Cell Physiology

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Cell Physiology

- Membrane Transport
- Protein Synthesis
- Reproduction
- Membrane transport—movement of substances into and out of the cell
- Two basic methods of transport
- Passive transport
- No energy is required
- Active transport
- Cell must provide metabolic energy (ATP)
- Solution—homogeneous mixture of two or more components (air, sea water, rubbing alcohol)
- Solvent—dissolving medium; typically water in the body
- Solutes—components in smaller quantities within a solution
- Intracellular fluid—nucleoplasm and cytosol.
- Interstitial fluid—fluid on the exterior of the cell.
- The plasma membrane allows some materials to pass while excluding others
- This permeability influences movement both into and out of the cell

Passive Transport Processes

- Diffusion
  - Particles tend to distribute themselves evenly within a solution
  - Movement is from high concentration to low concentration, or down a concentration
    gradient
  - As molecule diffuse a state of equilibrium occurs
  - Speed is affected by size and temp

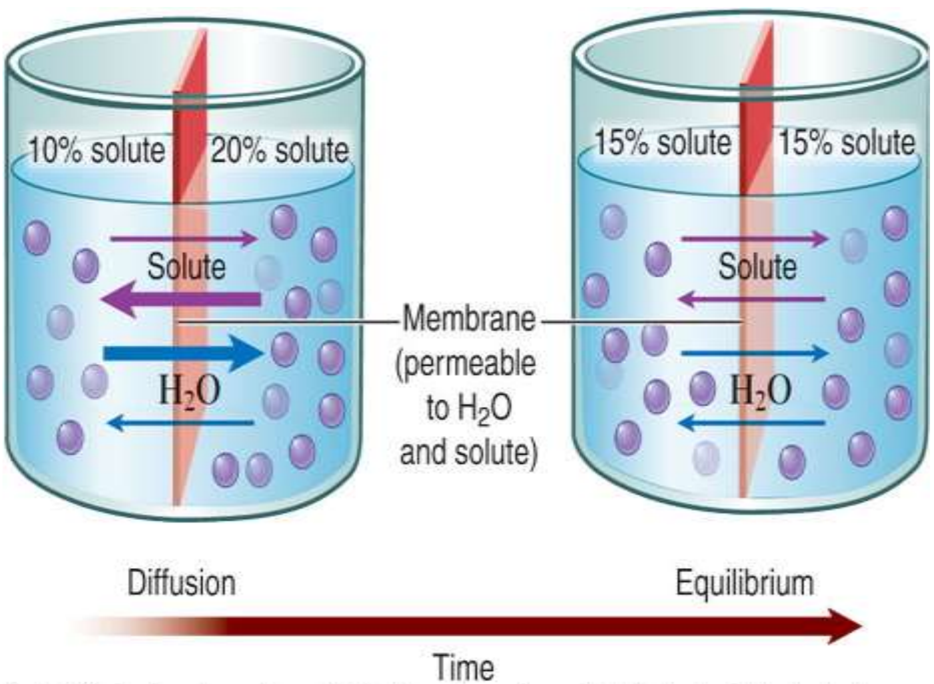


Fig. 4-2. **Diffusion through a membrane.** Note that the membrane allows solute (a dissolved particle) and water to pass and that it separates a 10% solution from a 20% solution. The container on the left shows the two solutions separated by the membrane at the start of diffusion. The container on the right shows the result of diffusion after time.

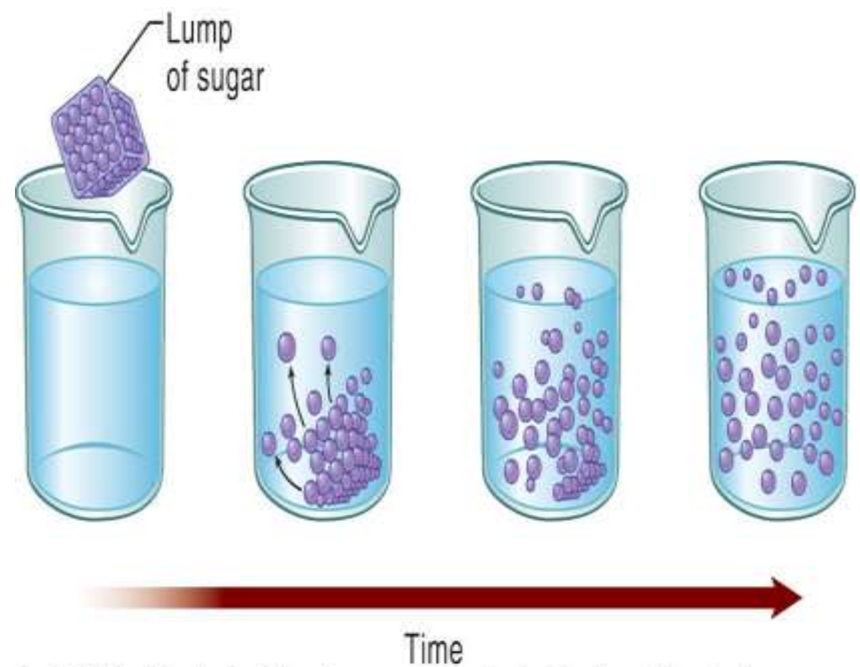


Fig. 4-1. **Diffusion.** The molecules of a lump of sugar are very densely packed when they enter the water. As sugar molecules collide frequently in the area of high concentration, they gradually spread away from each other—toward the area of lower concentration. Eventually, the sugar molecules become evenly distributed.

Passive Transport Processes

- Types of diffusion:
- – Simple diffusion
- An unassisted process
- Solutes are lipid-soluble materials or small enough to pass through membrane pores.
- Osmosis:
- Diffusion of water (solvent) across a selectively permeable membrane. Water moves from an area of low concentration of solute to an area of high concentration of solute
- Osmotic pressure: force required to prevent water from moving across a membrane by osmosis .

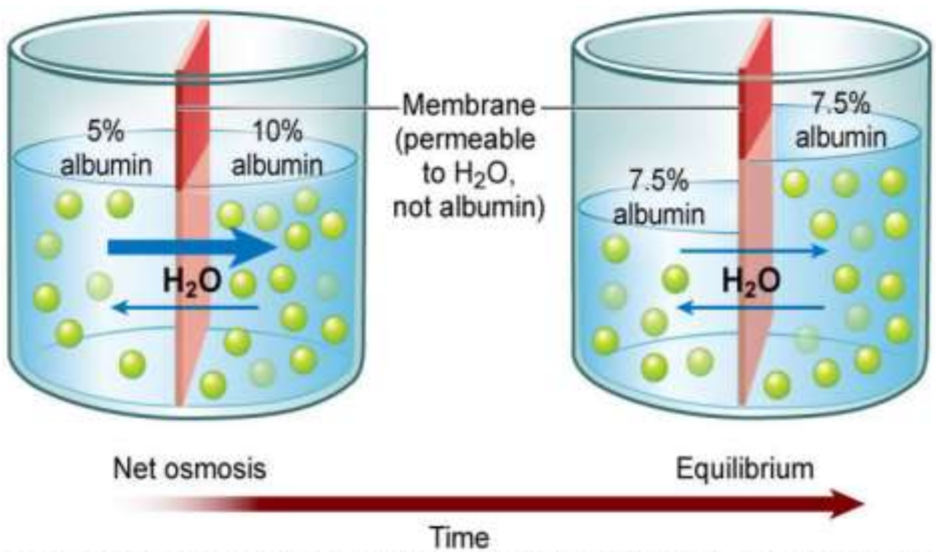


Fig. 4-4. **Osmosis.** Osmosis is the diffusion of water through a selectively permeable membrane. The membrane shown in this diagram is permeable to water but not to albumin. Because there are relatively more water molecules in 5% albumin than 10% albumin, more water molecules osmose from the more dilute into the more concentrated solution (as indicated by the larger arrow in the left diagram) than osmose in the opposite direction. The overall direction of osmosis, in other words, is toward the more concentrated solution. Net osmosis produces the following changes in these solutions: (1) their concentrations equilibrate, (2) the volume and pressure of the originally more concentrated solution increase, and (3) the volume and pressure of the other solution decrease proportionately.

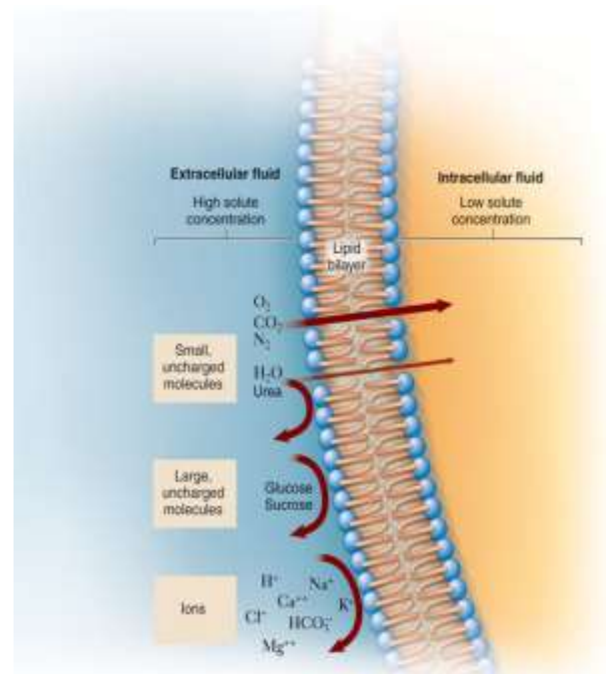
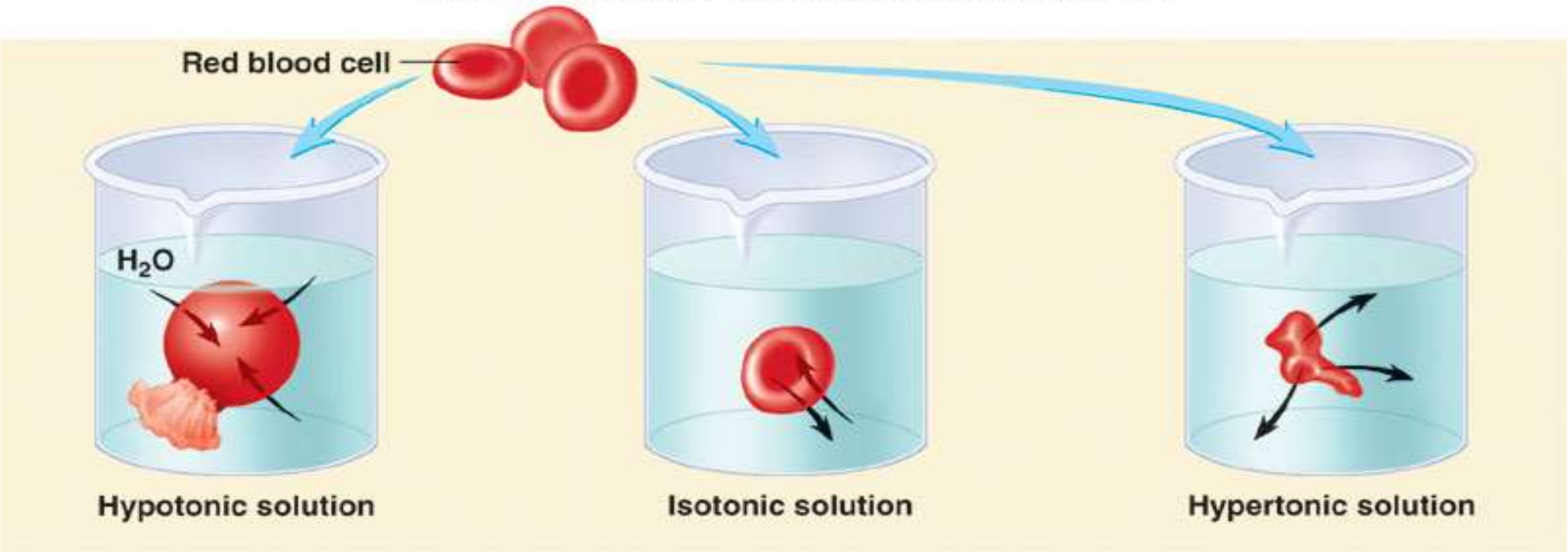


Fig. 4-3. **Simple diffusion through a phospholipid bilayer.** Some small, uncharged molecules can easily pass through the phospholipid membrane, but water and urea (a waste product of protein catabolism) rarely get through the membrane. Larger uncharged molecules and ions (charged molecules) may not pass through the phospholipid membrane at all.

Osmosis

- Important because large volume changes caused by water movement disrupt normal cell function.
  - Isotonic: when two fluids have the same potential osmotic pressure
  - Hypertonic (higher pressure): cells placed in solutions that are hypertonic to intracellular fluid always shrivel as water flows out of them; if medical treatment causes the extracellular fluid to become hypertonic to the cells of the body, serious damage may occur
  - Hypotonic (lower pressure): cells placed in a hypotonic solution may swell as water flows into them; water always osmoses from the hypotonic solution to the hypertonic solution.
  - Allows water to move across membranes
  - Results in a change in volume
  - Causes a change in pressure



- Facilitated diffusion
- Substances require a protein carrier for passive transport
- Channel and carrier mediated
- Transports lipid-insoluble and large substances
- Transports substances down a concentration gradient.
- Channel-mediated passive transport
- Channels are specific; allow only one type of solute to pass through
- Gated channels may be open or closed (or inactive); may be triggered by any of a variety of stimuli
- Channels allow membranes to be selectively permeable
- Aquaporins are water channels that permit rapid osmosis.
- Carrier-mediated passive transport
- Carriers attract and bind to the solute, change shape, and release the solute on the other side of the carrier
- Carriers are usually reversible depending on the direction of the concentration gradient

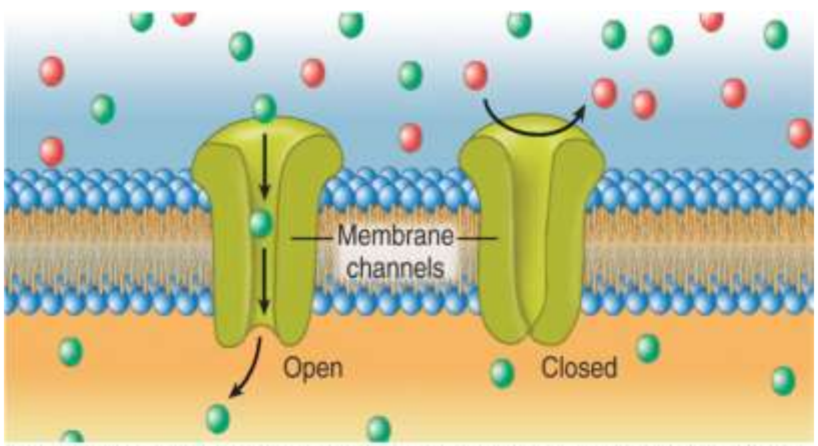


Fig. 4-6. **Membrane channels.** Gated channel proteins form tunnels through which only specific molecules may pass—as long as the "gates" are open. Molecules that do not have a specific shape and charge are never permitted to pass through the channel. Notice that the transported molecules move from an area of high concentration to an area of low concentration. The cell membrane is said to be *permeable* to the type of molecule in question. Filtration, another type of passive transport process, is discussed in Box 4-2 on p. 95.

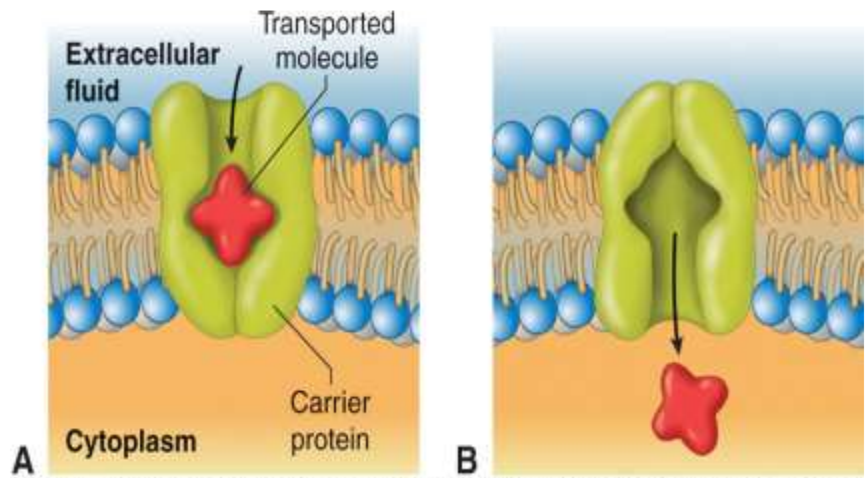
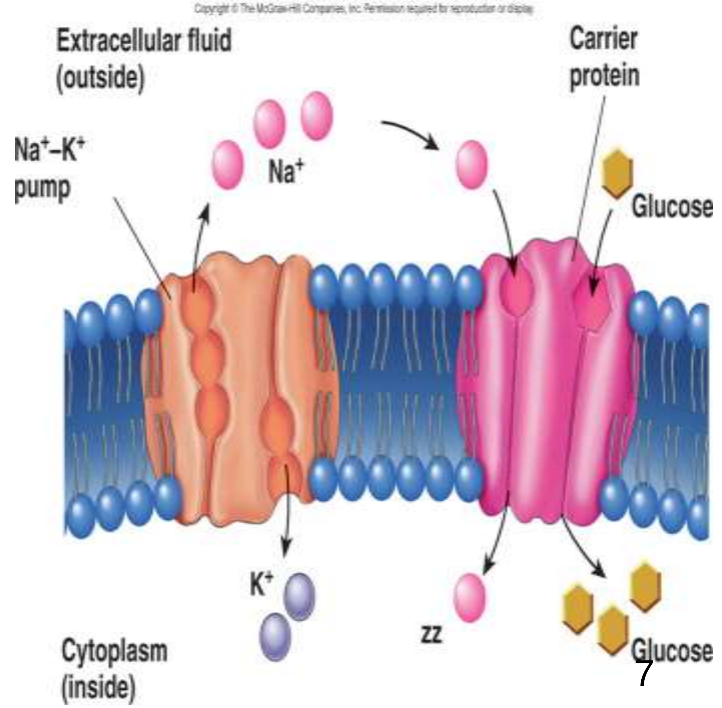


Fig. 4-7. **Membrane carrier.** In carrier-mediated transport, a membrane-bound carrier protein attracts a solute molecule to a binding site **(A)** and changes shape in a manner that allows the solute to move to the other side of the membrane **(B).** Passive carriers may transport molecules in either direction, depending on the concentration gradient.

Active Transport Processes:

Substances are transported that are unable to pass by diffusion
Substances may be too large
Substances may not be able to dissolve in the fat core of the membrane
Substances may have to move against a concentration gradient
ATP is used for transport.
Two common forms of active transport
Transport by Pumps
Vesicular transport: Exocytosis , Endocytosis, Phagocytosis, Pinocytosis.
Transport by pumps
Amino acids, some sugars, and ions are transported by protein carriers called solute pumps

- ATP energizes protein carriers
- In most cases, substances are moved against concentration gradients
- Ex Na+/K+ pumps:
- Ions or molecules move in same (symport) or different (antiport) direction.
- A sodium-potassium exchange pump maintains a concentration of Na that is higher outside the cell than inside. Active transport.
- Na moves back into the cell by a carrier protein that also moves glucose. The concentration gradient for Na provides the energy required to move glucose against its concentration gradient



Vesicular Transport

•Transport by vesicles allows substances to enter or leave the interior of a cell without moving through its plasma membrane

Endocytosis: the plasma membrane “traps” some extracellular material and brings it into the cell in a vesicle

Two basic types of endocytosis

Phagocytosis (“condition of cell eating”): large particles are engulfed by the plasma membrane and enter the cell in vesicles; the vesicles fuse with lysosomes, which digest the particles

Pinocytosis (“condition of cell drinking”): fluid and the substances dissolved in it enter the cell

Receptor-mediated endocytosis: membrane receptor molecules recognize substances to be brought into the cell .

Exocytosis

Moves materials out of the cell

Material is carried in a membranous vesicle

Vesicle migrates to plasma membrane

Vesicle combines with plasma membrane

Material is emptied to the outside.

Examples

- Secretion of digestive enzymes by pancreas
- Secretion of mucous by salivary glands
- Secretion of milk by mammary glands

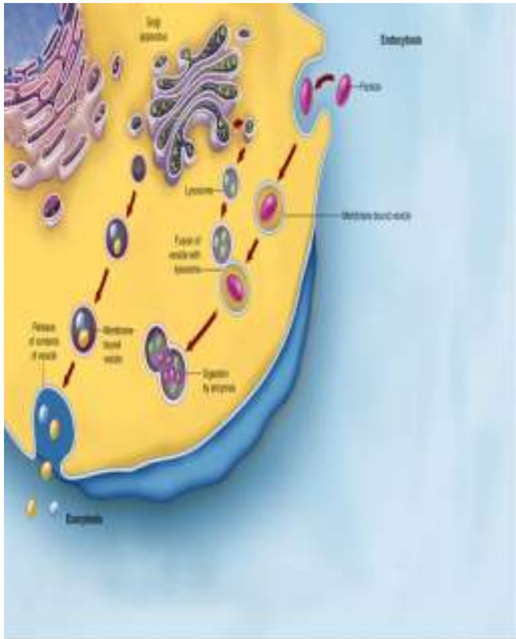
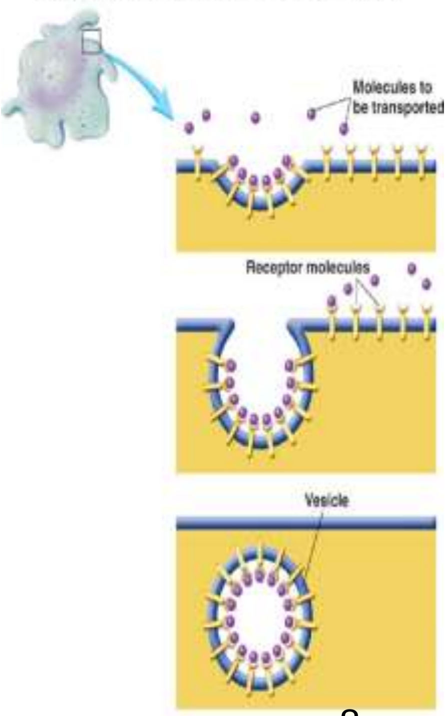


Fig. 4-10. **Bulk transport by vesicles.** This sketch summarizes the essential difference between endocytosis, which moves substances into the cell by means of a vesicle, and exocytosis, which moves substances out of the cell by means of a vesicle. The type of endocytosis shown here is phagocytosis, in which the endocytic vesicle fuses with a lysosome to allow digestive enzymes to break down the ingested material.



CELL METABOLISM

- Metabolism is the set of chemical reactions in a cell
– Catabolism: breaks large molecules into smaller ones; usually releases energy
– Anabolism: builds large molecules from smaller ones; usually consumes energy.
– Role of enzymes
– Enzymes are chemical catalysts that reduce the activation energy needed for a reaction
– Enzymes regulate cell metabolism.
– Proteins of a complex shape
– The active site is where the enzyme molecule fits the substrate molecule—the lock-and-key model .
– Classification and naming of enzymes
– Enzymes usually have an -ase ending, with the first part of the word signifying the substrate or the type of reaction catalyzed
– Oxidation-reduction enzymes: known as oxidases, hydrogenases, and dehydrogenases; energy release depends on these enzymes
– Hydrolyzing enzymes: hydrolases; digestive enzymes belong to this group
– Phosphorylating enzymes: phosphorylases or phosphatases; add or remove phosphate groups
– Enzymes that add or remove carbon dioxide: carboxylases or decarboxylases
– Hydrases add water to a molecule without splitting it

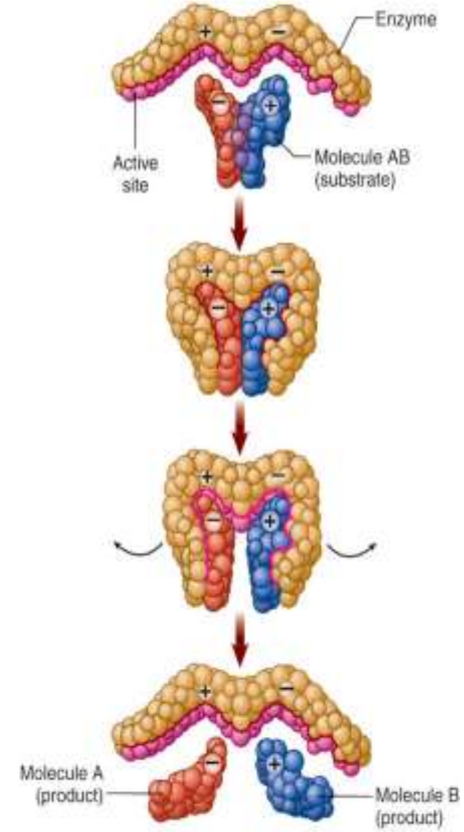


Fig. 4-13. **Model of enzyme action.** Enzymes are functional proteins whose molecular shape allows them to catalyze chemical reactions. Substrate molecule *AB* is acted on by a digestive enzyme to yield simpler molecules *A* and *B* as products of the reaction. Notice how the active site

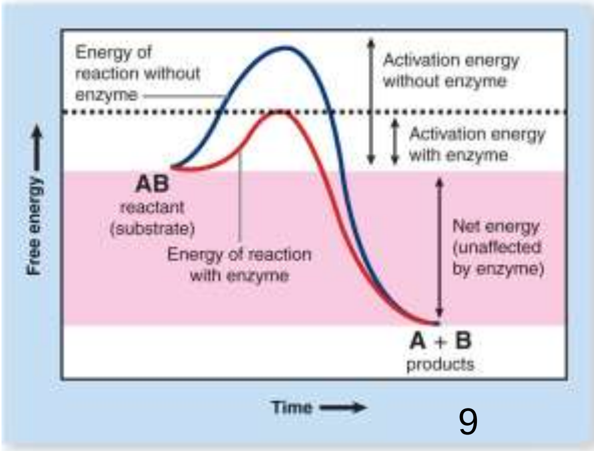
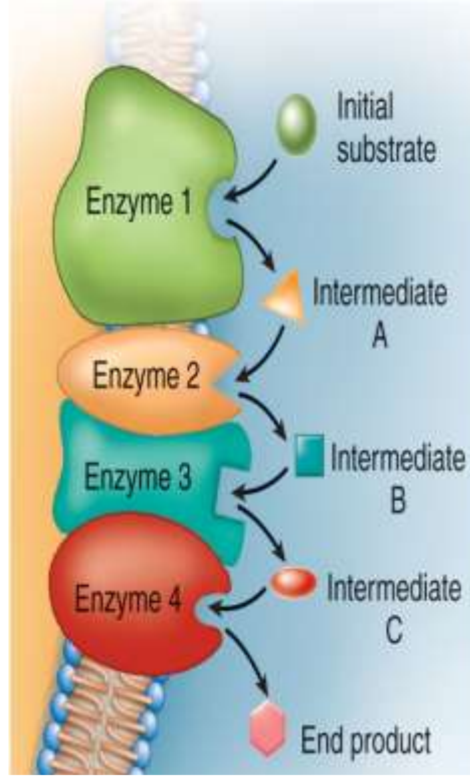


Fig. 4-12. **Enzymes as catalysts.** A catalyst is a chemical that reduces the activation energy of a reaction—the energy needed to get a reaction started. Enzymes thus allow reactions to occur at the low level of free energy available at normal human body temperatures.

– General functions of enzymes

- Enzymes regulate cell functions by regulating metabolic pathways
- Enzymes are specific in their actions.
- Various chemical and physical agents known as allosteric effectors affect enzyme action by changing the shape of the enzyme molecule



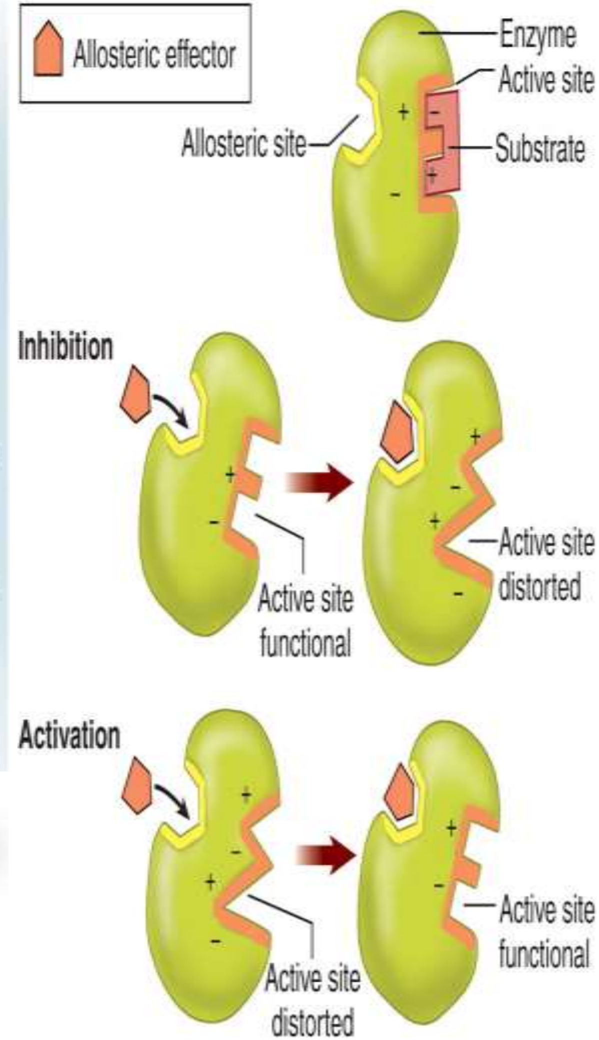


Fig. 4-15. **Allosteric effect.** The allosteric effect occurs when some agent, in this case an allosteric effector molecule, binds to the enzyme at an allosteric site and thereby changes the shape of the enzyme's active site. Such an allosteric effect may inhibit enzyme action (by distorting the active site) or activate the enzyme (by giving the active site its functional shape).

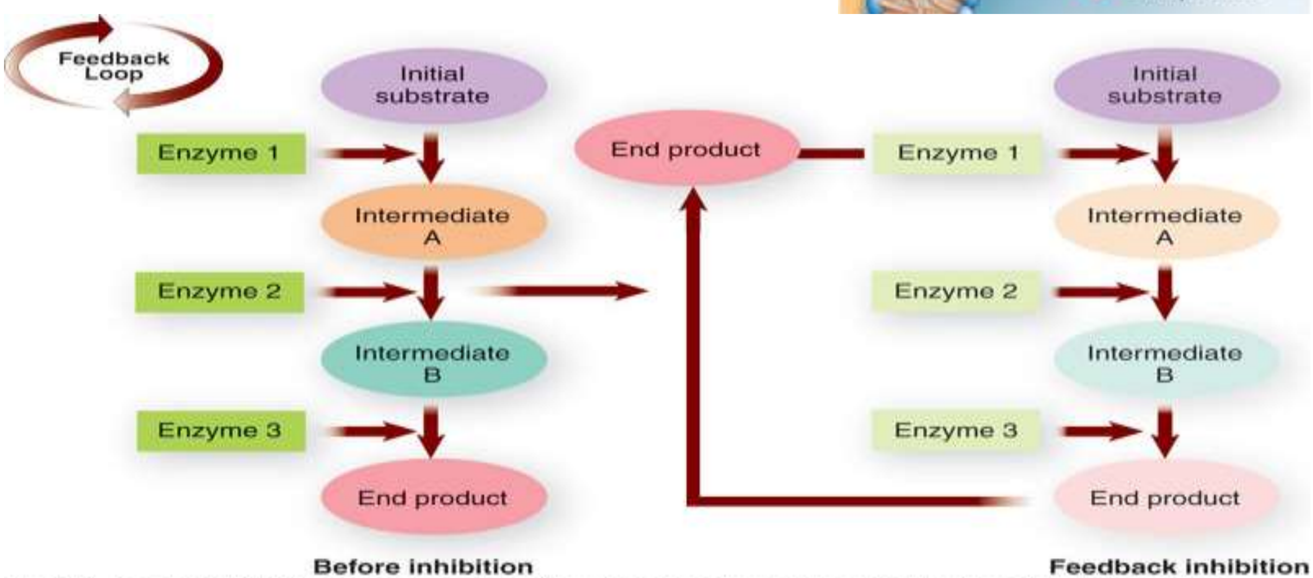


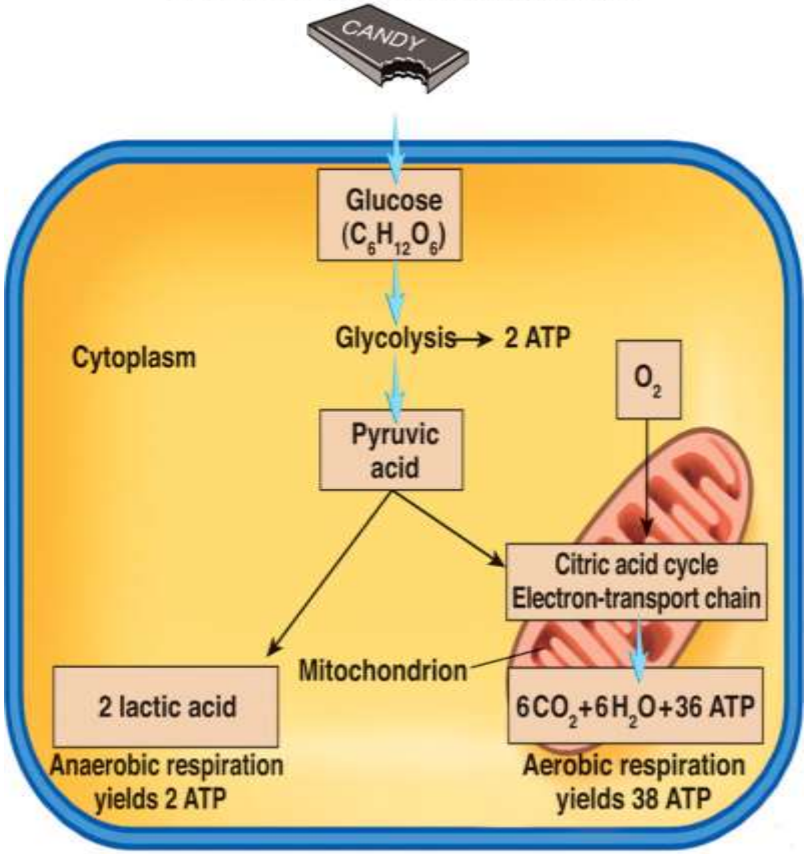
Fig. 4-17. **Feedback inhibition of enzymes.** Formation of an excessive amount of end product can be inhibited by a negative feedback mechanism. In this example, the end product itself inhibits the function of an enzyme needed early in the pathway. Thus the entire pathway is inhibited—as long as there is an excess of the end product.

- Catabolism

– Cellular respiration: the pathway by which glucose is broken down to yield its stored energy; an important example of cell catabolism

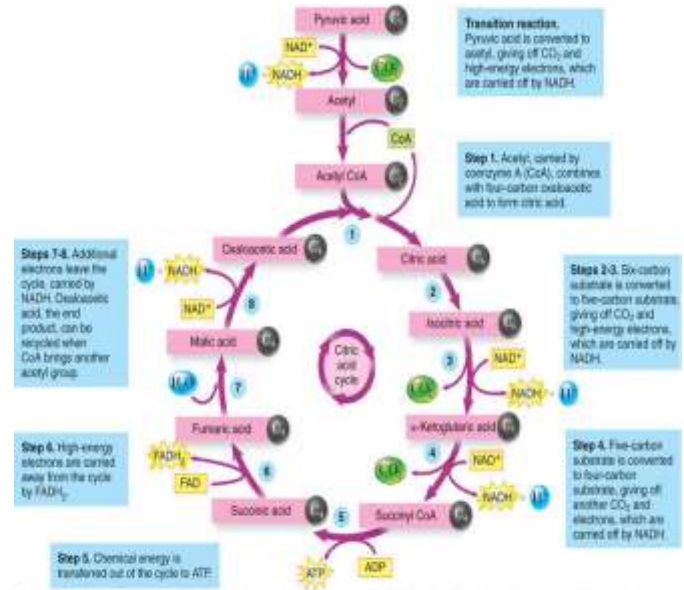
– Cellular respiration has three pathways that are chemically linked :

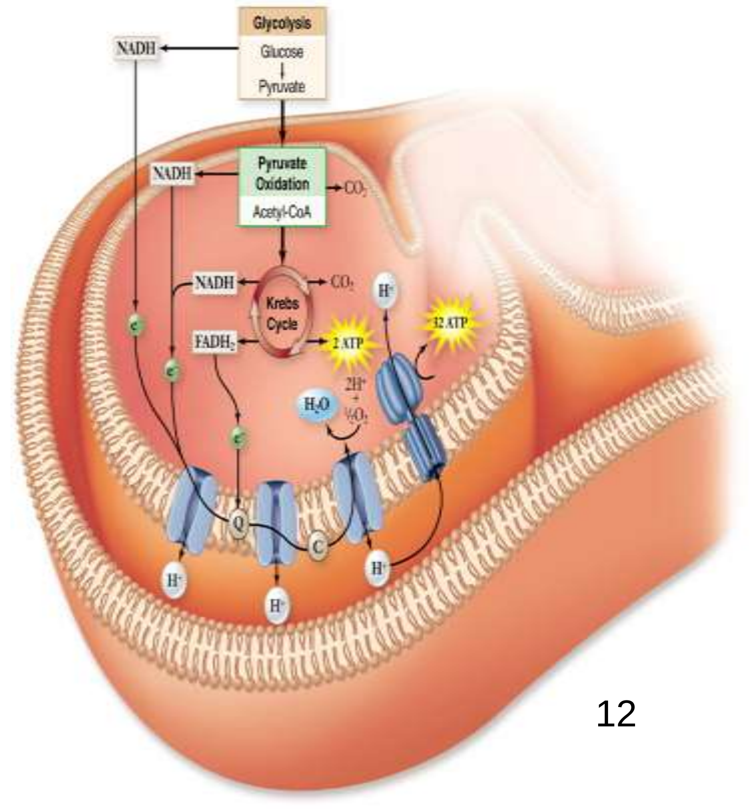
- Glycolysis
- Citric acid cycle
- Electron transport system .
- Production of ATP necessary for life
- ATP production takes place in the cytosol (anaerobic) and mitochondria (aerobic)
- Anaerobic does not require oxygen. Results in very little ATP production.
- Aerobic requires oxygen. Results in large amount of ATP.
- Glycolysis
- Pathway in which glucose is broken apart into two pyruvic acid molecules to yield a small amount of energy (which is transferred to adenosine triphosphate [ATP] and reduced nicotinamide adenine dinucleotide [NADH])
- Includes many chemical steps (reactions that follow one another), each regulated by specific enzymes
- anaerobic (requires no oxygen)
- Occurs within cytosol (outside the mitochondria)



– Citric acid cycle (Krebs cycle)

- Pyruvic acid (from glycolysis) is converted into acetyl coenzyme A (CoA) and enters the citric acid cycle after losing carbon dioxide (CO_2) and transferring some energy to NADH
- Citric acid cycle is a repeating (cyclic) sequence of reactions that occurs inside the inner chamber of a mitochondrion; acetyl splits from CoA and is broken down to yield waste CO_2 and energy (in the form of energized electrons), which is transferred to ATP, NADH, and reduced flavin adenine dinucleotide ($FADH_2$).
- Electron transport system (ETS)
- Energized electrons are carried by NADH and FADH2 from glycolysis and the citric acid cycle to electron acceptors embedded in the cristae of the mitochondrion
- As electrons are shuttled along a chain of electron-accepting molecules in the cristae, their energy is used to pump accompanying protons (H+) into the space between mitochondrial membranes
- Protons flow back into the inner chamber through pump molecules in the cristae, and their energy of movement is transferred to ATP
- Low-energy electrons coming off the ETS bind to oxygen and rejoin their protons to form water





CELL METABOLISM: ANABOLISM

- Protein synthesis is the most important anabolic reaction

-influences all cell structures and functions

- begins with gene expression, the process where a gene's DNA is used to direct the synthesis of a specific protein.

Transcription: DNA used to form RNA

Translation: synthesis of a protein at the ribosomes using mRNA, tRNA and rRNA .

Transcription:

Duble stranded DNA "unzips"

DNA sense strand is template for mRNA strand

Transcription begins at the promoter sequence where RNA polymerase attaches

When RNA polymerase reaches the terminator sequence it detaches and transcription stops

Pre-mRNA contains intron regions that are cut out by enzymes

Exon regions of mRNA will code for segments of the protein

Three-base sequences on mRNA are called codons

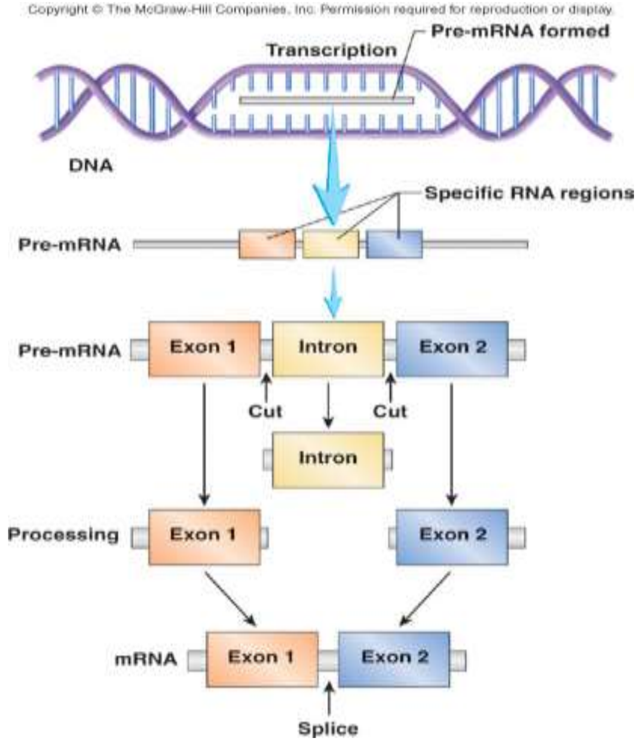
DNA triplet AAT then the mRNA codon is UUA .

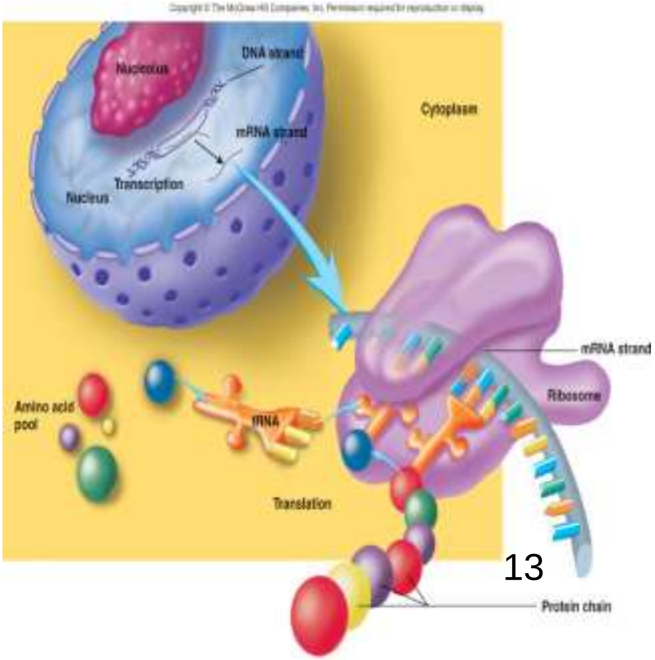
Sequence of nucleotides on mRNA is read by rRNA to construct a protein with a specific sequence of aa (amino acid).

3 nucleotide sequence on mRNA is called a codon

Specific tRNA molecules carry specific aa

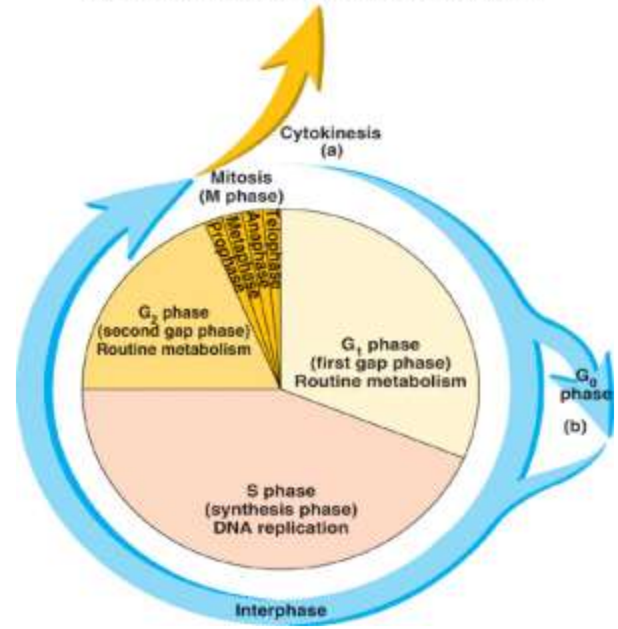
Anticodons on tRNA match to specific codons on mRNA so aa can be strung together to create a specific protein

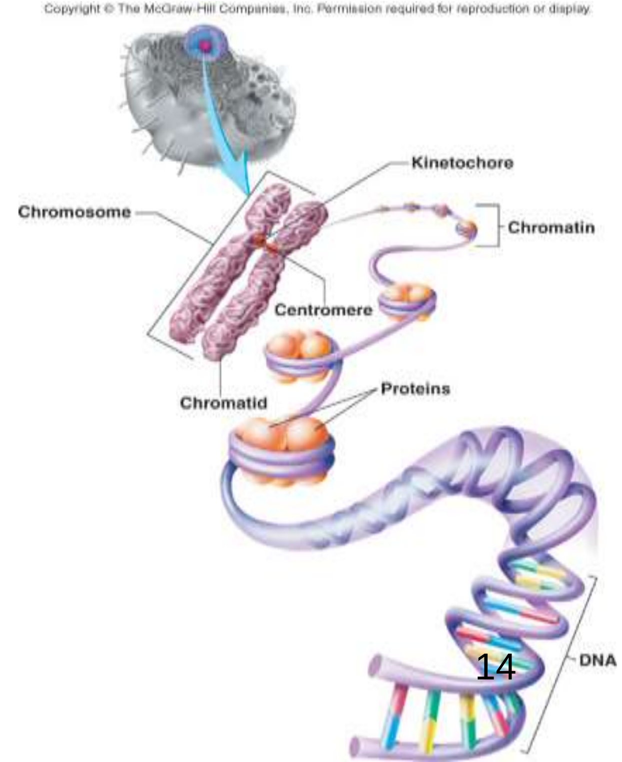




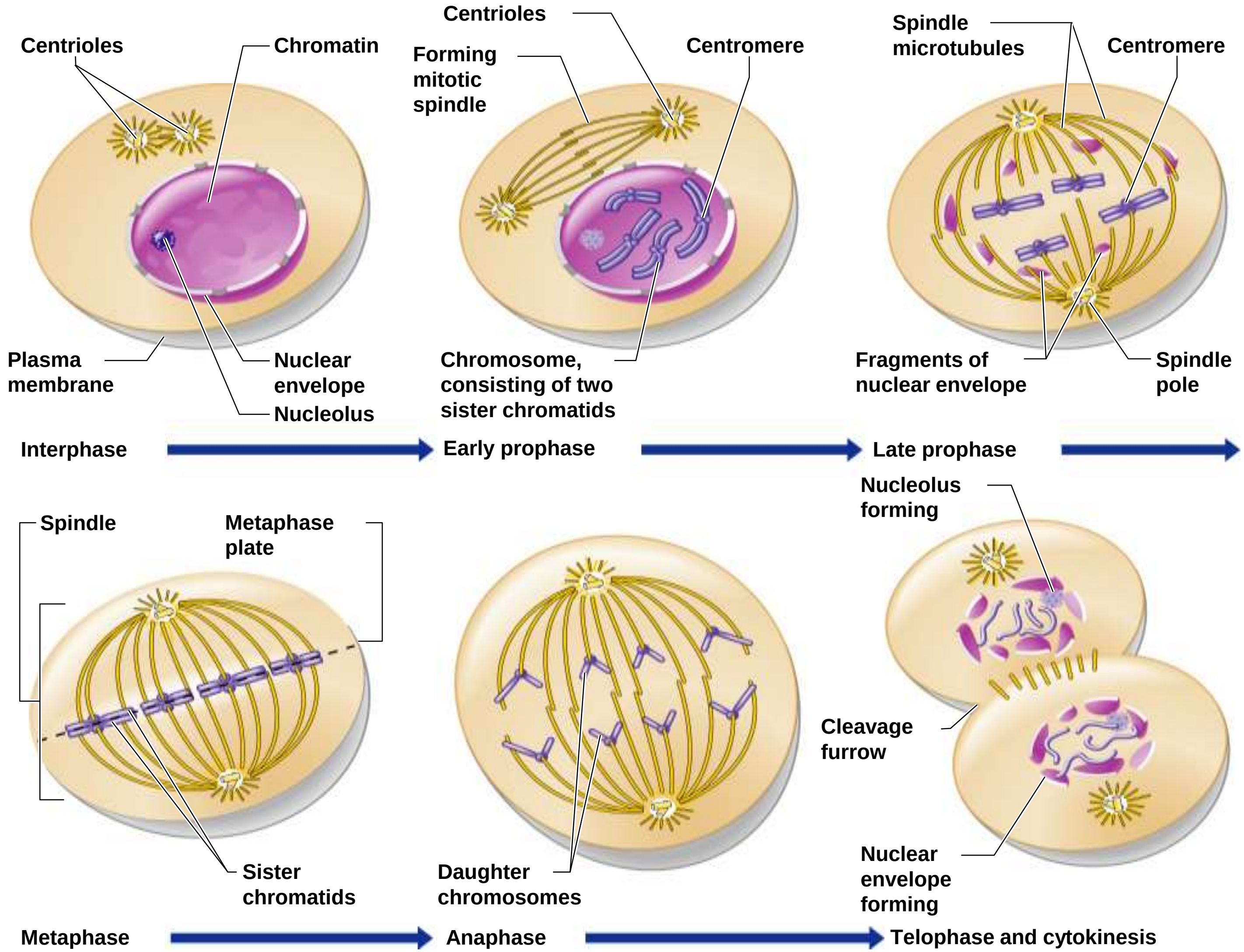
Cell Growth and Reproduction

- Cell growth and reproduction of cells are the most fundamental of all living functions and together constitute the cell life cycle
  - Cell growth: depends on using genetic information in DNA to make the structural and functional proteins needed for cell survival
  - Cell reproduction: ensures that genetic information is passed from one generation to the next.
  - Interphase: phase between cell divisions
  - Replication of DNA
  - Ongoing normal cell activities
  - Mitosis: series of events that leads to the production of two cells by division of a mother cell into two daughter cells. Cells are genetically identical.
  - Prophase, Metaphase, Anaphase, Telophase
  - Cytokinesis: division of cell cytoplasm.
  - Chromatin: DNA complexed with proteins (histones)
  - During cell division, chromatin condenses into pairs of chromatids called chromosomes. Each pair of chromatids is joined by a centromere





Mitosis



Centrioles
Chromatin
Plasma membrane
Nuclear envelope
Nucleolus
Interphase
Centrioles
Forming mitotic spindle
Centromere
Chromosome, consisting of two sister chromatids
Early prophase
Spindle microtubules
Centromere
Fragments of nuclear envelope
Spindle pole
Late prophase
Spindle
Metaphase plate
Sister chromatids
Metaphase
Daughter chromosomes
Anaphase
Nucleolus forming
Cleavage furrow
Nuclear envelope forming
Telophase and cytokinesis

Meiosis

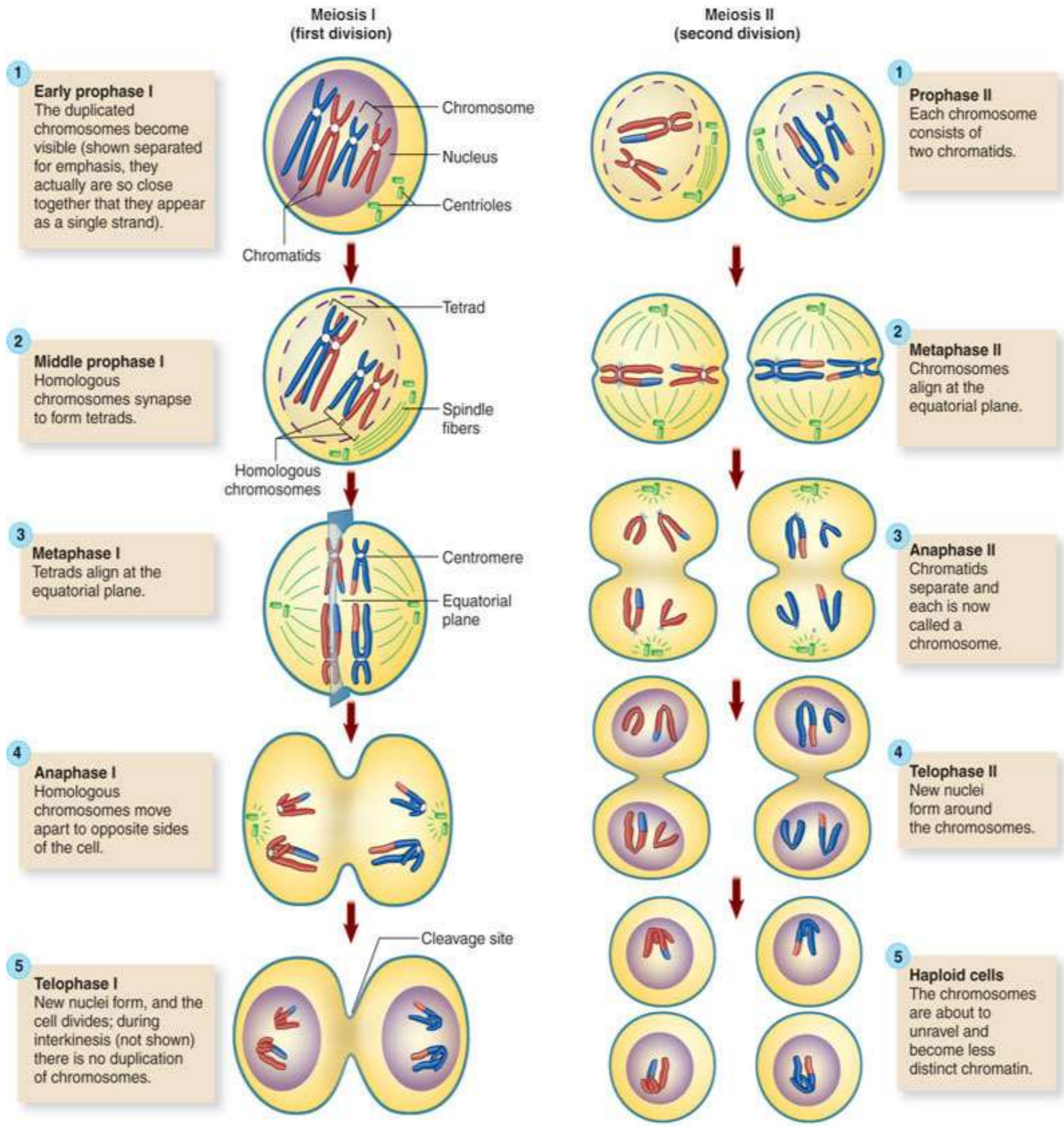


Fig. 33-1. **Meiotic cell division.** Meiosis is a series of events that involves two separate division processes called meiosis I and meiosis II. Notice that four daughter cells, each with the haploid number of chromosomes, are produced from each parent cell that enters meiotic cell division. For simplicity's sake, only four chromosomes are shown in the parent cell instead of the usual 46.

- Meiosis produces the reproductive cells (egg and sperm)
- Produces haploid cells which contain 23 chromosomes
- 2 successive stages meiosis I and meiosis II