Fluid mosaic model describes its structure
  - "sea of lipids in which proteins float like icebergs"
  - membrane is 50 % lipid & 50 % protein

- held together by hydrogen bonds
  - lipid is barrier to entry or exit of polar substances
  - proteins are “gatekeepers” -- regulate traffic
- 50 lipid molecules for each protein molecule



Lipid Bilayer of the Cell Membrane

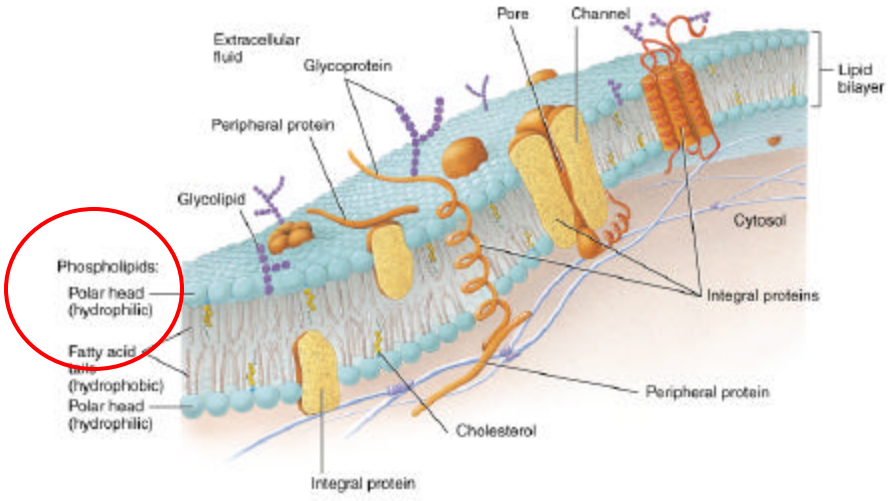
- Two back-to-back layers of 3 types of lipid molecules
- Cholesterol and glycolipids scattered among a double row of phospholipid molecules

Phospholipids

- Comprises 75% of lipids
- Phospholipid bilayer = 2 parallel layers of molecules
- Each molecule is amphipathic (has both a polar & nonpolar region)
  - polar parts (heads) are hydophilic and face on both surfaces a watery environment
  - nonpolar parts (tails) are hydrophobic and line up next to each other in the interior

Glycolipids within the Cell Membrane

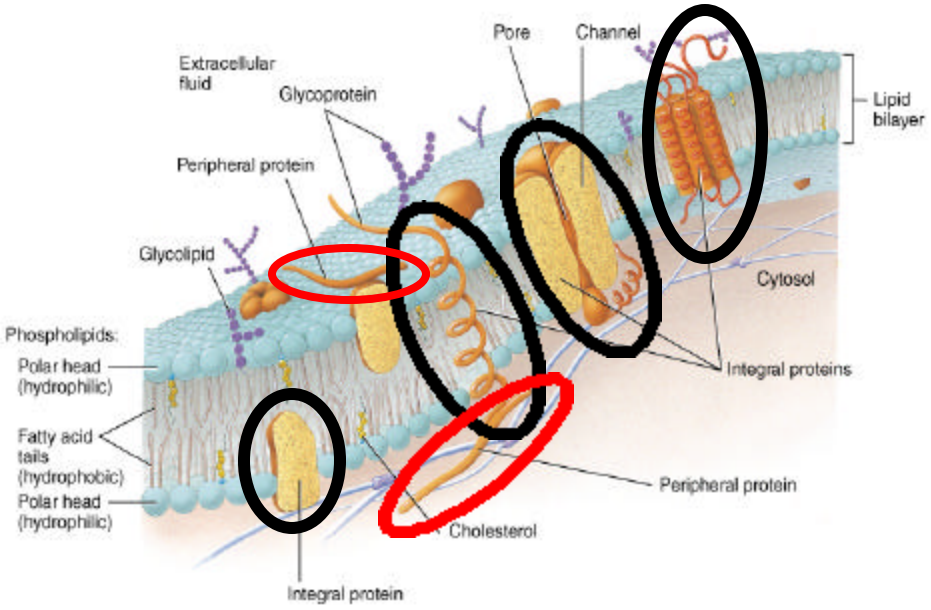
- Comprises 5% of the lipids of the cell membrane
- Carbohydrate groups form a polar head only on the side of the membrane facing the extracellular fluid



Types of Membrane Proteins

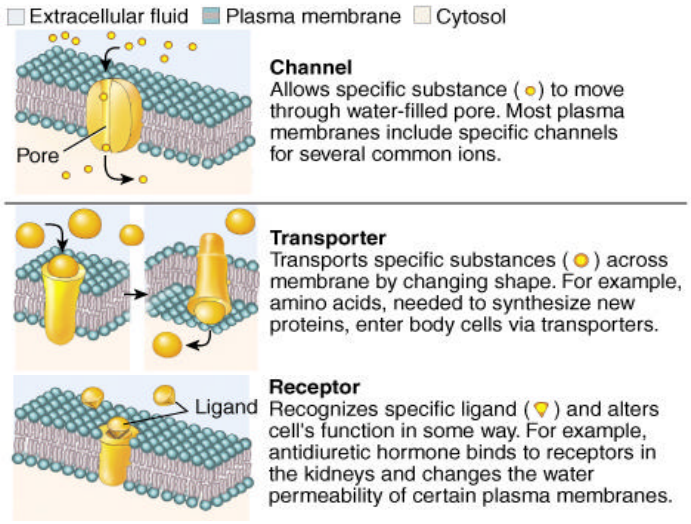
- Integral proteins
  - extend into or completely across cell membrane
    - if extend completely across = transmembrane proteins
  - all are amphipathic with hydrophobic portions hiding among the phospholipid tails
  - glycoproteins have the sugar portion facing the extracellular fluid to form a glycocalyx
    - gives cell "uniqueness", protects it from being digested, creates a stickiness to hold it to other cells or so it can hold a fluid layer creating a slippery surface
- Peripheral proteins
  - attached to either inner or outer surface of cell membrane and are easily removed from it

Membrane Proteins



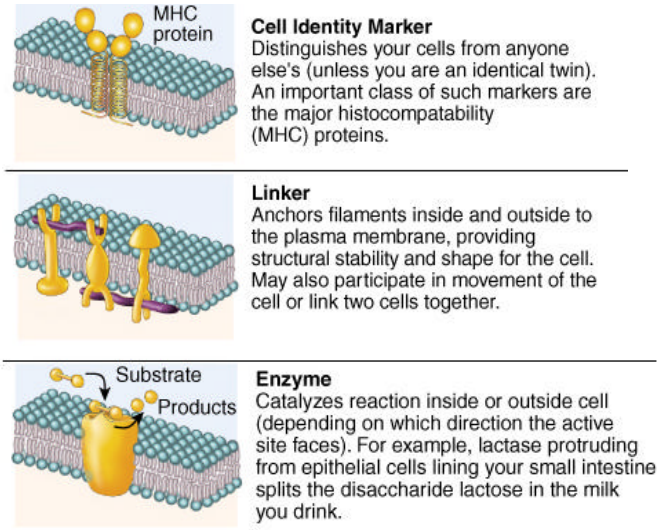
Functions of Membrane Proteins

- Formation of Channel
  - passageway to allow specific substance to pass through
- Transporter Proteins
  - bind a specific substance, change their shape & move it across membrane
- Receptor Proteins
  - cellular recognition site -- bind to substance



Functions of Membrane Proteins

- Cell Identity Marker
  - allow cell to recognize other similar cells
- Linker
  - anchor proteins in cell membrane or to other cells
  - allow cell movement
  - cell shape & structure
- Act as Enzyme
  - speed up reactions



Membrane Fluidity

- Membranes are fluid structures (oil layer)
  - self-sealing if punctured with needle
- Explanation -- a compromise of forces
  - membrane molecules can rotate & move freely
  - need to stay in one half of lipid bilayer
    - difficult for hydrophilic parts to pass through hydrophobic core of bilipid layer
  - fluidity is reduced by presence of cholesterol
    - increases stiffness of membrane it forms hydrogen bonds with neighboring phospholipid heads

Selective Permeability of Membrane

- Lipid bilayer
  - permeable to nonpolar, uncharged molecules -- oxygen, CO_2, steroids
  - permeable to water which flows through gaps that form in hydrophobic core of membrane as phospholipids move about
- Transmembrane proteins act as specific channels
  - small and medium polar & charged particles
- Macromolecules unable to pass through the membrane
  - vesicular transport

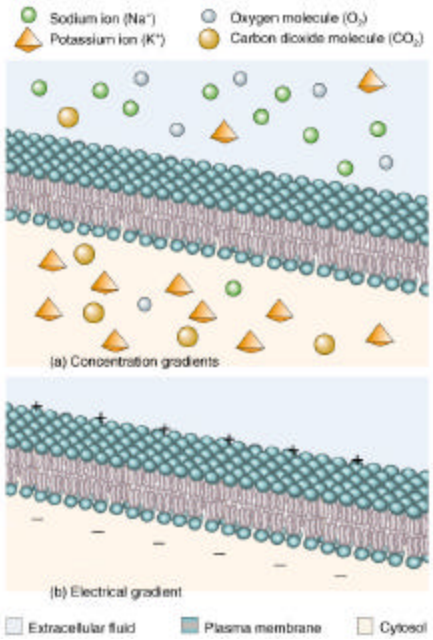
Gradients Across the Plasma Membrane

- Membrane can maintain difference in concentration of a substance inside versus outside of the membrane (concentration gradient)
  - more O_2 & Na+ outside of cell membrane
  - more CO_2 and K+ inside of cell membrane
- Membrane can maintain a difference in charged ions between inside & outside of membrane (electrical gradient or membrane potential)
- Thus, substances move down their concentration gradient and towards the oppositely charged area
  - ions have electrochemical gradients

Gradients Across Membrane

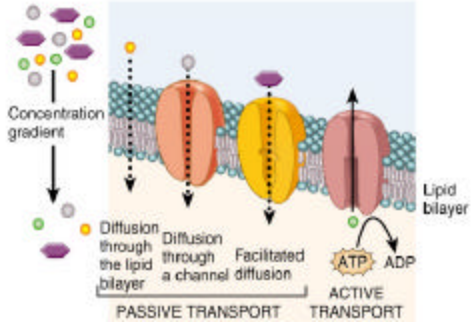
- Concentration gradient

- Electrical gradient



Transport Across the Plasma Membrane

- Substances cross membranes by a variety of processes:
  - mediated transport moves materials with the help of a transporter protein
  - nonmediated transport does not use a transporter protein



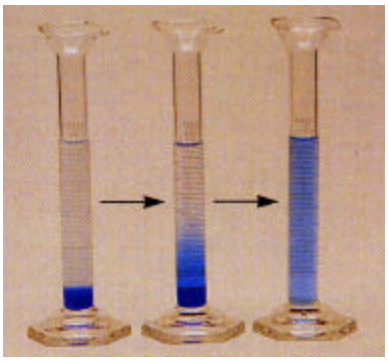
- active transport uses ATP to drive substances against their concentration gradients
- passive transport moves substances down their concentration gradient with only their kinetic energy
- vesicular transport move materials across membranes in small vesicles -- either by exocytosis or endocytosis

Principles of Diffusion

- Random mixing of particles in a solution as a result of the particle's kinetic energy
  - more molecules move away from an area of high concentration to an area of low concentration
    - the greater the difference in concentration between the 2 sides of the membrane, the faster the rate of diffusion
    - the higher the temperature, the faster the rate of diffusion
    - the larger the size of the diffusing substance, the slower the rate of diffusion
    - an increase in surface area, increases the rate of diffusion
    - increasing diffusion distance, slows rate of diffusion
- When the molecules are evenly distributed, equilibrium has been reached

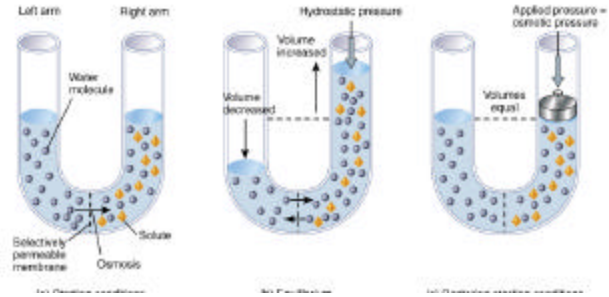
Diffusion

- Crystal of dye placed in a cylinder of water
- Net diffusion from the higher dye concentration to the region of lower dye
- Equilibrium has been reached in the far right cylinder



Osmosis

- Net movement of water through a selectively permeable membrane from an area of high water concentration to an area of lower water concentration
  - diffusion through lipid bilayer
  - aquaporins (transmembrane proteins) that function as water channels
- Only occurs if membrane is permeable to water but not to certain solutes



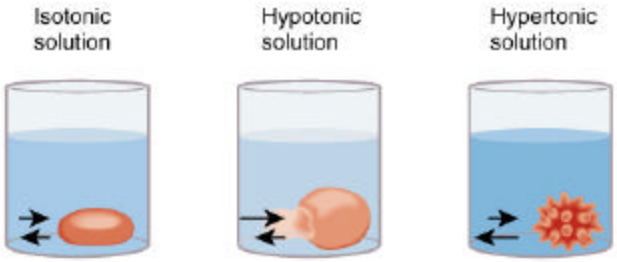
- Pure water on the left side & a membrane impermeable to the solute found on the right side
- Net movement of water is from left to right, until hydrostatic pressure (osmotic pressure) starts to push water back to the left

Affects of Tonicity on RBCs in Lab

- Normally the osmotic pressure of the inside of the cell is equal to the fluid outside the cell
  - cell volume remains constant (solution is isotonic)
- Effects of fluids on RBCs in lab
  - water enters the cell faster than it leaves
  - water enters & leaves the cell in equal amounts
  - water leaves the cell

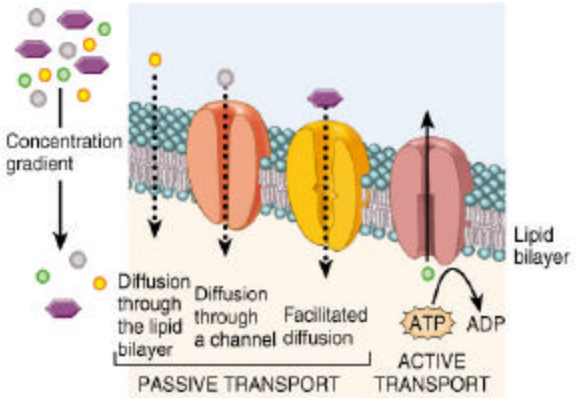
Effects of Tonicity on Cell Membranes

- Isotonic solution
  - water concentration the same inside & outside of cell results in no net movement of water across cell membrane
- Hypotonic solution
  - higher concentration of water outside of cell results in hemolysis
- Hypertonic solution
  - lower concentration of water outside of cell causes crenation



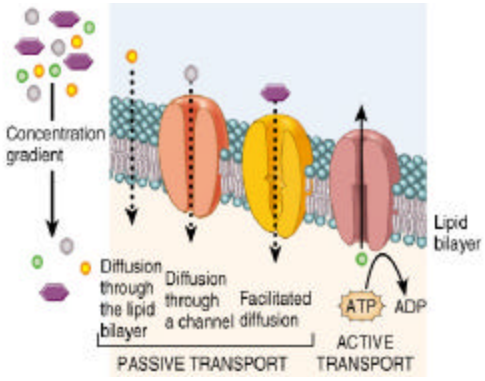
Diffusion Through the Lipid Bilayer

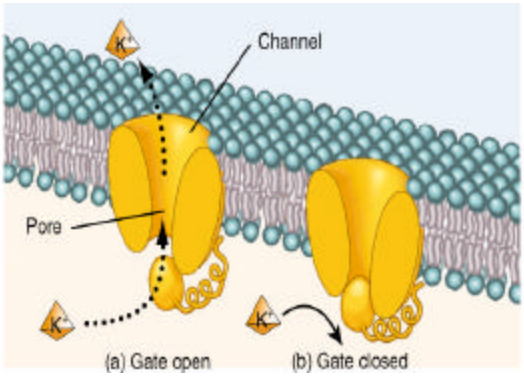
- Important for absorption of nutrients -- excretion of wastes
- Nonpolar, hydrophobic molecules
  - oxygen, carbon dioxide, nitrogen, fatty acids, steroids, small alcohols, ammonia and fat-soluble vitamins (A, E, D and K)



Diffusion Through Membrane Channels

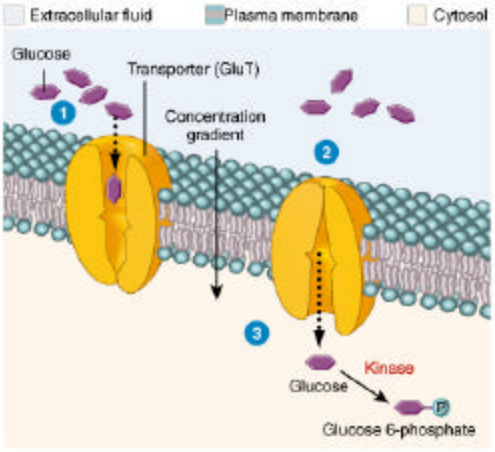
- Each membrane channel specific for particular ion (K+, Cl-, Na+ or Ca+2)
- Slower than diffusion through membrane but still 1million K+ through a channel in one second
- Channels may be open all the time or gated (closed randomly or as ordered)





Facilitated Diffusion

- Substance binds to specific transporter protein
- Transporter protein conformational change moves substance across cell membrane
- Facilitated diffusion occurs down concentration gradient only
  - if no concentration difference exists, no net movement across membrane occurs
- Rate of movement depends upon
  - steepness of concentration gradient
  - number of transporter proteins (transport maximum)

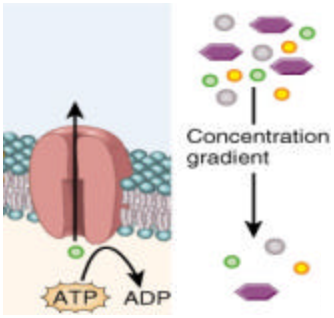


Active Transport

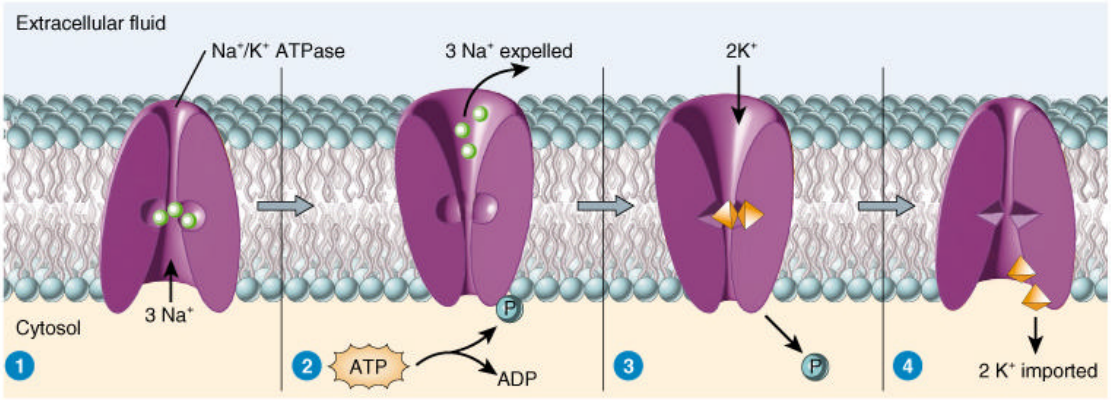
- Movement of polar or charged substances against their concentration gradient
  - energy-requiring process
    - energy from hydrolysis of ATP (primary active transport)
    - energy stored in an ionic concentration gradient (secondary active transport)
- Exhibits transport maximums and saturation
- Na+, K+, H+, Ca+2, I- and Cl-, amino acids and monosaccharides

Primary Active Transport

- Transporter protein called a pump
  - works against concentration gradient
  - requires 40% of cellular ATP
- Na+/K+ ATPase pump
  most common example
  - all cells have 1000s of them
  - maintains low concentration of Na+
    and a high concentration of K+ in the cytosol
  - operates continually



- Maintenance of osmotic pressure across membrane
  - cells neither shrink nor swell due to osmosis & osmotic pressure
    - sodium continually pumped out as if sodium could not enter the cell (factor in osmotic pressure of extracellular fluid)
    - K+ inside the cell contributes to osmotic pressure of cytosol

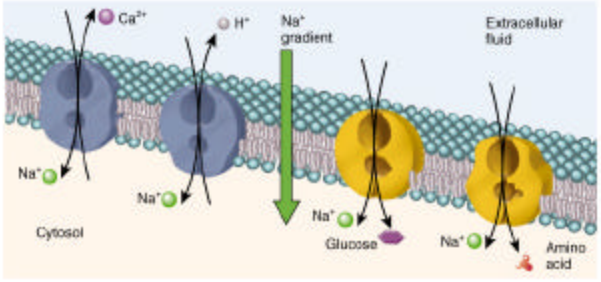


Secondary Active Transport

- Uses energy stored in an ion concentration gradient to move other substances against their own concentration gradient
- Na+/K+ pump maintains low concentration of Na+ inside of cells
  - provide route for Na+ to leak back in and use energy of motion to transport other substances
  - Na+ symporter proteins
    - glucose or amino acids rush inward with Na+ ions
  - Na+ antiporters protein
    - as Na+ ions rush inward, Ca+2 or H+ pushed out

Antiporters and Symporters

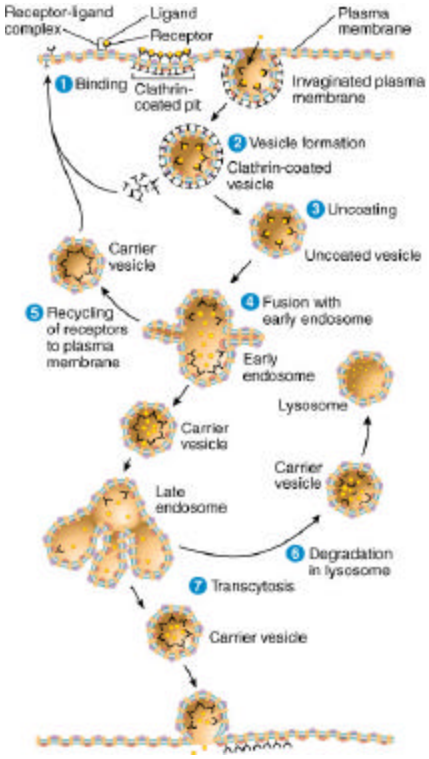
One in & one out. Both going in



Vesicular Transport of Particles

- Endocytosis = bringing something into cell
  - phagocytosis = cell eating by macrophages & WBCs
    - particle binds to receptor protein
    - whole bacteria or viruses are engulfed & later digested
  - pinocytosis = cell drinking
    - no receptor proteins
  - receptor-mediated endocytosis = selective input
    - mechanism by which HIV virus enters cells
- Exocytosis = release something from cell
  - Vesicles form inside cell, fuse to cell membrane
  - Release their contents
    - digestive enzymes, hormones, neurotransmitters or waste products
  - replace cell membrane lost by endocytosis

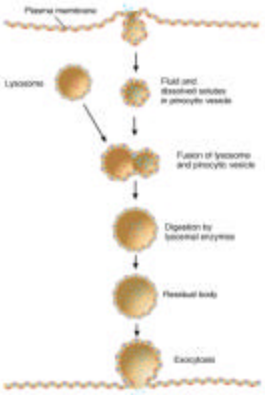
Receptor-Mediated Endocytosis



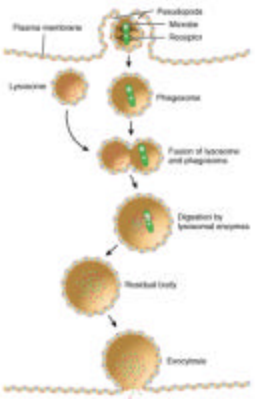
- Mechanism for uptake of specific substances -- ligands
- Desired substance binds to receptor protein in clathrin-coated pit region of cell membrane causing membrane to fold inward
- Vesicles become uncoated & combine with endosome
- Receptor proteins separate from ligands and return to surface
- Ligands are digested by lysosomal enzymes or transported across cell -- epithelial cell crossing accomplished

Pinocytosis and Phagocytosis

No pseudopods form
Nonselective drinking of extracellular fluid



Pseudopods extend to form phagosome
Lysosome joins it

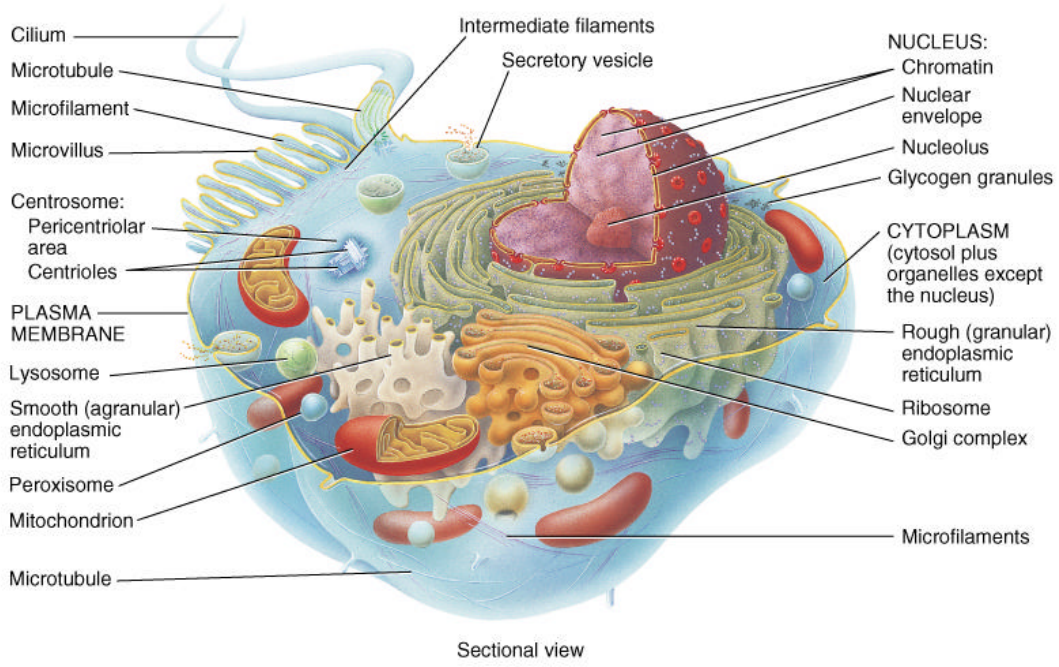


Cytosol = Intracellular fluid

- 55% of cell volume
- 75-90% water with other components
  - large organic molecules (proteins, carbos & lipids)
    - suspended by electrical charges
  - small organic molecules (simple sugars) & ions
    - dissolved
  - inclusions (large aggregates of one material)
    - lipid droplets
    - glycogen granules
- Site of many important chemical reactions
  - production of ATP, synthesis of building blocks

Cell Organelles

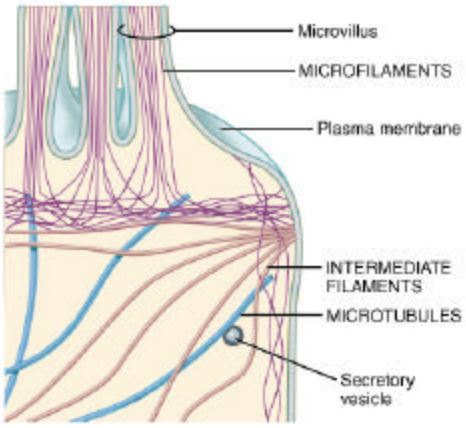
- Nonmembranous organelles lack membranes & are indirect contact with cytoplasm
- Membranous organelles surrounded by one or two lipid bilayer membranes



Sectional view

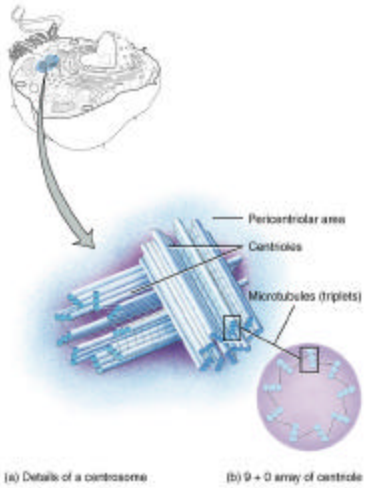
Cytoskeleton

- Network of protein filaments throughout the cytosol
- Functions
  - cell support and shape
  - organization of chemical reactions
  - cell & organelle movement
- Continually reorganized



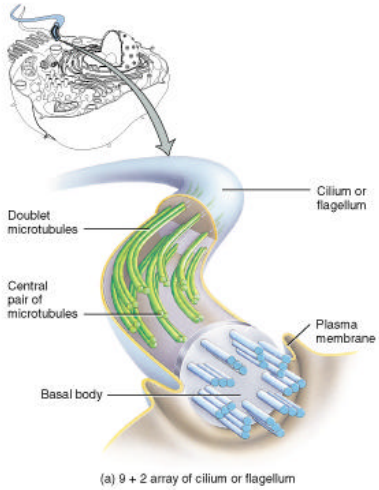
Centrosome

- Found near nucleus
- Pericentriolar area
  - formation site for mitotic spindle and microtubules
- Centrosome
  - 2 centrioles(90 degrees to each other)
  - 9 clusters of 3 microtubules (9+0 array)
  - role in formation of cilia & flagella



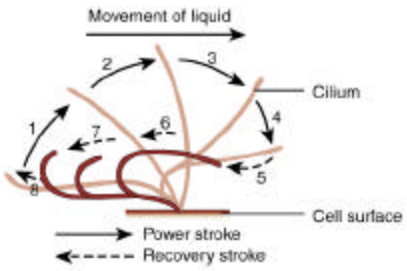
Cilia and Flagella

- Structure
  - pairs of microtubules (9+2 array)
  - covered by cell membrane
  - basal body is centriole responsible for initiating its assembly
- Differences
  - cilia
    - short and multiple
  - flagella
    - longer and single



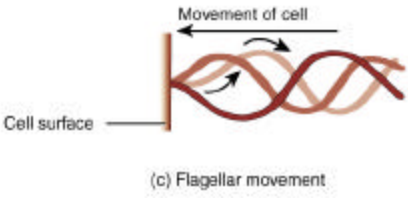
Movement of Cilia and Flagella

- Cilia
  - stiff during power stroke but flexible during recovery
  - many coordinated together
  - airways & uterine tube
- Flagella
  - single flagella wiggles in a wavelike pattern
  - propels sperm forward



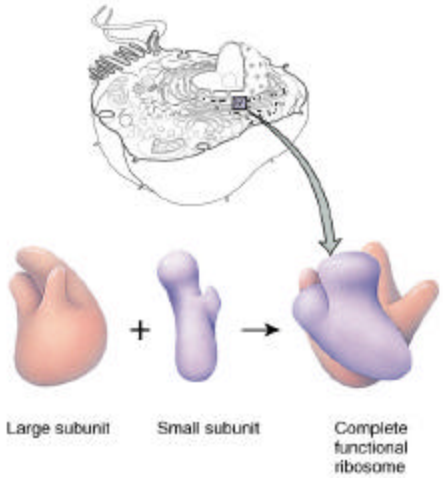
Ribosomes

- Packages of Ribosomal RNA & protein
- Free ribosomes are loose in cytosol
  - synthesize proteins found inside the cell
- Membrane-bound ribosomes
  - attached to endoplasmic reticulum or nuclear membrane
  - synthesize proteins needed for plasma membrane or for export
  - 10 to 20 together form a polyribosome
- Inside mitochondria, synthesize mitochondrial proteins



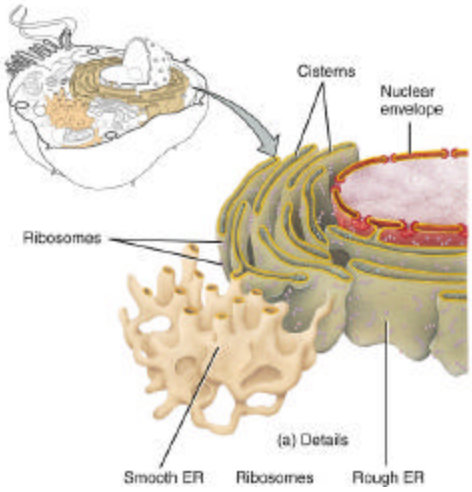
Ribosomal Subunits

- Large + small subunits
  - made in the nucleolus
  - assembled in the cytoplasm



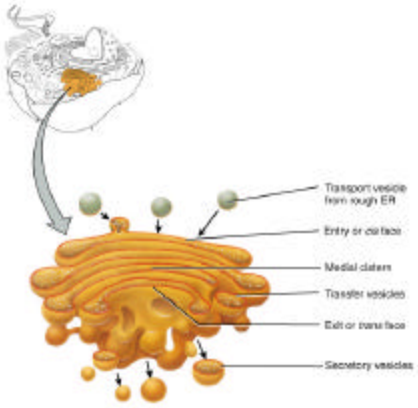
Endoplasmic Reticulum

- Network of membranes forming flattened sacs or tubules called cisterns
  - half of membranous surfaces within cytoplasm
- Rough ER
  - continuous with nuclear envelope & covered with attached ribosomes
  - synthesizes, processes & packages proteins for export
  - free ribosomes synthesize proteins for local use
- Smooth ER -- no attached ribosomes
  - synthesizes phospholipids, steroids and fats
  - detoxifies harmful substances (alcohol)



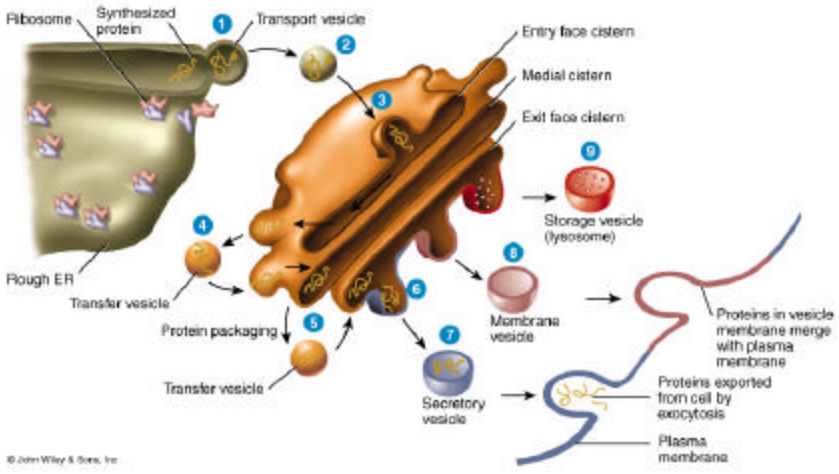
Golgi Complex

- 3-20 flattened, curved membranous sacs called cisterns
- Convex side faces ER & concave side faces cell membrane
- Processes & packages proteins produced by rough ER

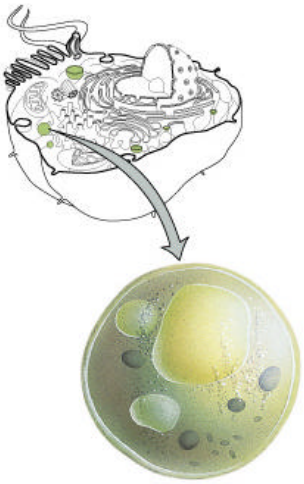


Packaging by Golgi Complex

- Proteins pass from rough ER to golgi complex in transport vesicles
- Processed proteins pass from entry cistern to medial cistern to exit cistern in transfer vesicle
- Finished proteins exit golgi as secretory, membrane or storage vesicle (lysosome)



Lysosomes

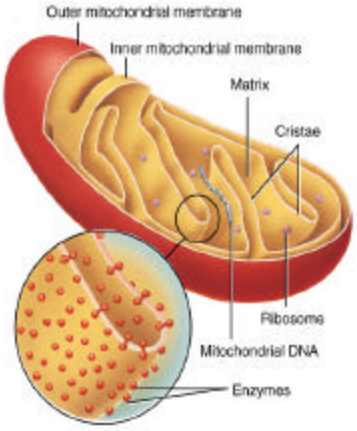


- Membranous vesicles
  - formed in Golgi complex
  - filled with digestive enzymes
  - pumps in H+ ions until internal pH reaches 5.0
- Functions
  - digest foreign substances
  - autophagy(autophagosome forms)
    - recycles own organelles
  - autolysis
    - lysosomal damage after death

Peroxisomes

- Membranous vesicles
  - smaller than lysosomes
  - form by division of preexisting peroxisomes
  - contain enzymes that oxidize organic material
- Function
  - part of normal metabolic breakdown of amino acids and fatty acids
  - oxidizes toxic substances such as alcohol and formaldehyde
  - contains catalase which decomposes H_2O_2

Mitochondria

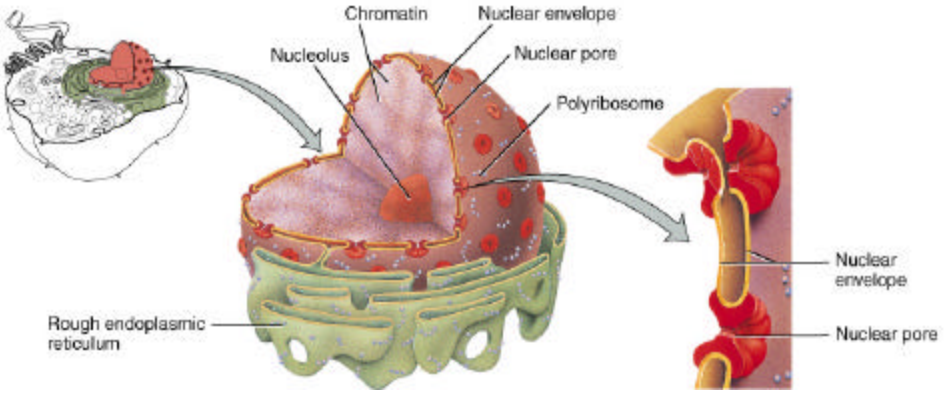


- Double membrane organelle
  - central cavity known as matrix
  - inner membrane folds known as crista
    - surface area for chemical reactions of cellular respiration
- Function
  - generation of ATP
  - powerhouse of cell

- Mitochondria self-replicate
  - increases with need for ATP
  - circular DNA with 37 genes
  - only inherited from mother

Nucleus

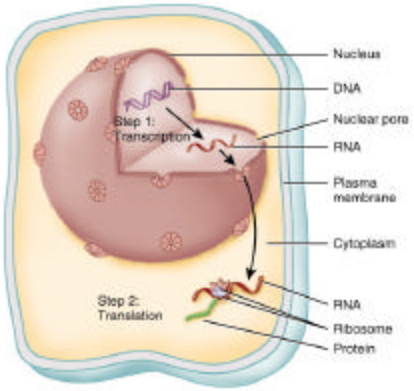
- Large organelle with double membrane nuclear envelope
  - outer membrane continuous with rough ER
  - perforated by water-filled nuclear pores (10X channel pore size)
- Nucleolus
  - spherical, dark bodies within the nucleus (no membrane)
  - site of ribosome assembly



Function of Nucleus

- 46 human DNA molecules or chromosomes
  - genes found on chromosomes
  - gene is directions for a specific protein
- Non-dividing cells contain nuclear chromatin
  - loosely packed DNA
- Dividing cells contain chromosomes
  - tightly packed DNA
  - it doubled (copied itself) before condensing

Protein Synthesis

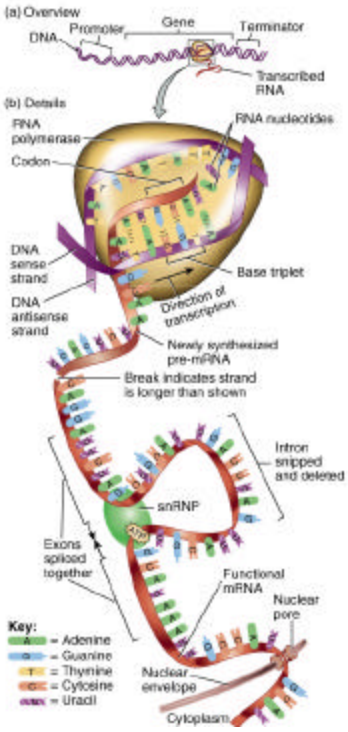


- Instructions for making specific proteins is found in the DNA (your genes)
  - transcribe that information onto a messenger RNA molecule
    - each sequence of 3 nucleotides in DNA is called base triplet
    - each base triplet is transcribed as 3 RNA nucleotides (codon)
  - translate the "message" into a sequence of amino acids in order to build a protein

molecule

- each codon must be matched by an anticodon found on the tRNA carrying a specific amino acid

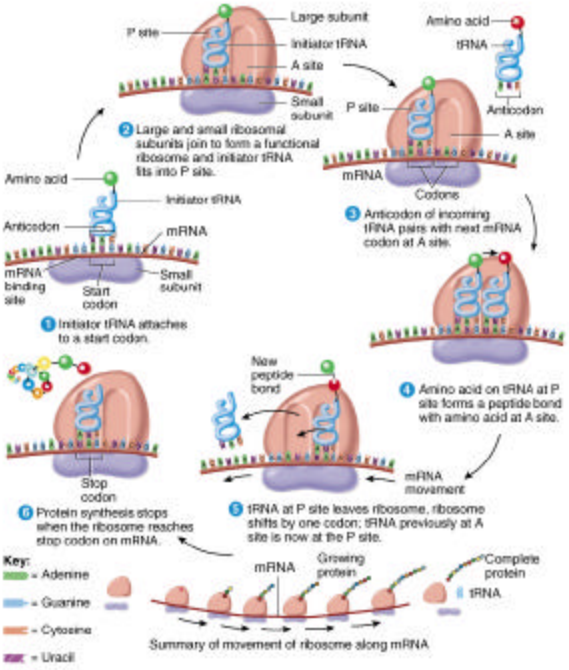
Transcription



- DNA sense strand is template for the creation of messenger RNA strand

Translation

- Process where mRNA, rRNA & tRNA are used to form a specific protein



Normal Cell Division

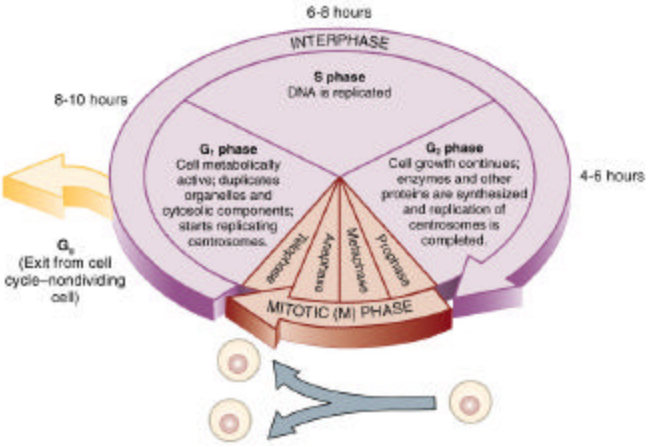
- Mitosis (somatic cell division)
  - one parent cell gives rise to 2 identical daughter cells
    - mitosis is nuclear division
    - cytokinesis is cytoplasmic division
  - occurs in billions of cells each day
  - needed for tissue repair and growth
- Meiosis (reproductive cell division)
  - egg and sperm cell production
  - in testes and ovary only

The Cell Cycle in Somatic Cells

- Process where cell duplicates its contents & divides in two
  - 23 homologous pairs of chromosomes must be duplicated
  - genes must be passed on correctly to the next generation of cells
- Nuclear division = mitosis
  - continuous process divided into 4 stages
  - prophase, metaphase, anaphase & telophase
- Cytoplasmic division = cytokinesis

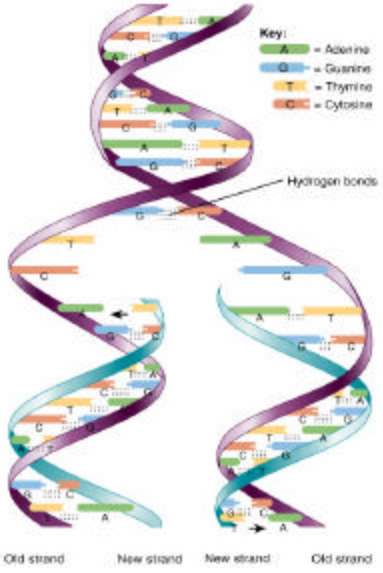
Interphase Stage of Cell Cycle

- Doubling of DNA and centrosome
- Phases of interphase stage -- G1, S, and G2
  - G1 = cytoplasmic increase (G0 if never divides again)
  - S = replication of chromosomes
  - G2 = cytoplasmic growth



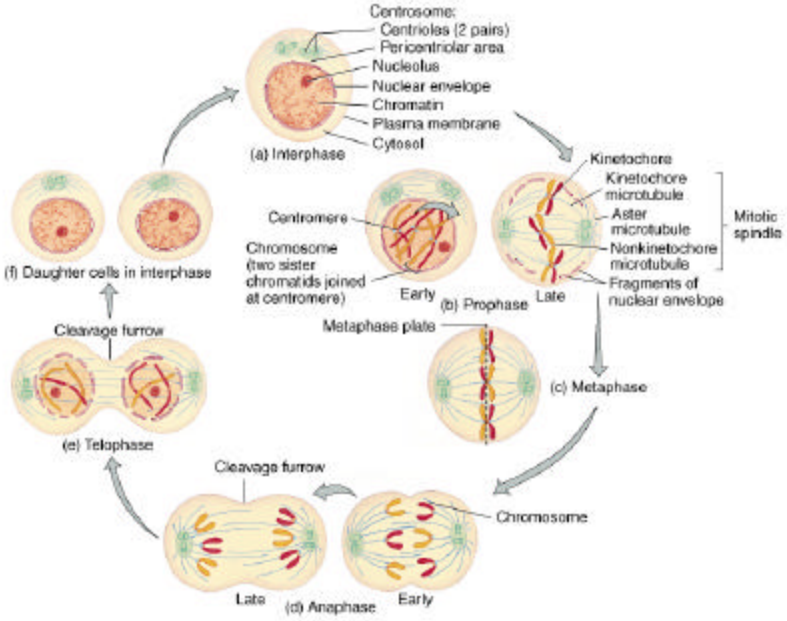
Replication of Chromosomes

- Doubling of genetic material during interphase. (S phase)
- DNA molecules unzip
- Mirror copy is formed along each old strand.
- Nitrogenous bases pick up complementary base
- 2 complete identical DNA molecules formed



Stages of Nuclear Division:Mitosis

- Prophase
- Metaphase
- Anaphase
- Telophase



Control of Cell Destiny

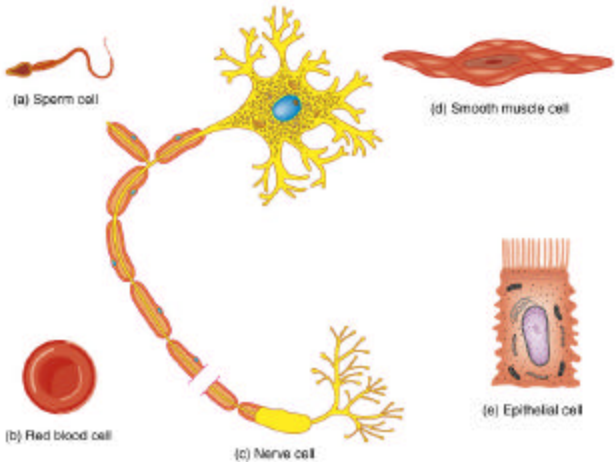
- Cell destiny is either to remain alive & functioning, to grow & divide or to die
- Homeostasis must maintain balance between cell multiplication & cell death
- The protein cyclin builds up during interphase and triggers mitosis
- Programmed cell death (apoptosis) occurs if a triggering agent turns on suicide enzymes that kills the cell
- Necrosis is cell death caused by injury or infection

Aging

- Age alters the body's ability to adapt to changes in the environment
- Theories to explain aging
  - cells have a limited number of divisions
  - glucose bonds irreversibly with proteins
  - free radical theory---electrically charged molecules with an unpaired electron cause cell damage
  - autoimmune responses due to changes in cell identity markers
- Evidence of aging
  - damaged skin, hardened arteries, stiff joints

Cellular Diversity

- 100 trillion cells in the body -- 200 different types
- Vary in size and shape related to their function



Cancer = out of control cell division

- Hyperplasia = increased number of cell divisions
  - benign tumor does not metatasize or spread
  - malignant---spreads due to cells that detach from tumor and enter blood or lymph
- Causes -- carcinogens, x-rays, viruses
  - every cell has genes that regulate growth & development
  - mutation in those genes due to radiation or chemical agents causes excess production of growth factors
- Carcinogenesis
  - multistep process that takes years and many different mutations that need to occur