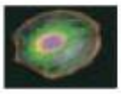
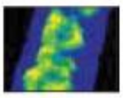
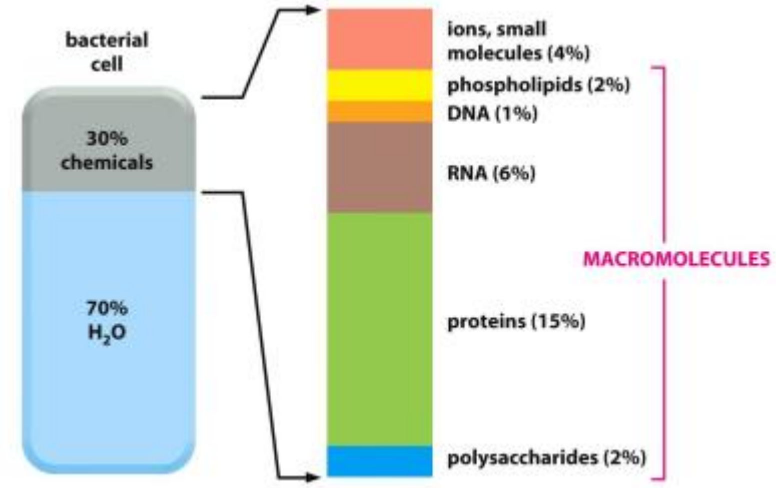
Cell Structure and Function

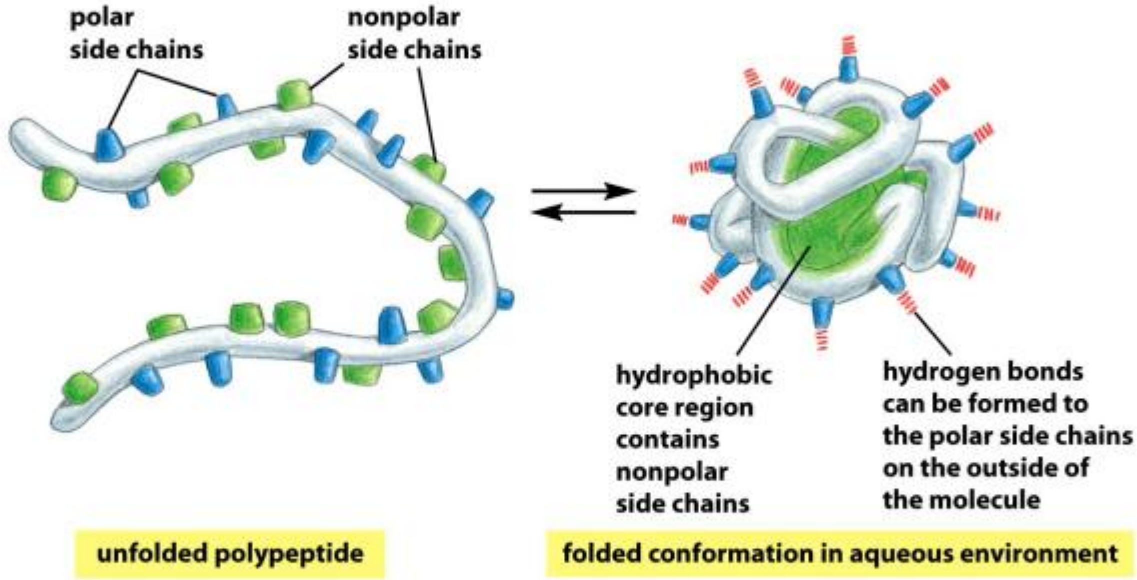
1. Microscopes

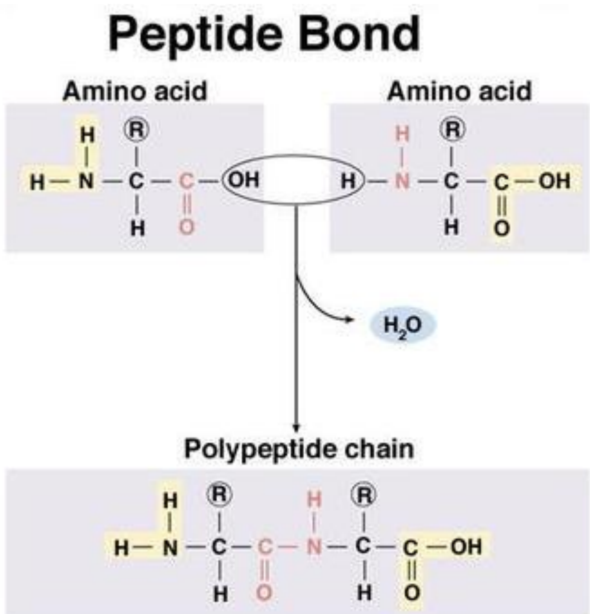
Table 4.2 Comparison of Types of Microscopes

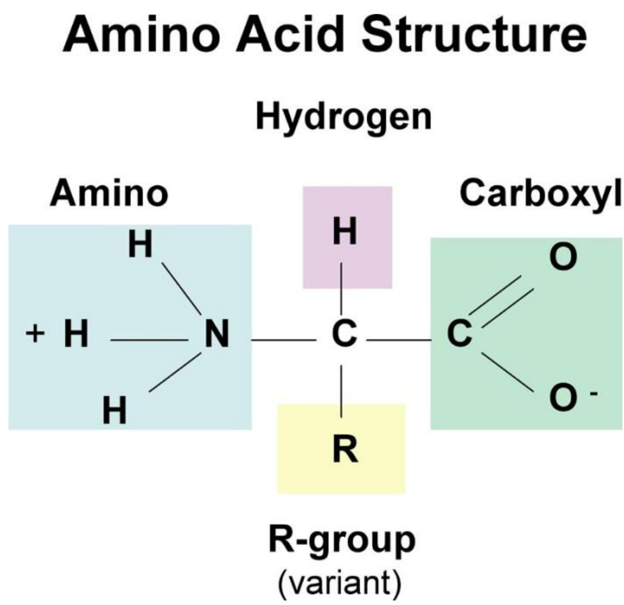
Type of Microscope	Typical Image	Description of Image	Special Features	Typical Uses
Light Microscopes		Useful magnification 1× to 2000×; resolution to 200 nm	Use visible light; shorter, blue wavelengths provide better resolution	
Bright-field		Colored or clear specimen against bright background	Simple to use; relatively inexpensive; stained specimens often required	Observation of killed stained specimens and naturally colored live ones; also used to count microorganisms
Dark-field		Bright specimen against dark background	Use a special filter in the condenser that prevents light from directly passing through a specimen; only light scattered by the specimen is visible	Observation of living, colorless, unstained organisms
Phase-contrast		Specimen has light and dark areas	Use a special condenser that splits a polarized light beam into two beams, one of which passes through the specimen, and one of which bypasses the specimen; the beams are then rejoined before entering the oculars; contrast in the image results from the interactions of the two beams	Observation of internal structures of living microbes
Differential interference contrast (Nomarski)		Image appears three-dimensional	Use two separate beams instead of a split beam; false color and a three-dimensional effect result from interactions of light beams and lenses; no staining required	Observation of internal structures of living microbes
Fluorescent		Brightly colored fluorescent structures against dark background	An ultraviolet light source causes fluorescent natural chemicals or dyes to emit visible light	Localization of specific chemicals or structures; used as an accurate and quick diagnostic tool for detection of pathogens
Light Microscopes Confocal		Single plane of structures or cells that have been specifically stained with fluorescent dyes	Use a laser to fluoresce only one plane of the specimen at a time	Detailed observation of structures of cells within communities
Electron Microscopes		Typical magnification 1000× to 100,000×; resolution to 0.001 nm	Use electrons traveling as waves with short wavelengths; require specimens to be in a vacuum, so cannot be used to examine living microbes	
Transmission		Monotone, two-dimensional, highly magnified images; may be color-enhanced	Produce two-dimensional image of ultrastructure of cells	Observation of internal ultrastructural detail of cells and observation of viruses and small bacteria
Scanning		Monotone, three-dimensional, surface images; may be color-enhanced	Produce three-dimensional view of the surface of microbes and cellular structures	Observation of the surface details of structures
Probe Microscopes		Magnification greater than 100,000,000× with resolving power greater than that of electron microscopes	Use microscopic probes that move over the surface of a specimen	
Scanning tunneling		Individual molecules and atoms visible	Measures the flow of electrical current between the tip of a probe and the specimen to produce an image of the surface at atomic level	Observation of the surface of objects; provide extremely fine detail, high magnification, and great resolution
Atomic force		Individual molecules and atoms visible	Measure the deflection of a laser beam aimed at the tip of a probe that travels across the surface of the specimen	Observation of living specimens at the molecular and atomic levels

2. Macromolecules

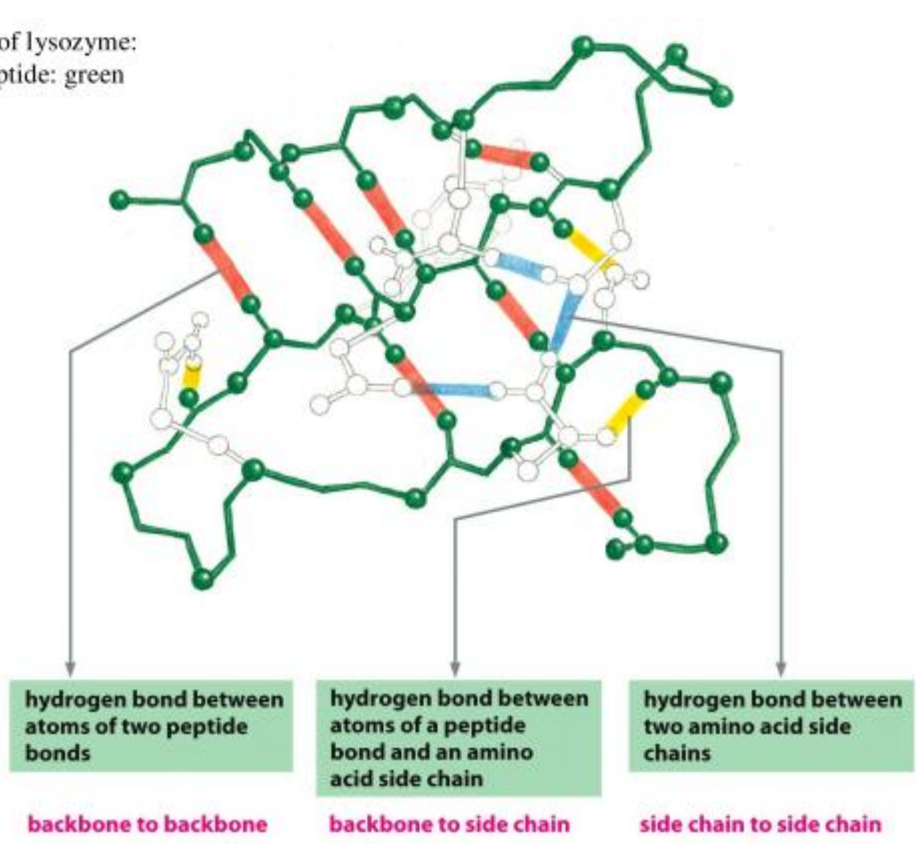


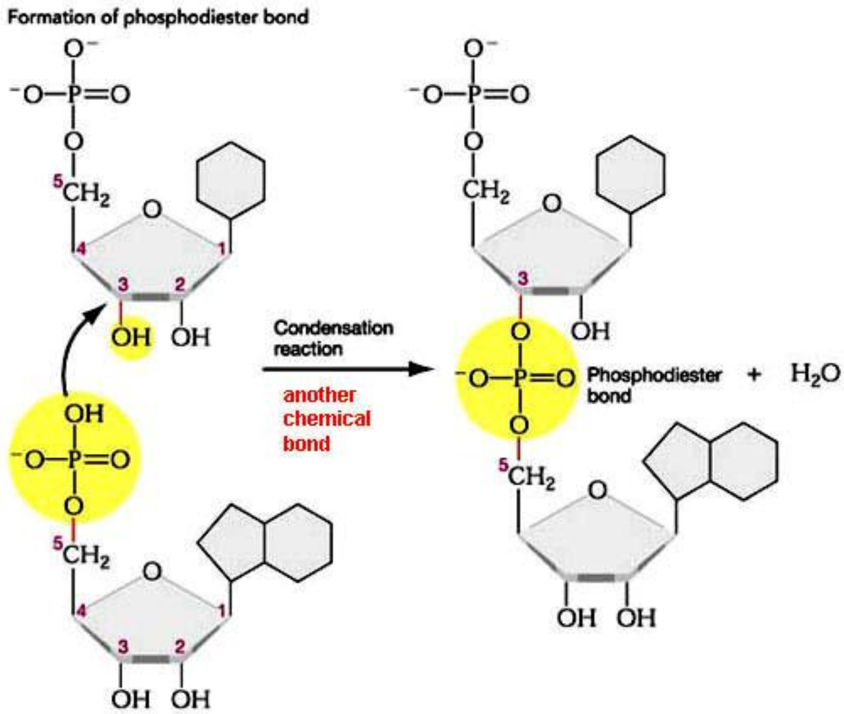


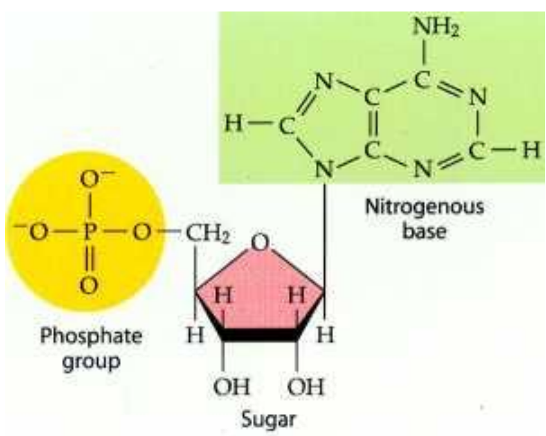


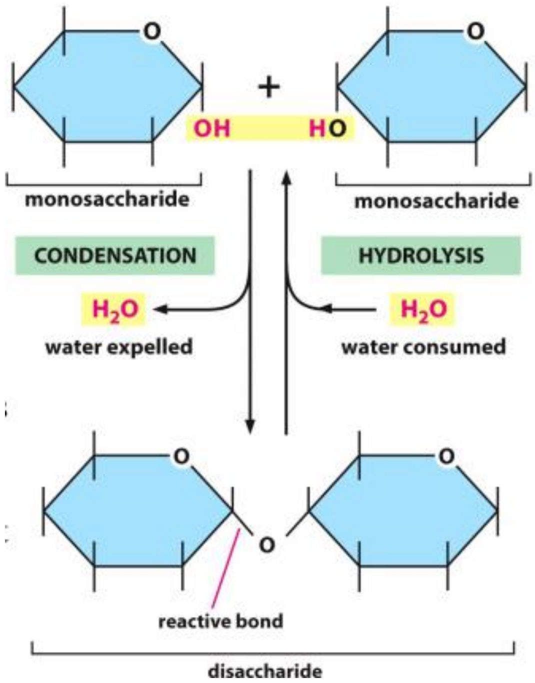


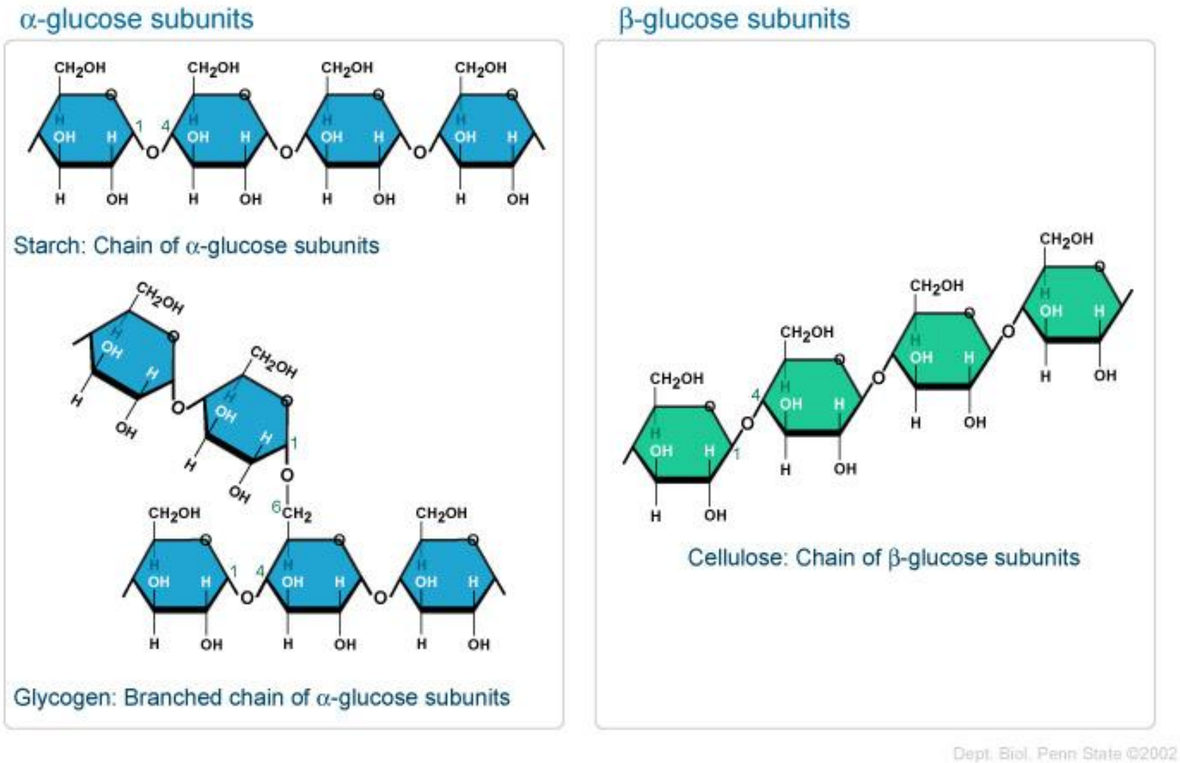
Section of lysozyme:
polypeptide: green

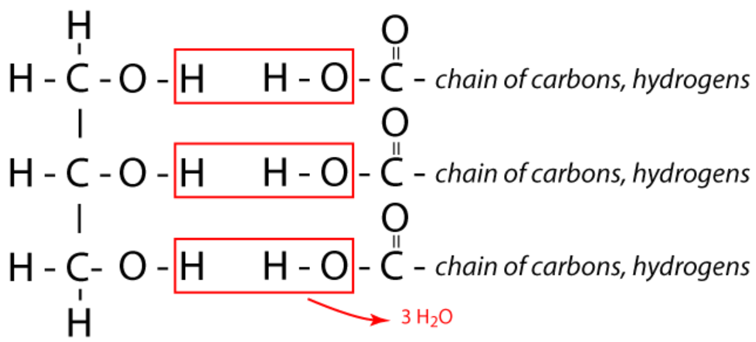




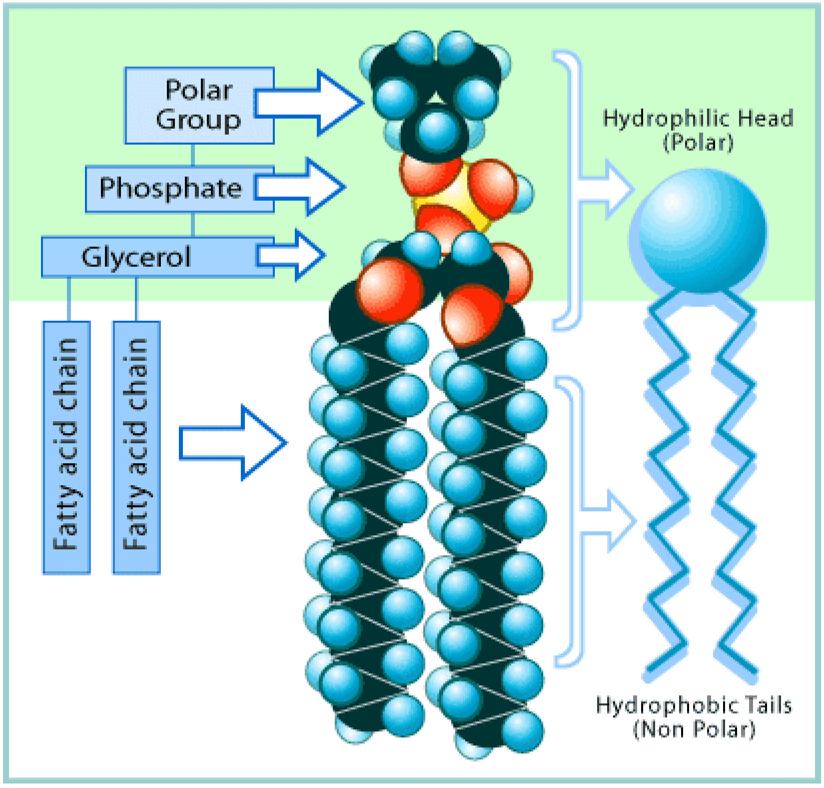


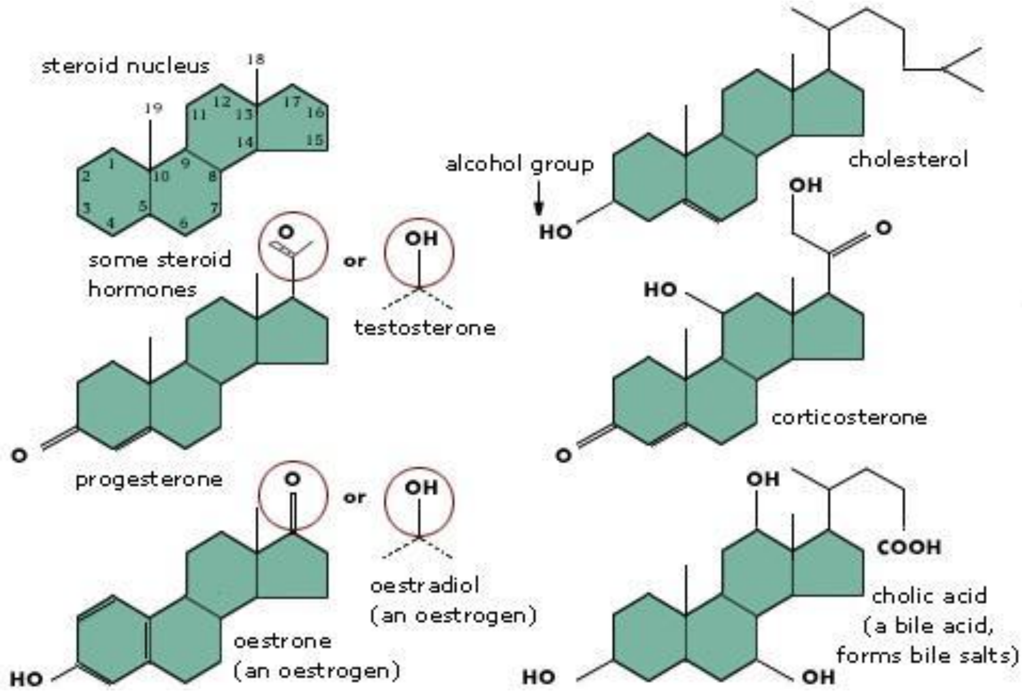






glycerol **3 fatty acids**


Polar Group
Phosphate
Glycerol
Fatty acid chain
Fatty acid chain
Hydrophilic Head (Polar)
Hydrophobic Tails (Non Polar)

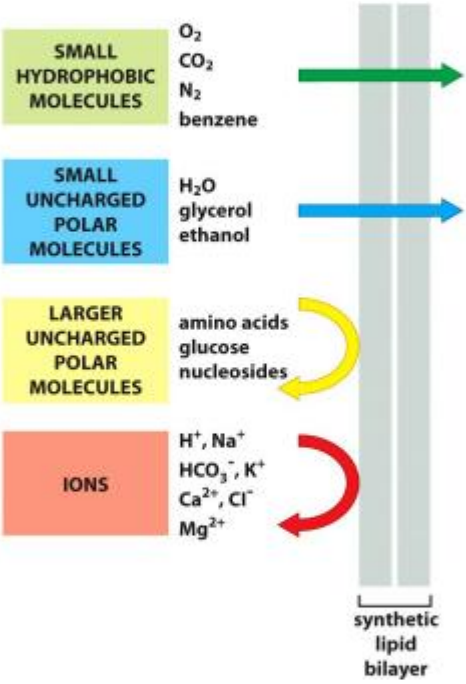

steroid nucleus
some steroid hormones
or
testosterone
alcohol group
HO
cholesterol
OH
O
HO
corticosterone
O
O
progesterone
or
OH
oestradiol
(an oestrogen)
oestrone
(an oestrogen)
HO
OH
COOH
cholic acid
(a bile acid, forms bile salts)
HO
OH

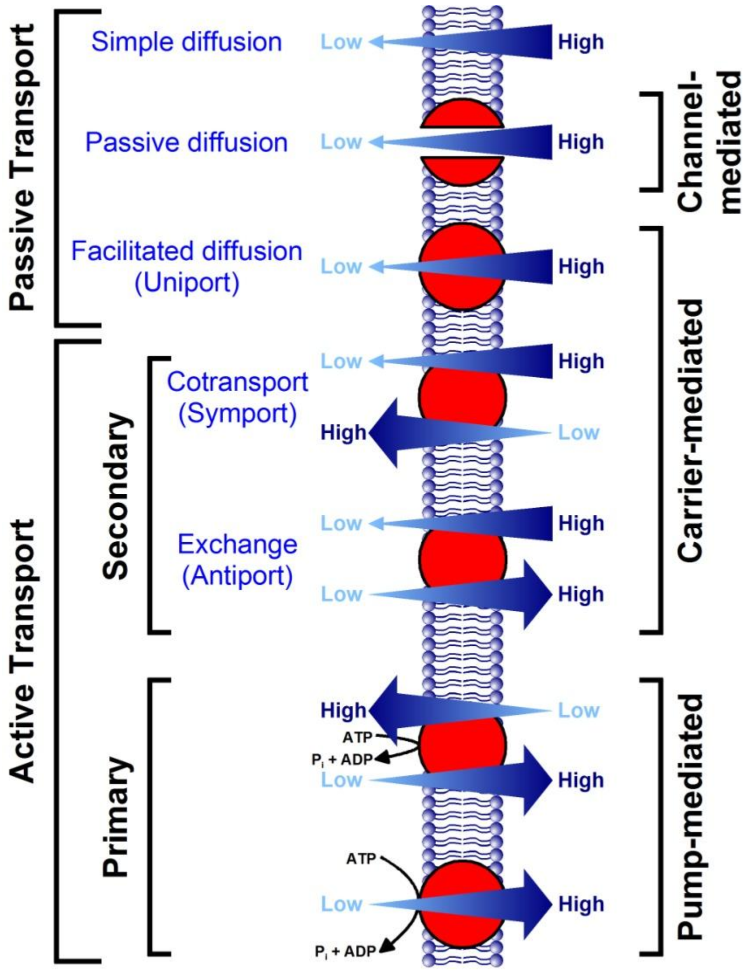
3. Cell Membrane

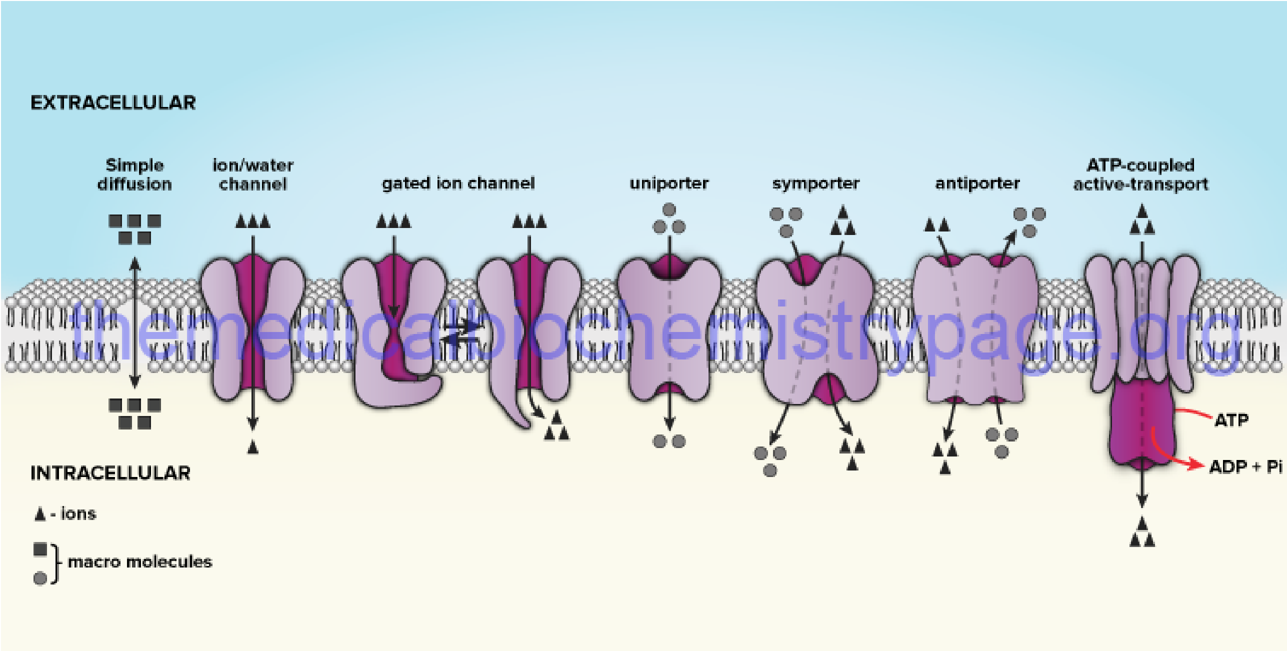
TABLE 12-1 A COMPARISON OF ION CONCENTRATIONS INSIDE AND OUTSIDE A TYPICAL MAMMALIAN CELL

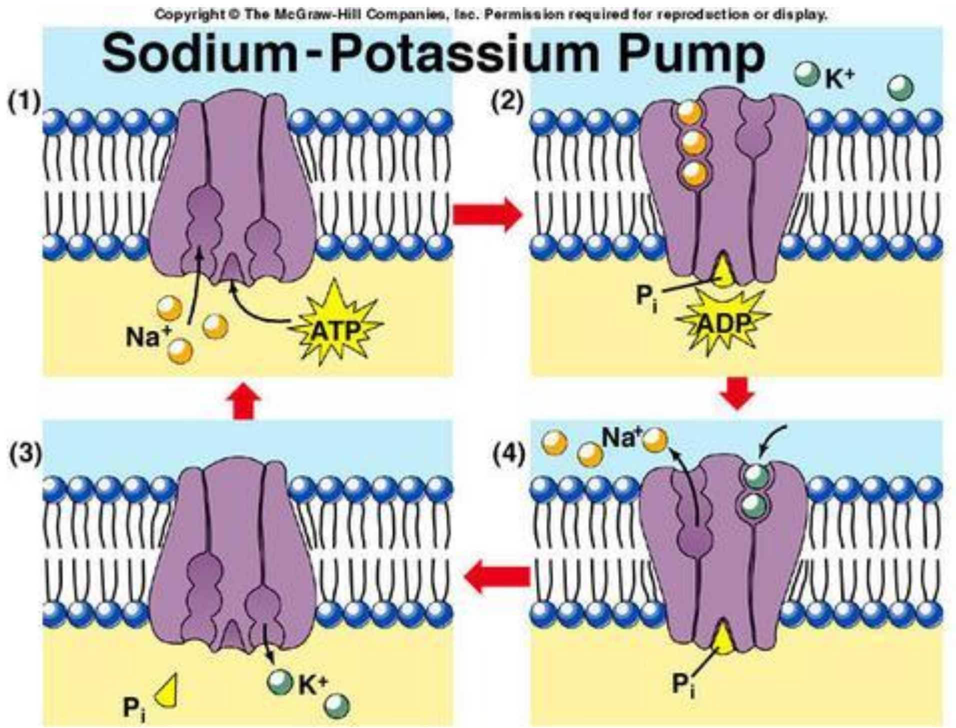
COMPONENT	INTRACELLULAR CONCENTRATION (mM)	EXTRACELLULAR CONCENTRATION (mM)
Cations		
Na^+	5–15	145
K^+	140	5
Mg^{2+}	0.5	1–2
Ca^{2+}	10^{-4}	1–2
H^+	7×10^{-5} ($10^{-7.2}$ M or pH 7.2)	4×10^{-5} ($10^{-7.4}$ M or pH 7.4)
Anions*		
Cl^-	5–15	110

* The cell must contain equal quantities of positive and negative charges (that is, be electrically neutral). Thus, in addition to Cl^-, the cell contains many other anions not listed in this table; in fact, most cellular constituents are negatively charged (HCO_3^-, PO_4^{3-}, proteins, nucleic acids, metabolites carrying phosphate and carboxyl groups, etc.). The concentrations of Ca^{2+} and Mg^{2+} given are for the free ions. There is a total of about 20 mM Mg^{2+} and 1–2 mM Ca^{2+} in cells, but this is mostly bound to proteins and other substances and, for Ca^{2+}, stored within various organelles.









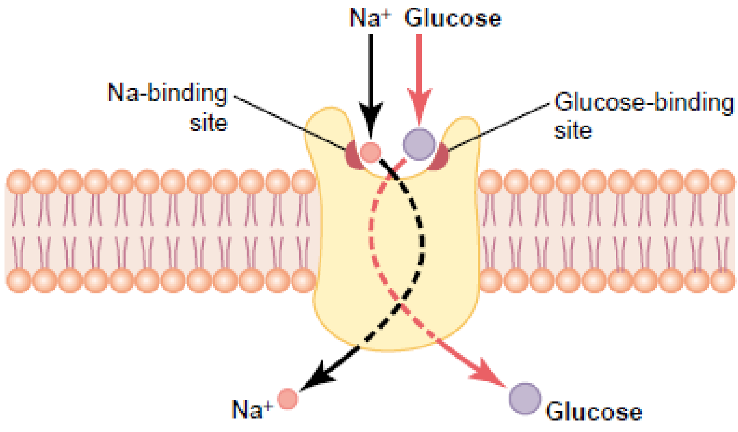
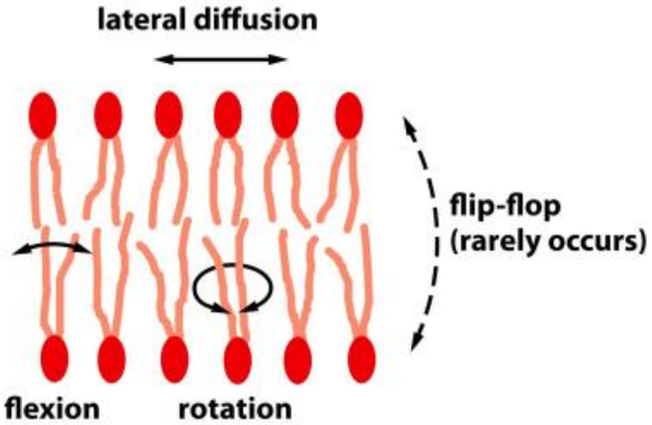
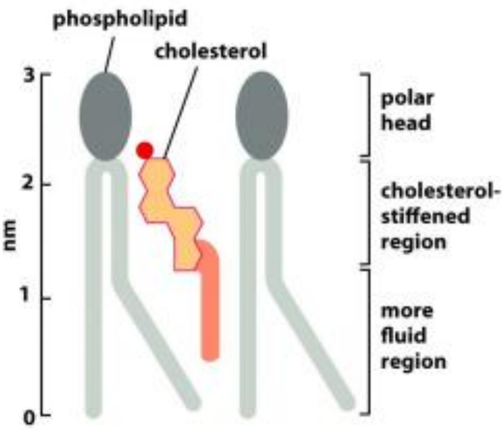


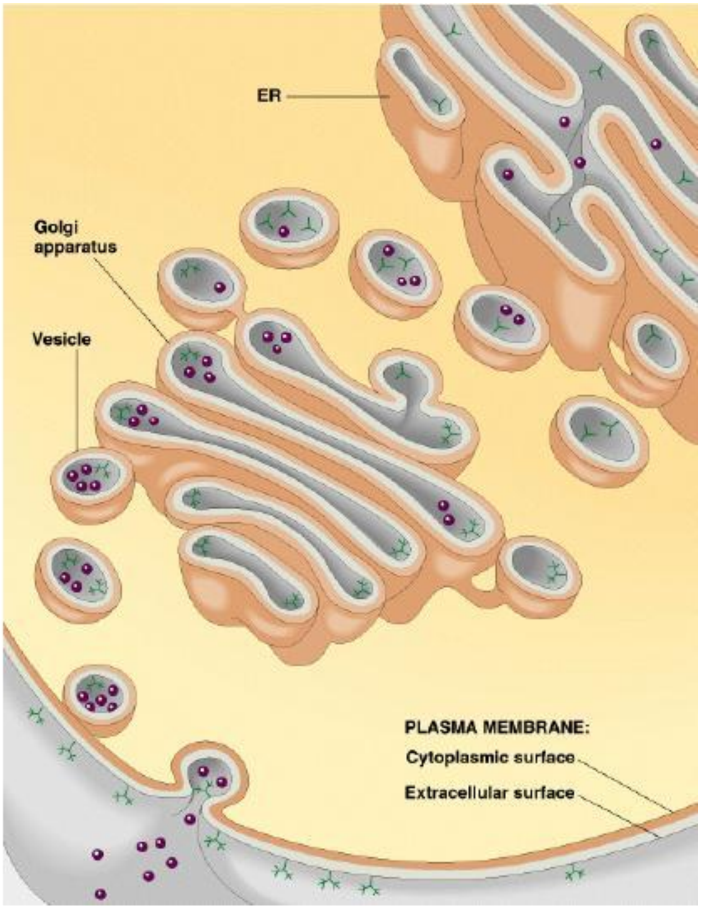
Figure 4–12

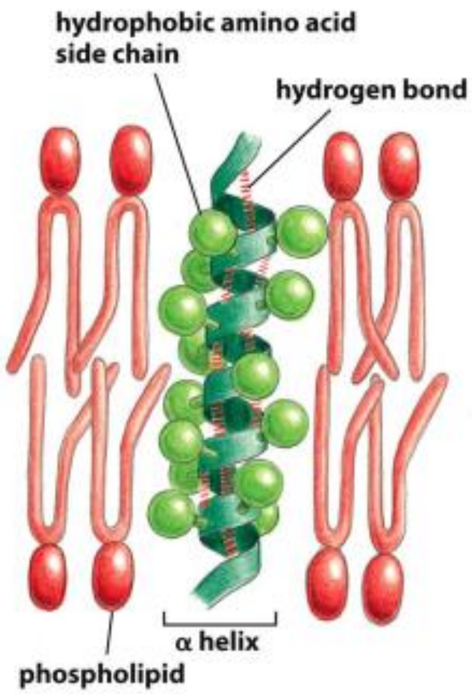
Postulated mechanism for sodium co-transport of glucose.





Sidedness of Membranes





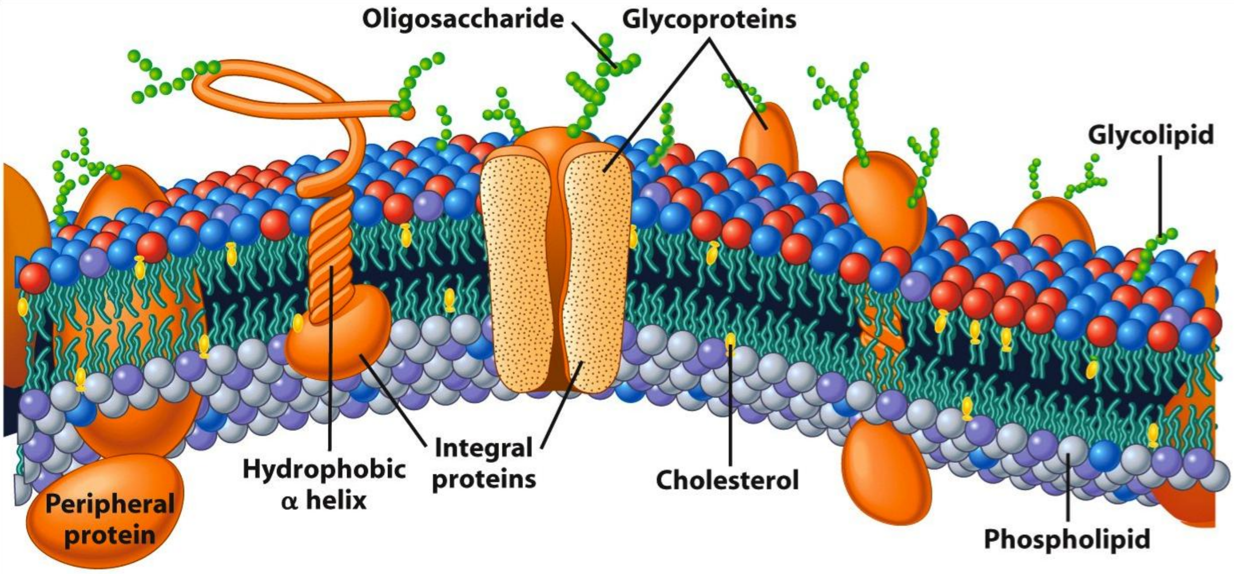
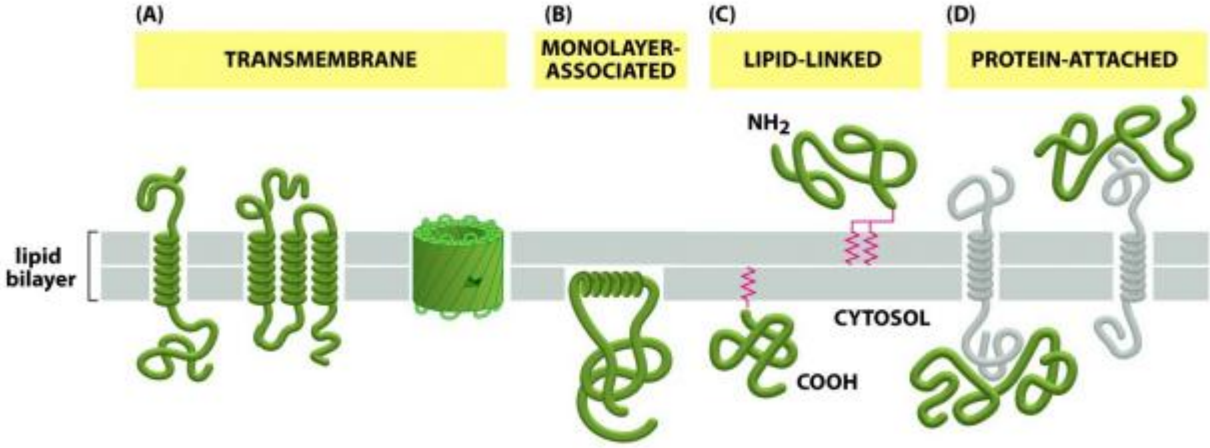
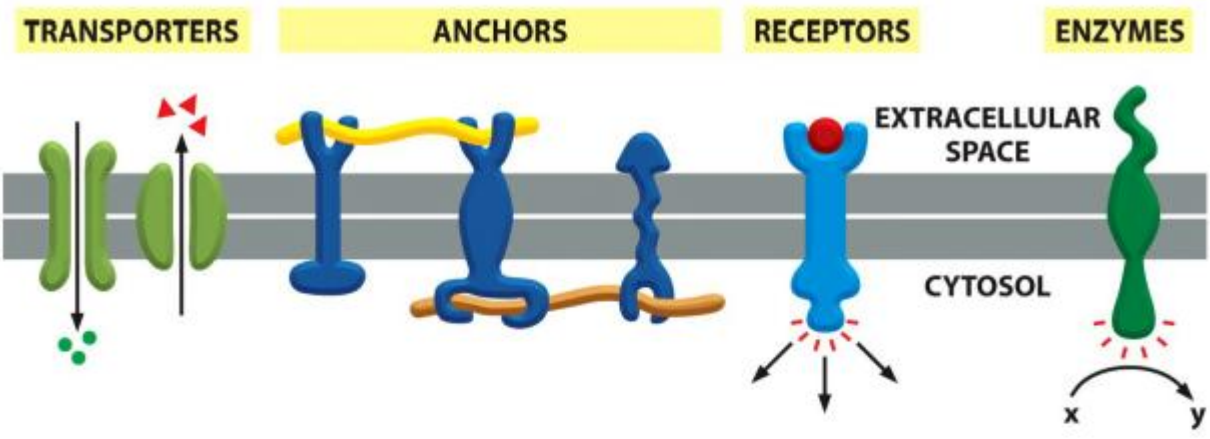
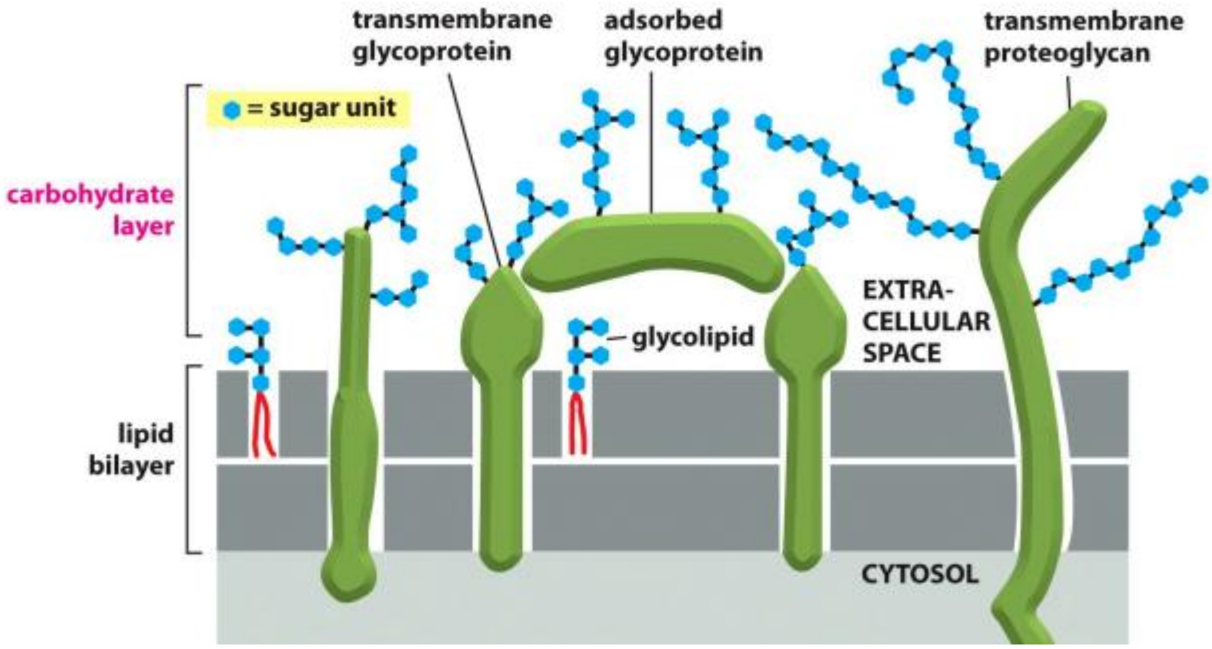
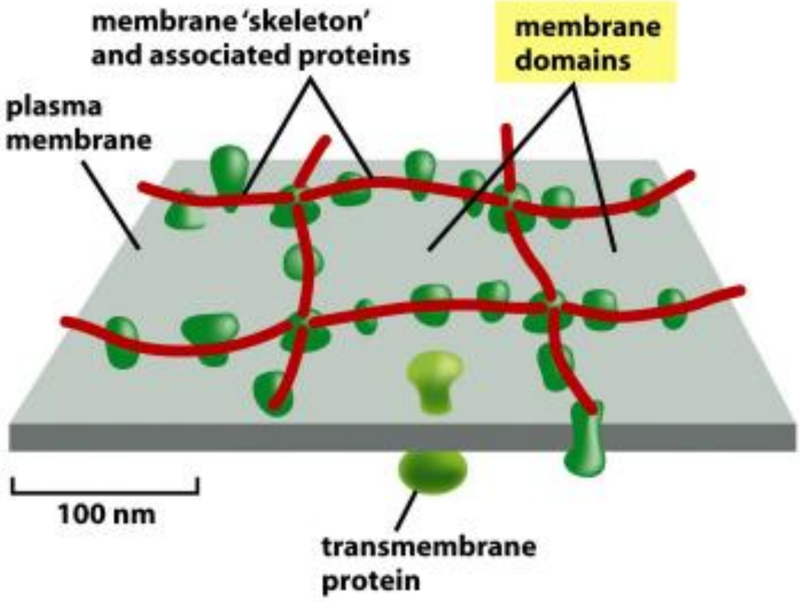


Figure 4-4c Cell and Molecular Biology, 5/e (© 2008 John Wiley & Sons)





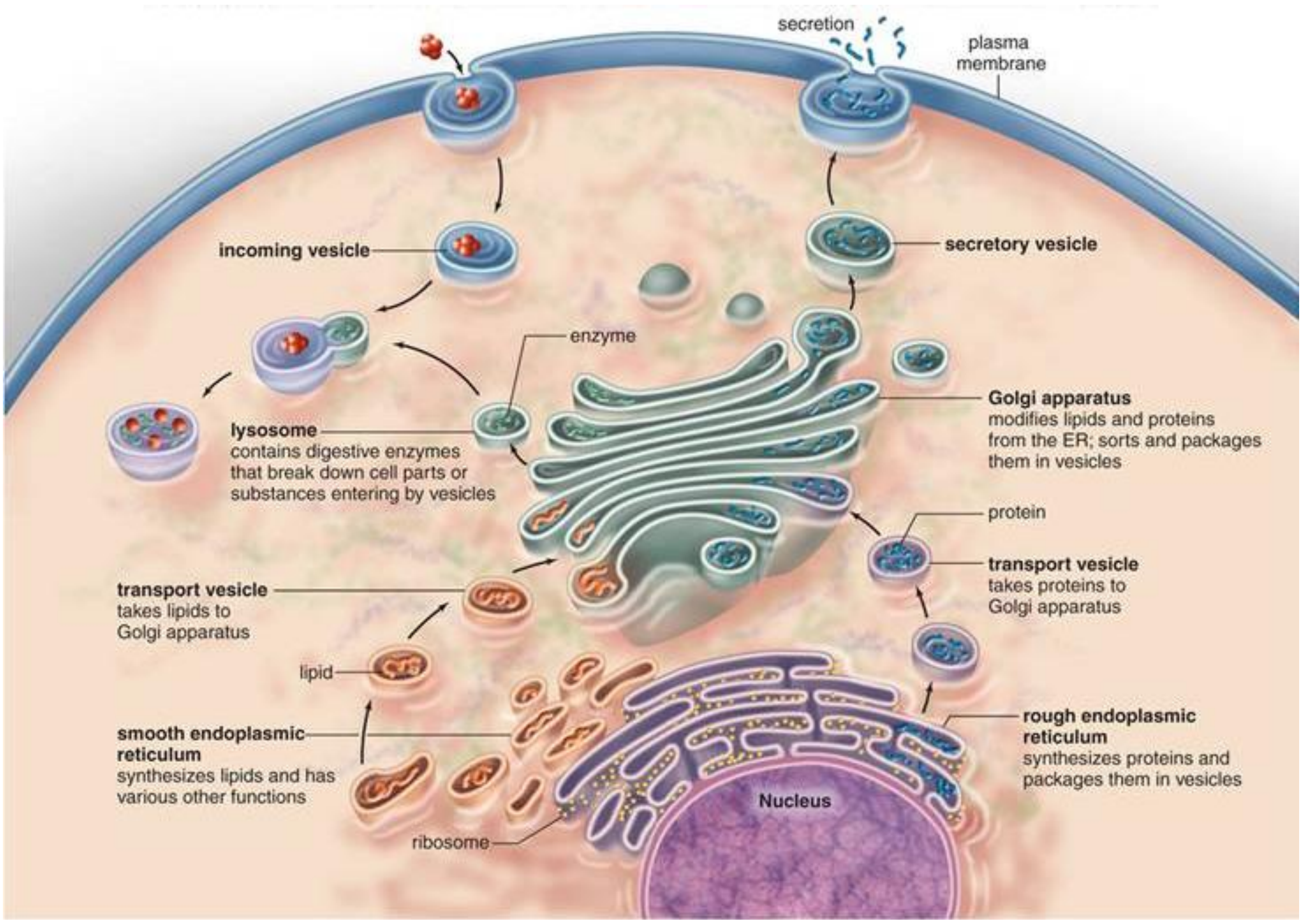

transmembrane glycoprotein
adsorbed glycoprotein
transmembrane proteoglycan
= sugar unit
carbohydrate layer
glycolipid
EXTRA-CELLULAR SPACE
lipid bilayer
CYTOSOL

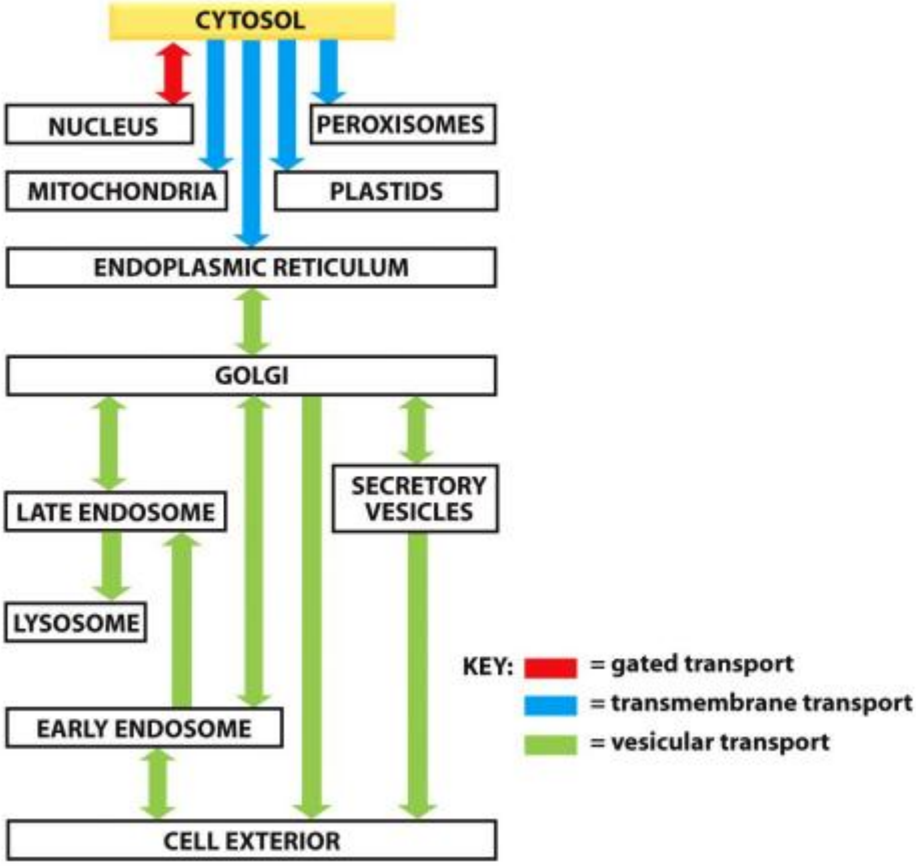

membrane 'skeleton' and associated proteins
membrane domains
plasma membrane
100 nm
transmembrane protein

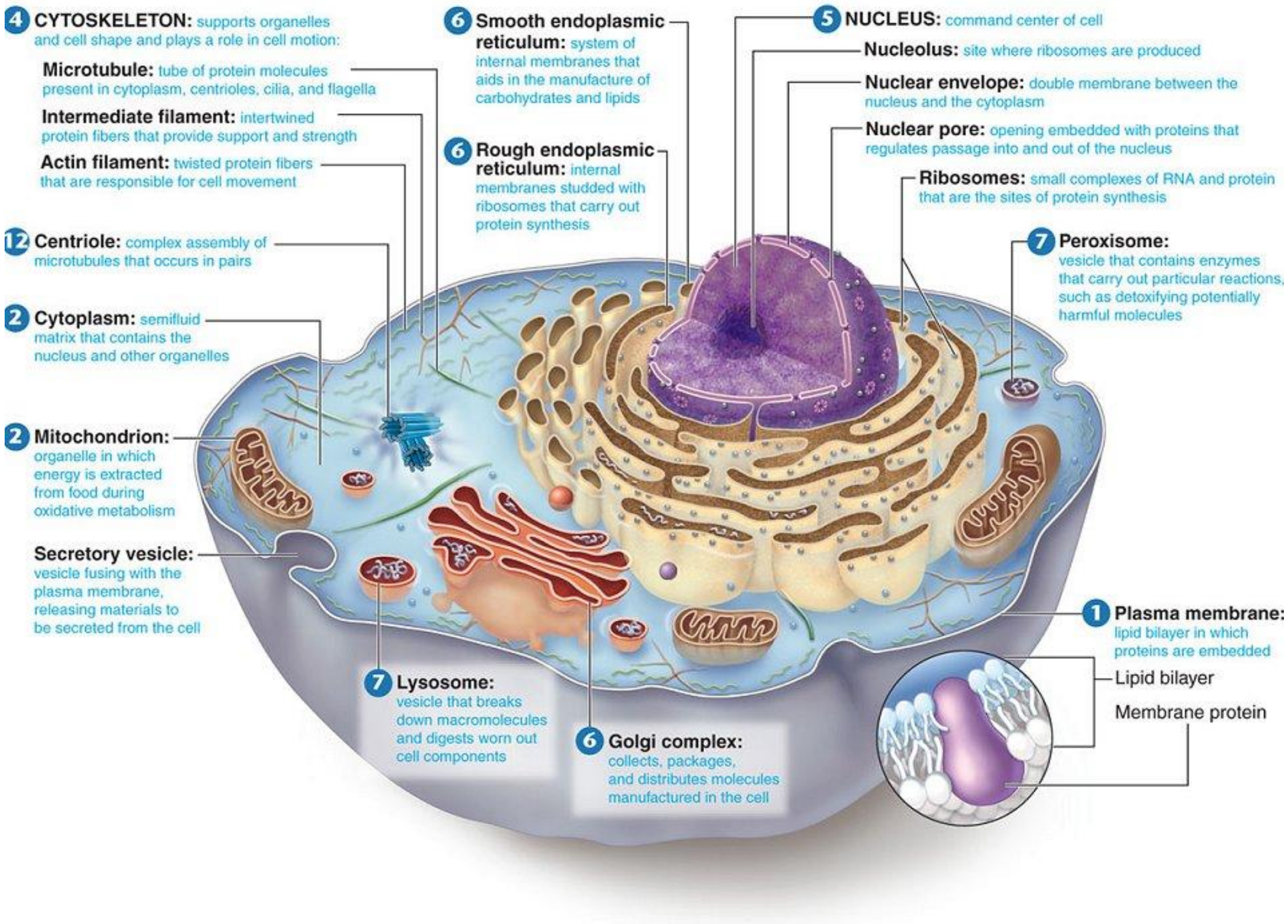
4. Cell Organelles

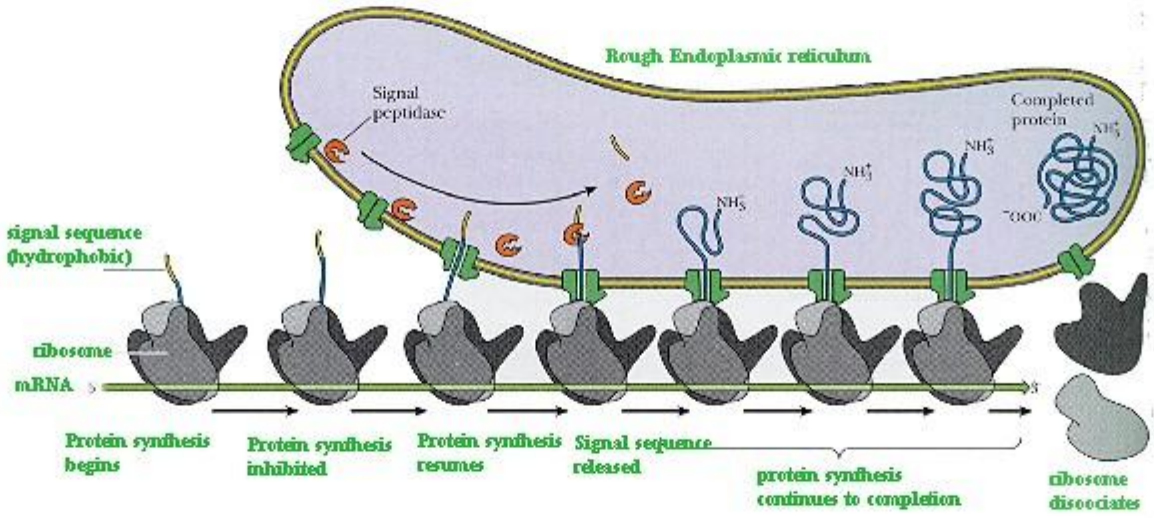
TABLE 15–2 THE RELATIVE VOLUMES OCCUPIED BY THE MAJOR MEMBRANE-ENCLOSED ORGANELLES IN A LIVER CELL (HEPATOCYTE)

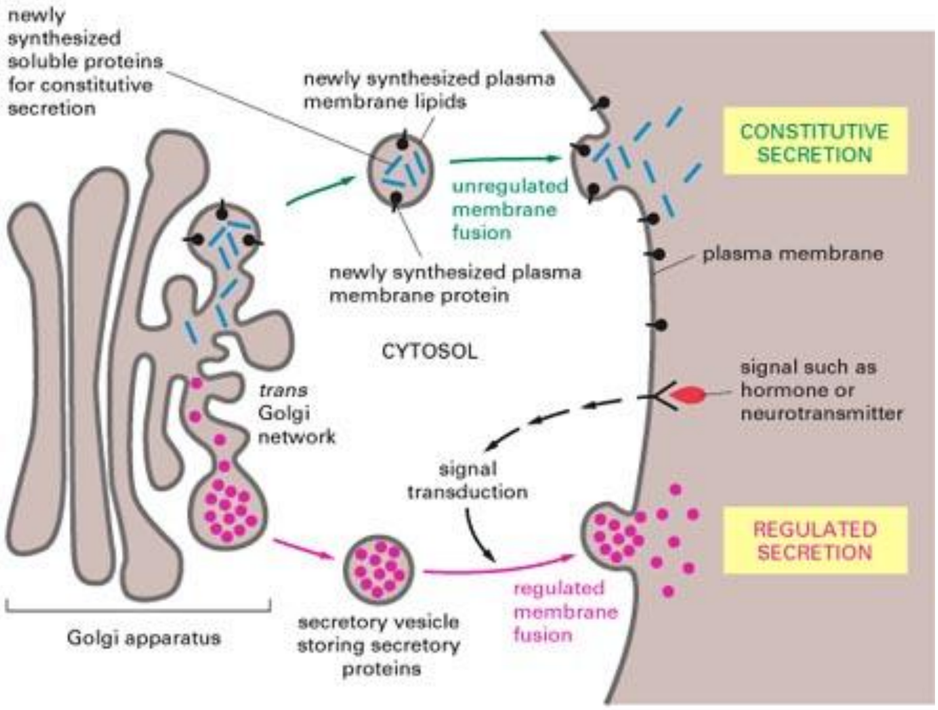
INTRACELLULAR COMPARTMENT	PERCENTAGE OF TOTAL CELL VOLUME	APPROXIMATE NUMBER PER CELL
Cytosol	54	1
Mitochondria	22	1700
Endoplasmic reticulum	12	1
Nucleus	6	1
Golgi apparatus	3	1
Peroxisomes	1	400
Lysosomes	1	300
Endosomes	1	200

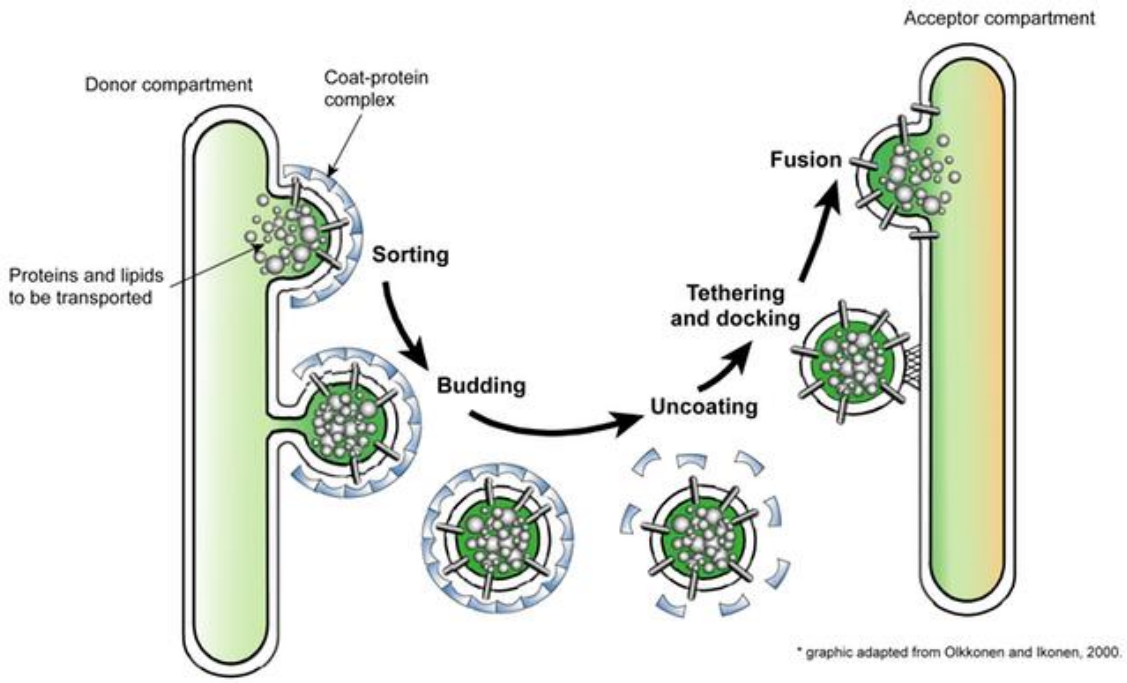


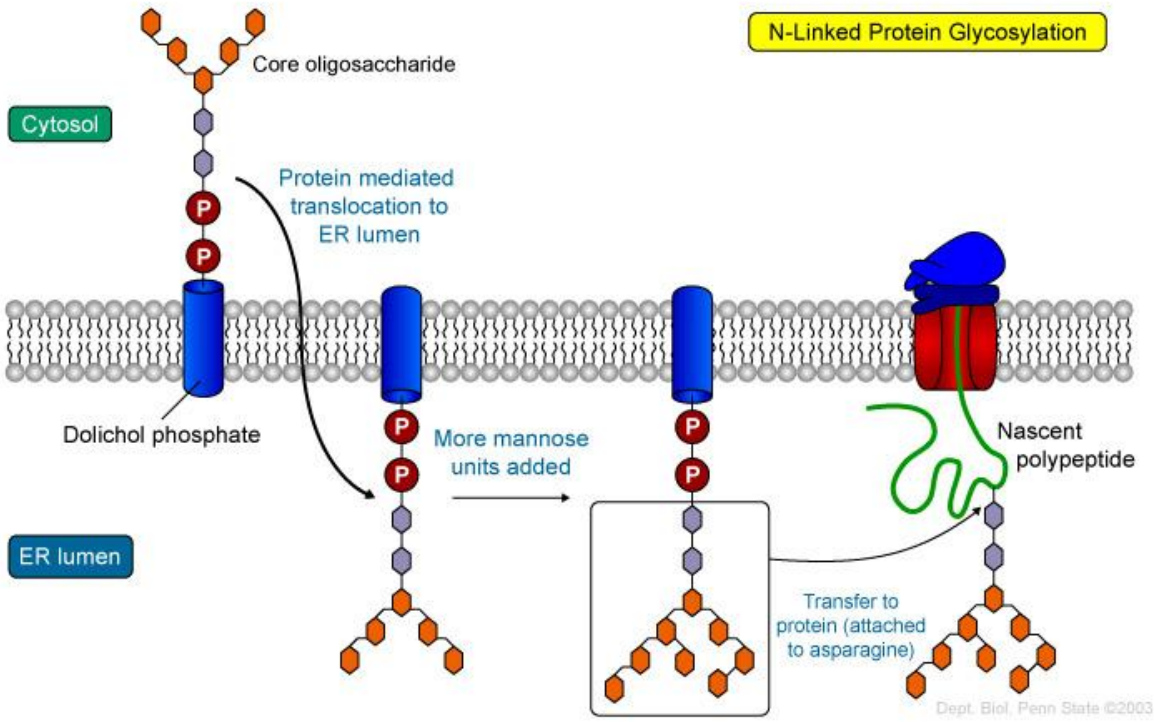

CYTOSOL
NUCLEUS
PEROXISOMES
MITOCHONDRIA
PLASTIDS
ENDOPLASMIC RETICULUM
GOLGI
LATE ENDOSOME
SECRETORY VESICLES
LYSOSOME
EARLY ENDOSOME
CELL EXTERIOR
KEY:
= gated transport
= transmembrane transport
= vesicular transport

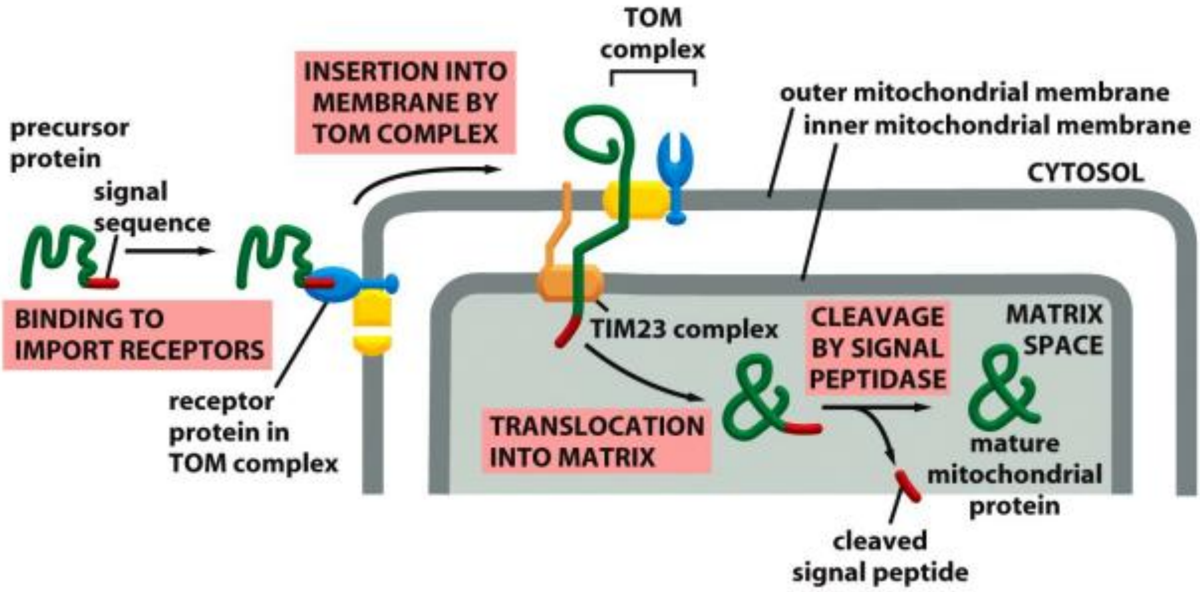

4 CYTOSKELETON: supports organelles and cell shape and plays a role in cell motion:
Microtubule: tube of protein molecules present in cytoplasm, centrioles, cilia, and flagella
Intermediate filament: intertwined protein fibers that provide support and strength
Actin filament: twisted protein fibers that are responsible for cell movement
12 Centriole: complex assembly of microtubules that occurs in pairs
2 Cytoplasm: semifluid matrix that contains the nucleus and other organelles
2 Mitochondrion: organelle in which energy is extracted from food during oxidative metabolism
Secretory vesicle: vesicle fusing with the plasma membrane, releasing materials to be secreted from the cell
6 Smooth endoplasmic reticulum: system of internal membranes that aids in the manufacture of carbohydrates and lipids
6 Rough endoplasmic reticulum: internal membranes studded with ribosomes that carry out protein synthesis
5 NUCLEUS: command center of cell
Nucleolus: site where ribosomes are produced
Nuclear envelope: double membrane between the nucleus and the cytoplasm
Nuclear pore: opening embedded with proteins that regulates passage into and out of the nucleus
Ribosomes: small complexes of RNA and protein that are the sites of protein synthesis
7 Peroxisome: vesicle that contains enzymes that carry out particular reactions, such as detoxifying potentially harmful molecules
1 Plasma membrane: lipid bilayer in which proteins are embedded
Lipid bilayer
Membrane protein
7 Lysosome: vesicle that breaks down macromolecules and digests worn out cell components
6 Golgi complex: collects, packages, and distributes molecules manufactured in the cell


Rough Endoplasmic reticulum
Signal peptidase
Completed protein
signal sequence (hydrophobic)
ribosome
mRNA
Protein synthesis begins
Protein synthesis inhibited
Protein synthesis resumes
Signal sequence released
protein synthesis continues to completion
ribosome disociates

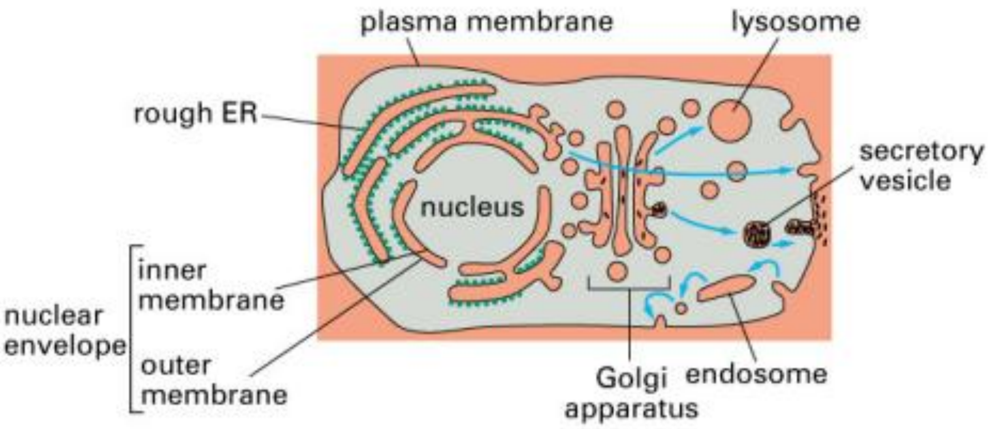

newly synthesized soluble proteins for constitutive secretion
newly synthesized plasma membrane lipids
unregulated membrane fusion
CONSTITUTIVE SECRETION
newly synthesized plasma membrane protein
plasma membrane
CYTOSOL
trans Golgi network
signal such as hormone or neurotransmitter
signal transduction
REGULATED SECRETION
regulated membrane fusion
secretory vesicle storing secretory proteins
Golgi apparatus

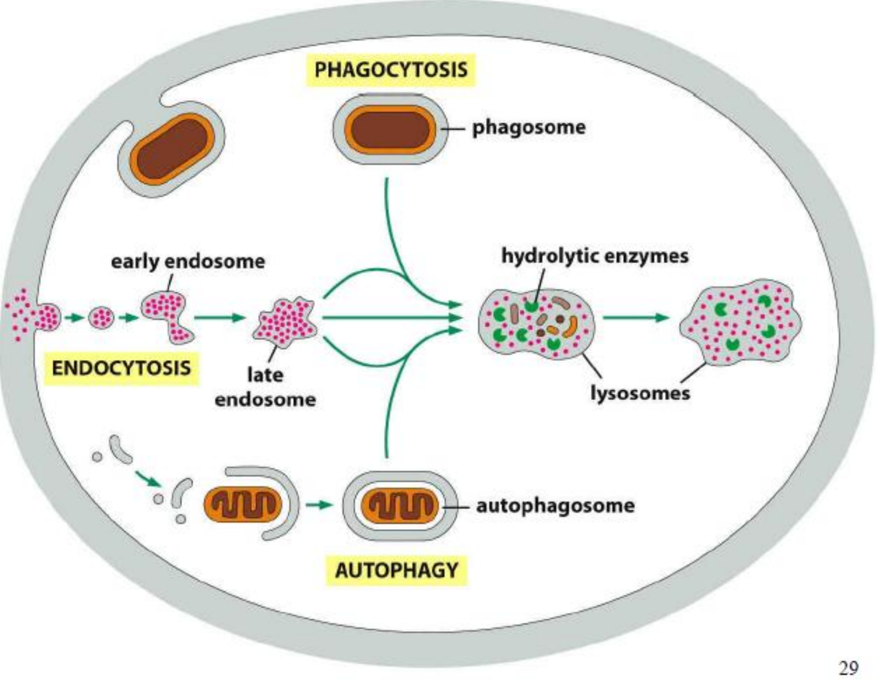

Acceptor compartment
Donor compartment
Coat-protein complex
Fusion
Sorting
Proteins and lipids to be transported
Tethering and docking
Budding
Uncoating
* graphic adapted from Olkkonen and Ikonen, 2000.



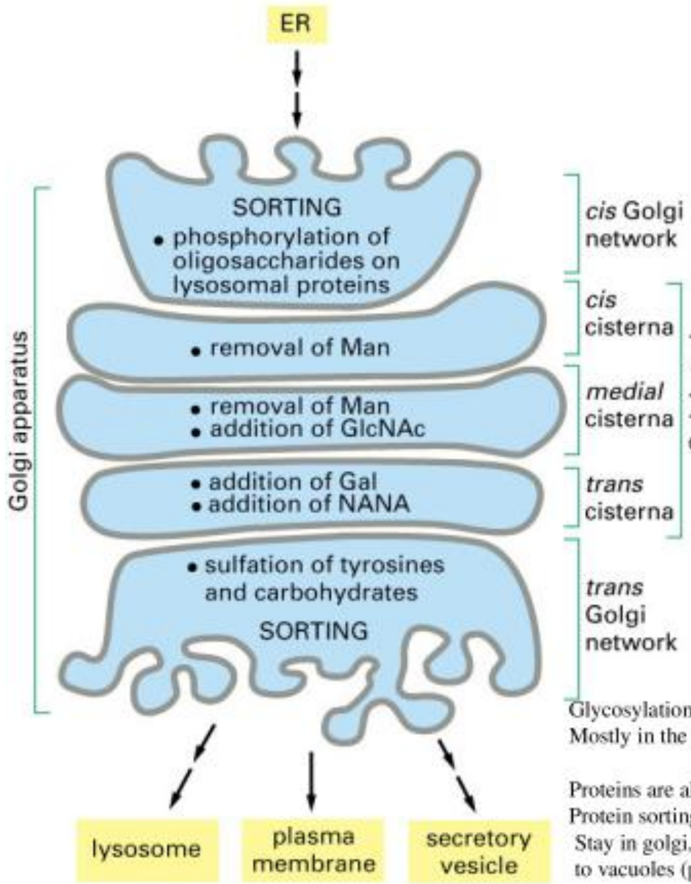


•Proteins Unfold to Enter Mitochondria and Chloroplasts



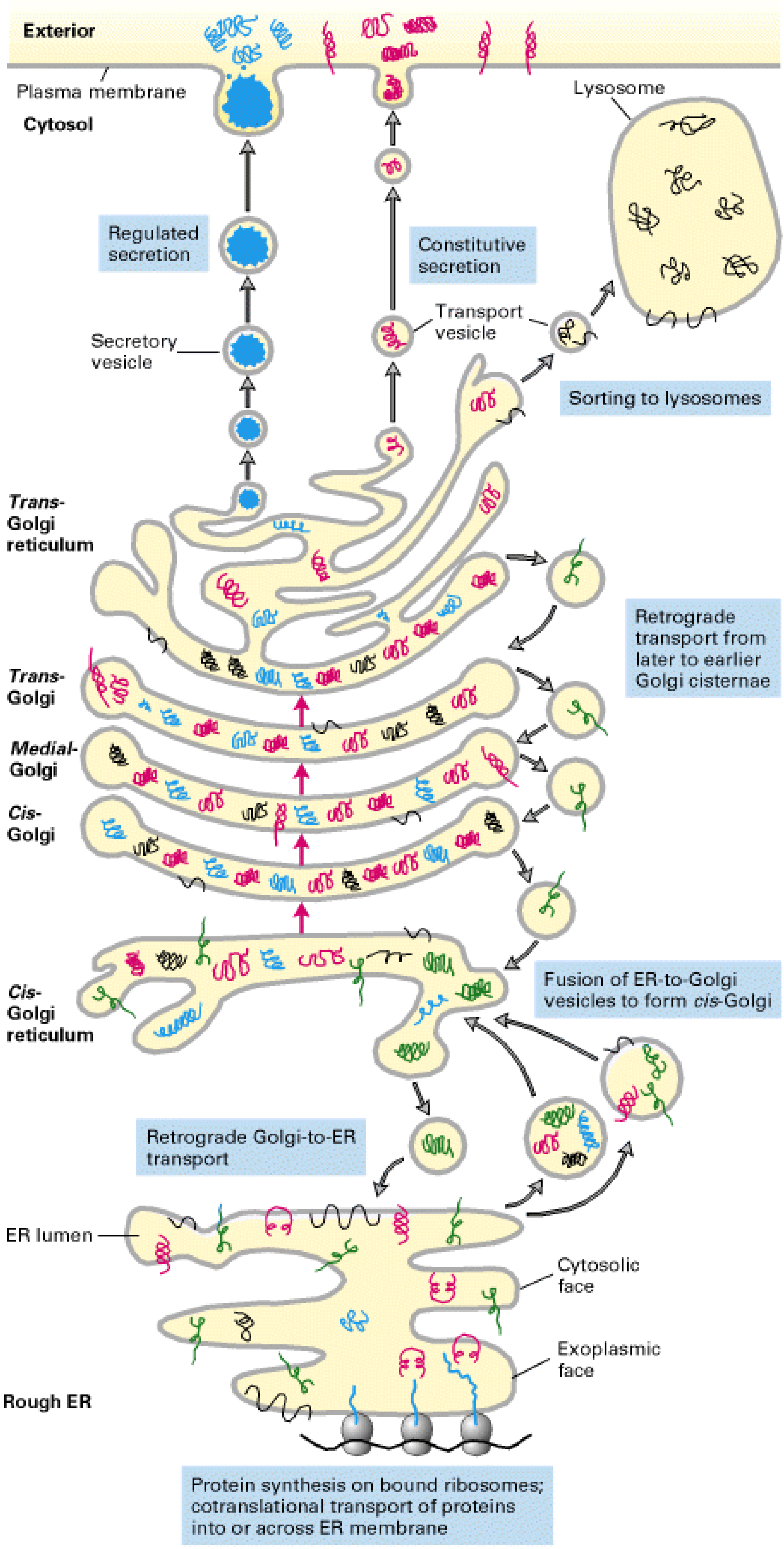


29

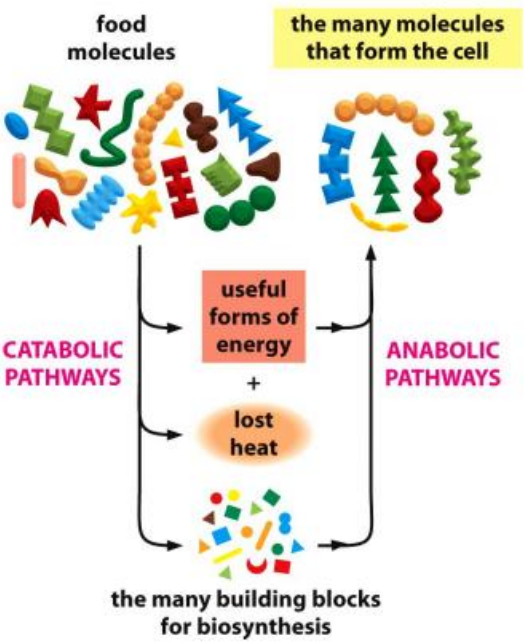


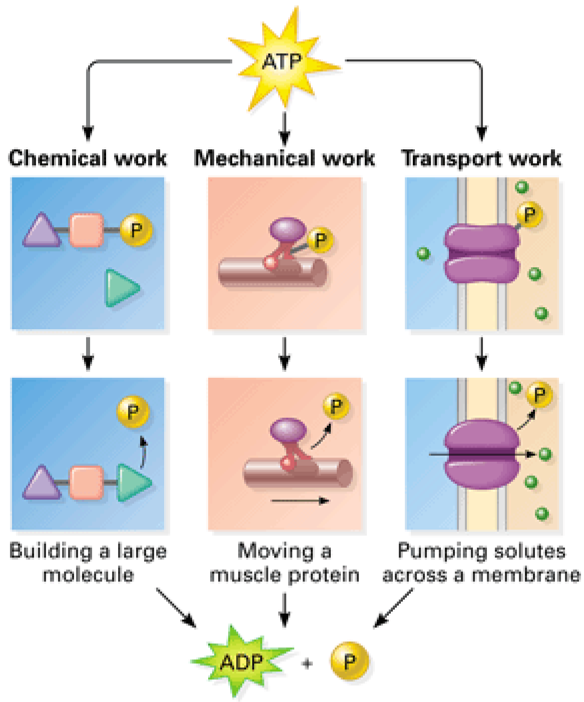
Glycosylation cc
Mostly in the mc

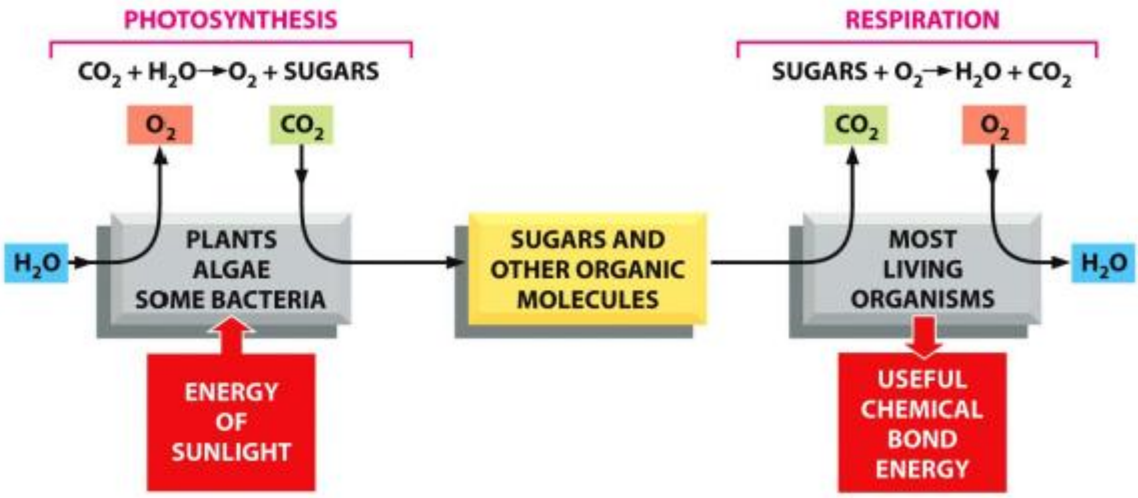
Proteins are also
Protein sorting:]
Stay in golgi, tr
to vacuoles (pla

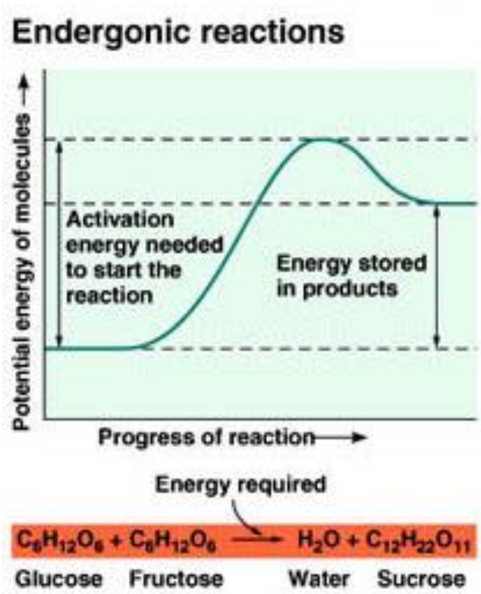

Exterior
Plasma membrane
Cytosol
Lysosome
Regulated secretion
Constitutive secretion
Secretory vesicle
Transport vesicle
Sorting to lysosomes
Trans-Golgi reticulum
Trans-Golgi
Medial-Golgi
Cis-Golgi
Retrograde transport from later to earlier Golgi cisternae
Cis-Golgi reticulum
Fusion of ER-to-Golgi vesicles to form cis-Golgi
Retrograde Golgi-to-ER transport
ER lumen
Cytosolic face
Exoplasmic face
Rough ER
Protein synthesis on bound ribosomes; cotranslational transport of proteins into or across ER membrane

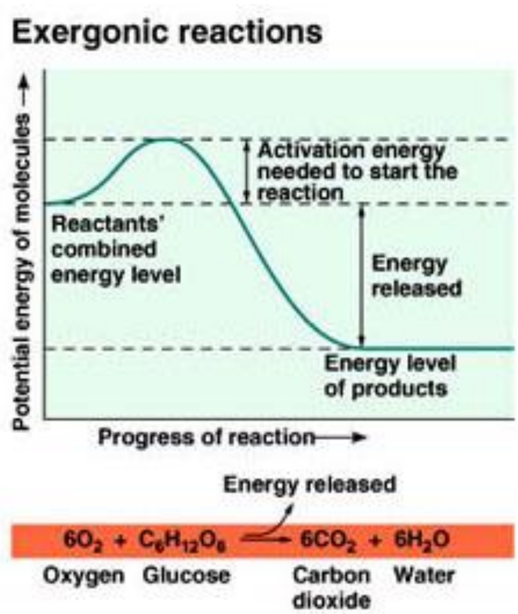
5. Bioenergetics











6. Enzymes

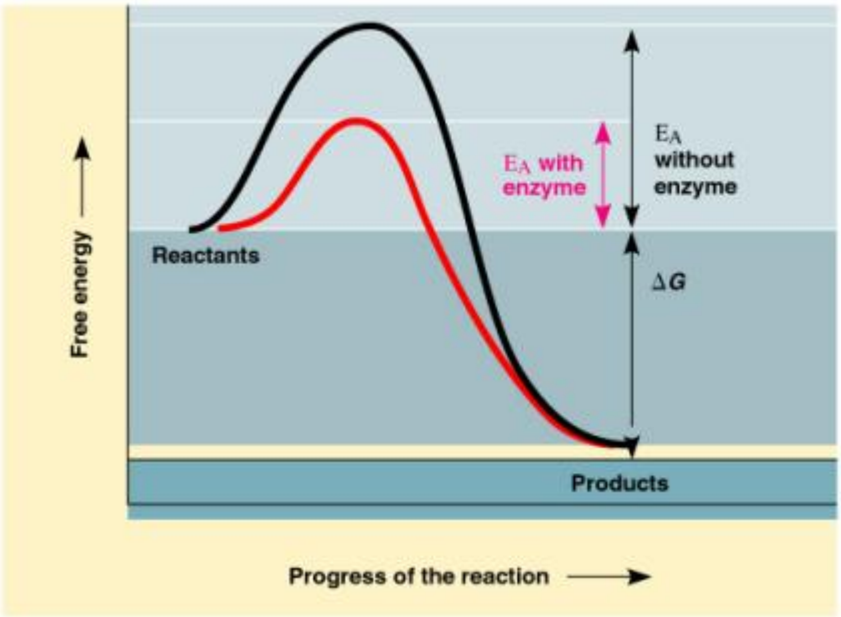
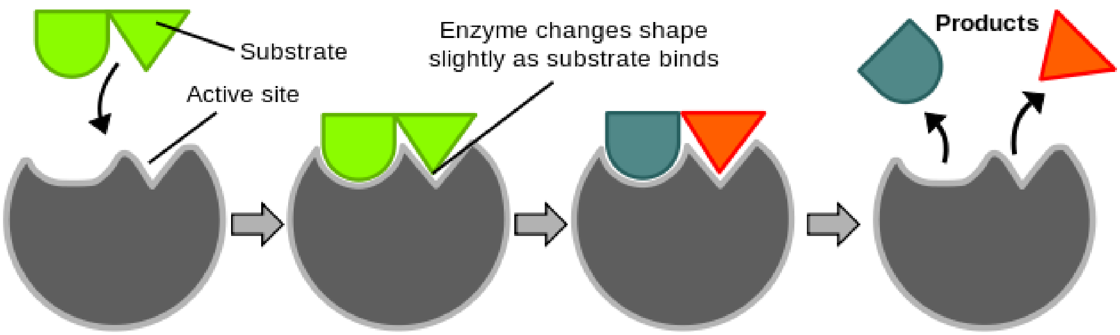
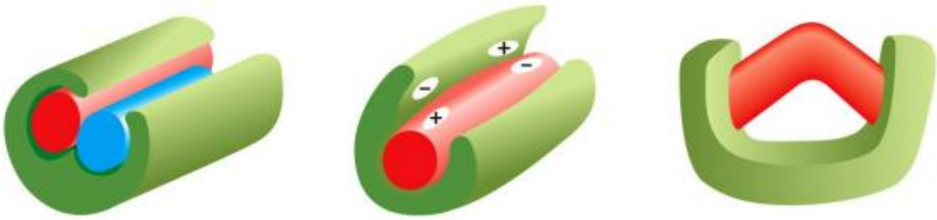


TABLE 4–1 SOME COMMON FUNCTIONAL CLASSES OF ENZYMES	
ENZYME CLASS	**BIOCHEMICAL FUNCTION**
Hydrolase	General term for enzymes that catalyze a hydrolytic cleavage reaction.
Nuclease	Breaks down nucleic acids by hydrolyzing bonds between nucleotides.
Protease	Breaks down proteins by hydrolyzing peptide bonds between amino acids.
Synthase	General name used for enzymes that synthesize molecules in anabolic reactions by condensing two molecules together.
Isomerase	Catalyzes the rearrangement of bonds within a single molecule.
Polymerase	Catalyzes polymerization reactions such as the synthesis of DNA and RNA.
Kinase	Catalyzes the addition of phosphate groups to molecules. Protein kinases are an important group of kinases that attach phosphate groups to proteins.
Phosphatase	Catalyzes the hydrolytic removal of a phosphate group from a molecule.
Oxido-reductase	General name for enzymes that catalyze reactions in which one molecule is oxidized while the other is reduced. Enzymes of this type are often called oxidases, reductases, or dehydrogenases.
ATPase	Hydrolyzes ATP. Many proteins with a wide range of roles have an energy-harnessing ATPase activity as part of their function, including motor proteins such as myosin and membrane transport proteins such as the sodium–potassium pump.

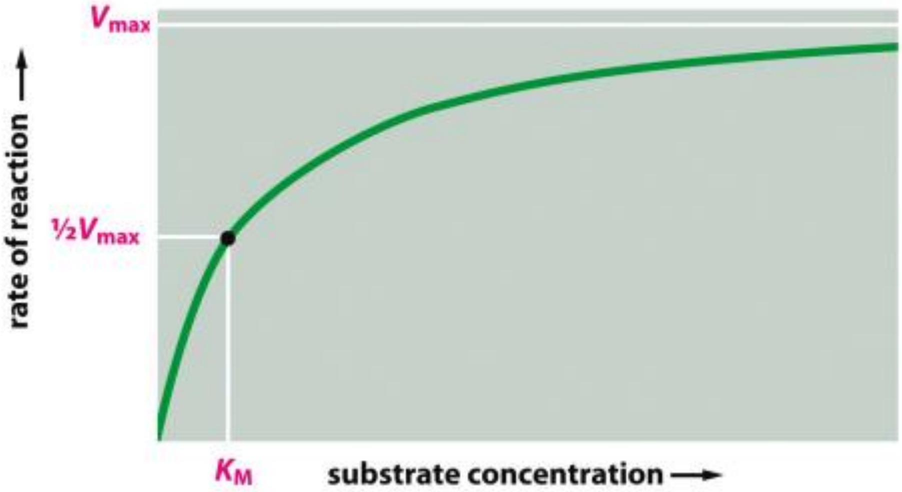


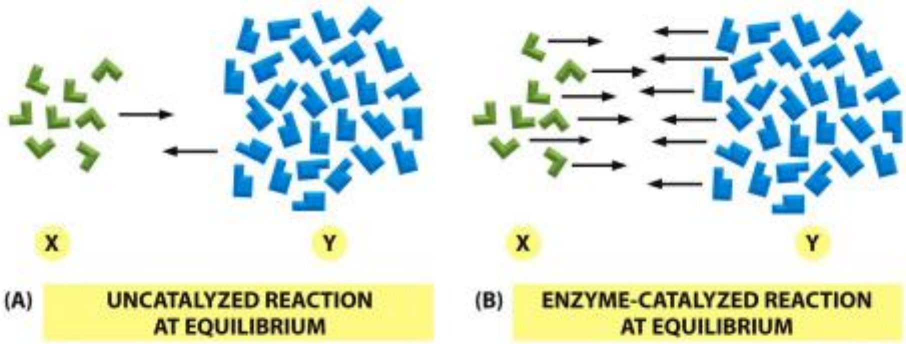


(A) enzyme binds to two substrate molecules and orients them precisely to encourage a reaction to occur between them

(B) binding of substrate to enzyme rearranges electrons in the substrate, creating partial negative and positive charges that favor a reaction

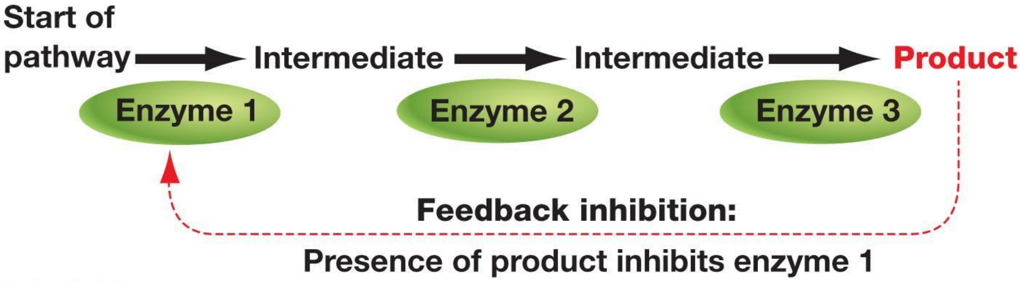
(C) enzyme strains the bound substrate molecule, forcing it toward a transition state to favor a reaction





Reaction rate and direction (extent) are different

- Enzymes, biological catalysts, enhance reaction rates but have no effect on reaction



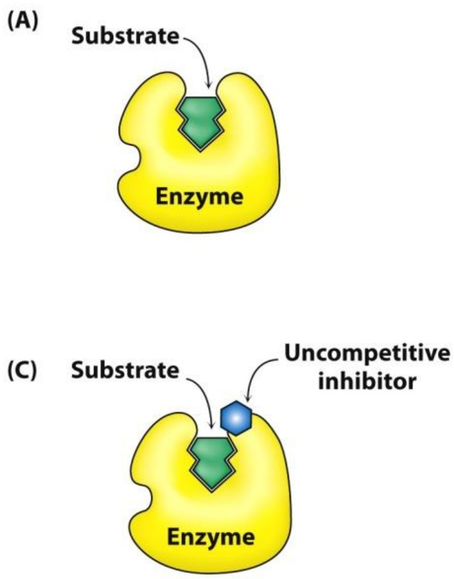
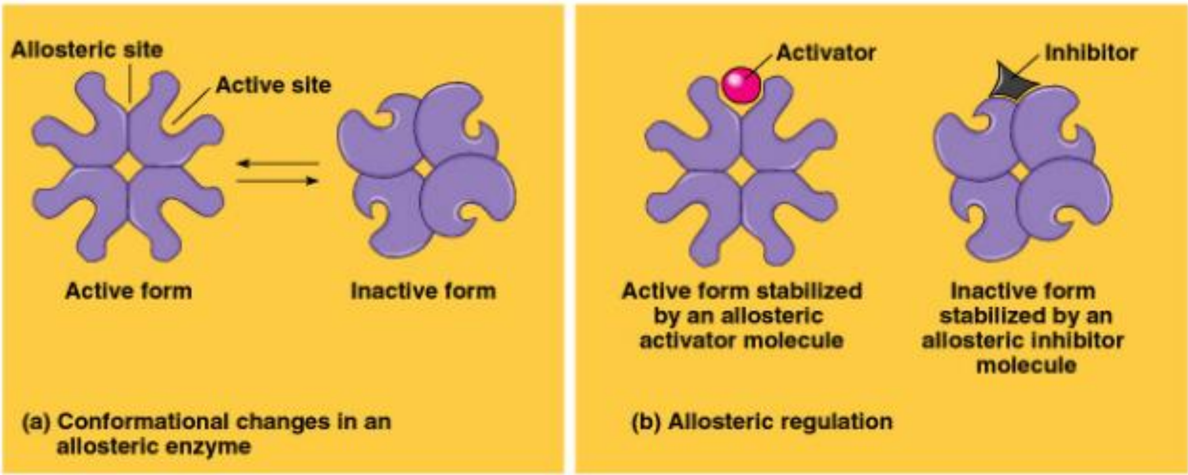
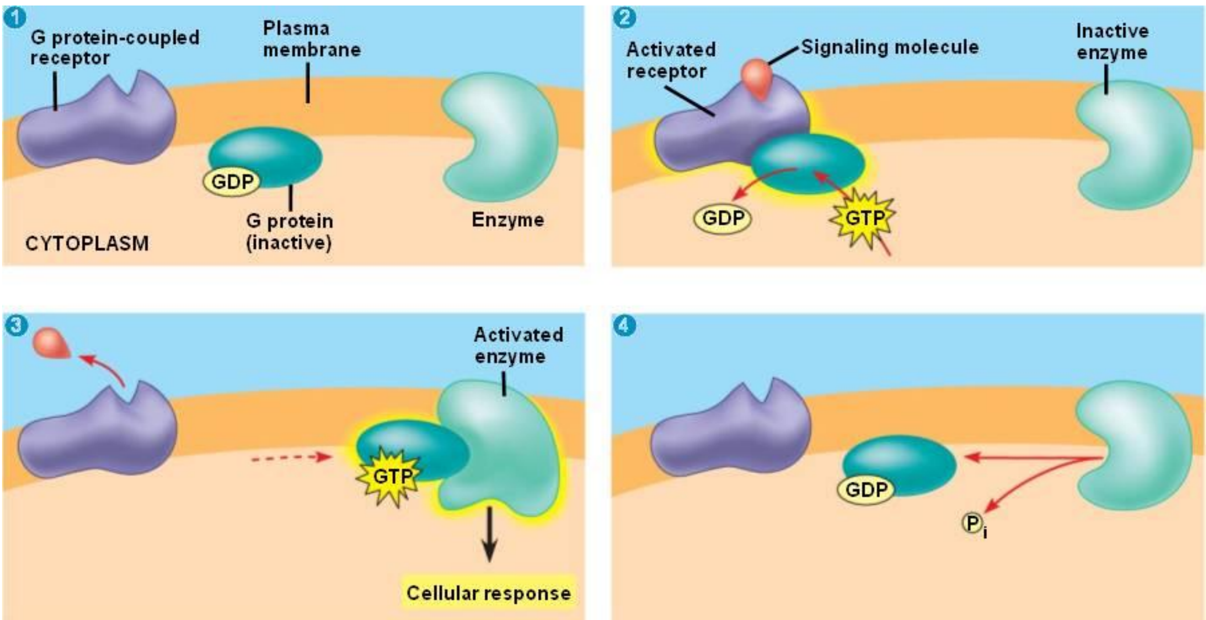


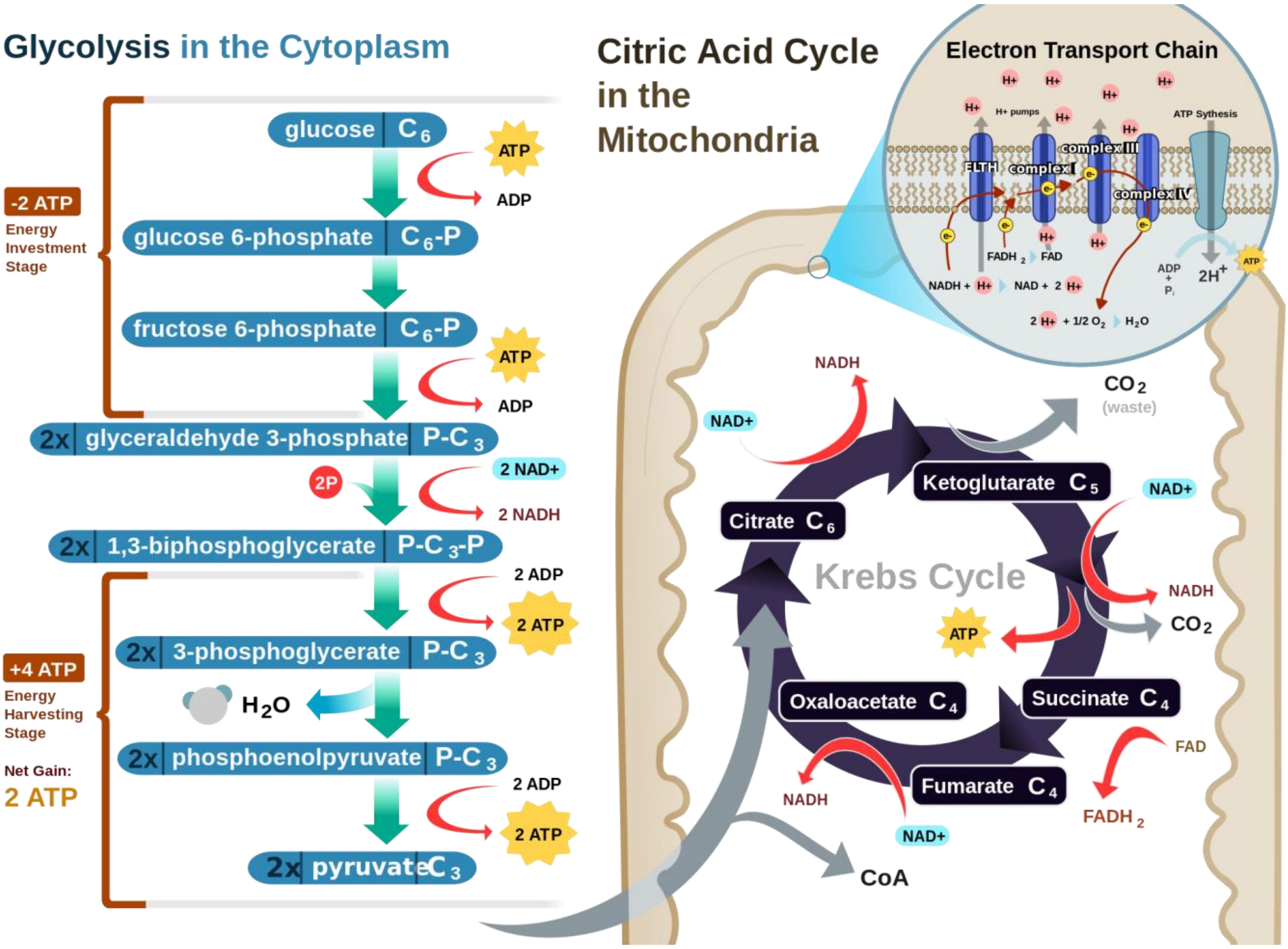
Figure 8.14
Biochemistry, Seventh Edition

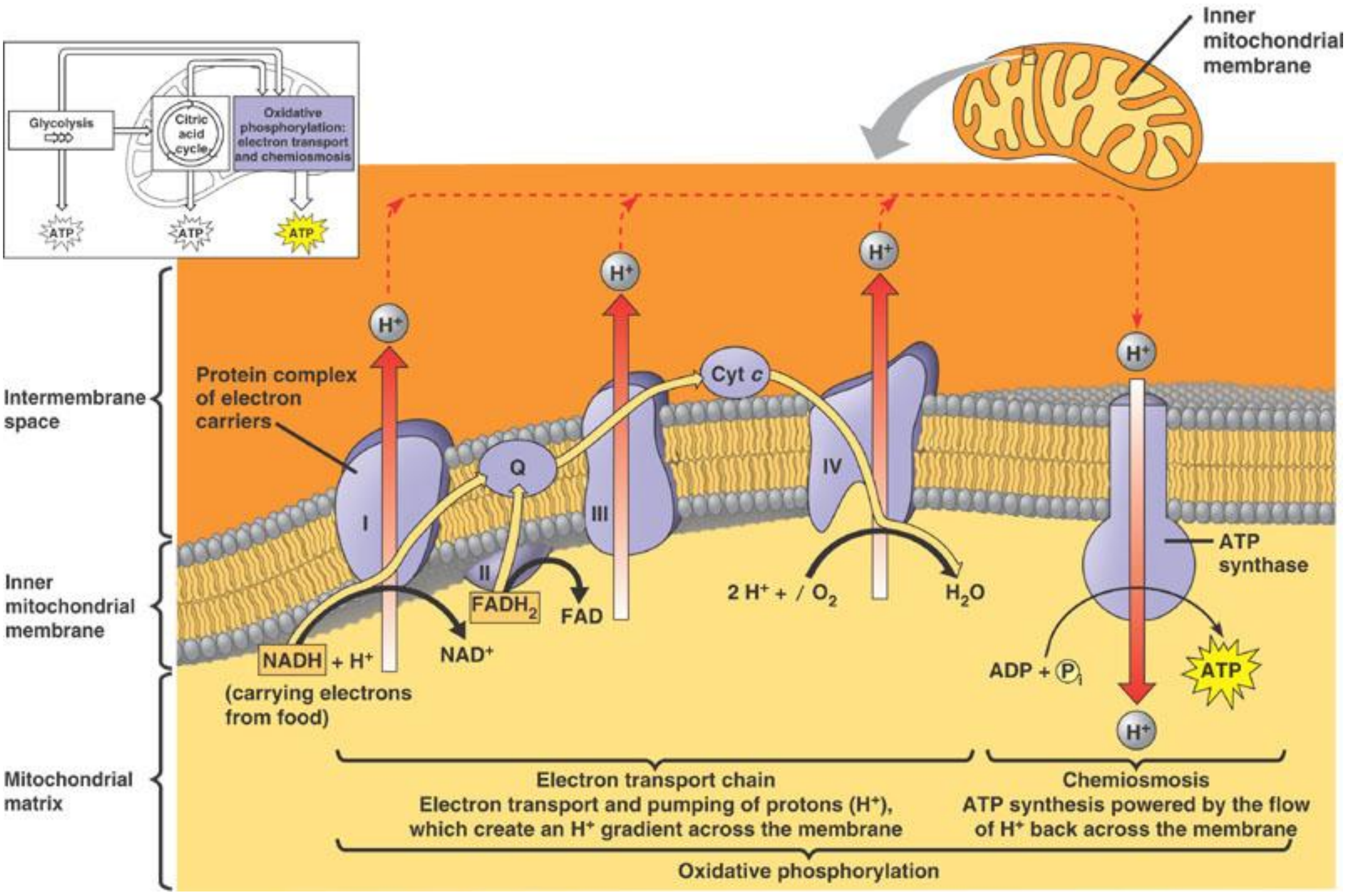


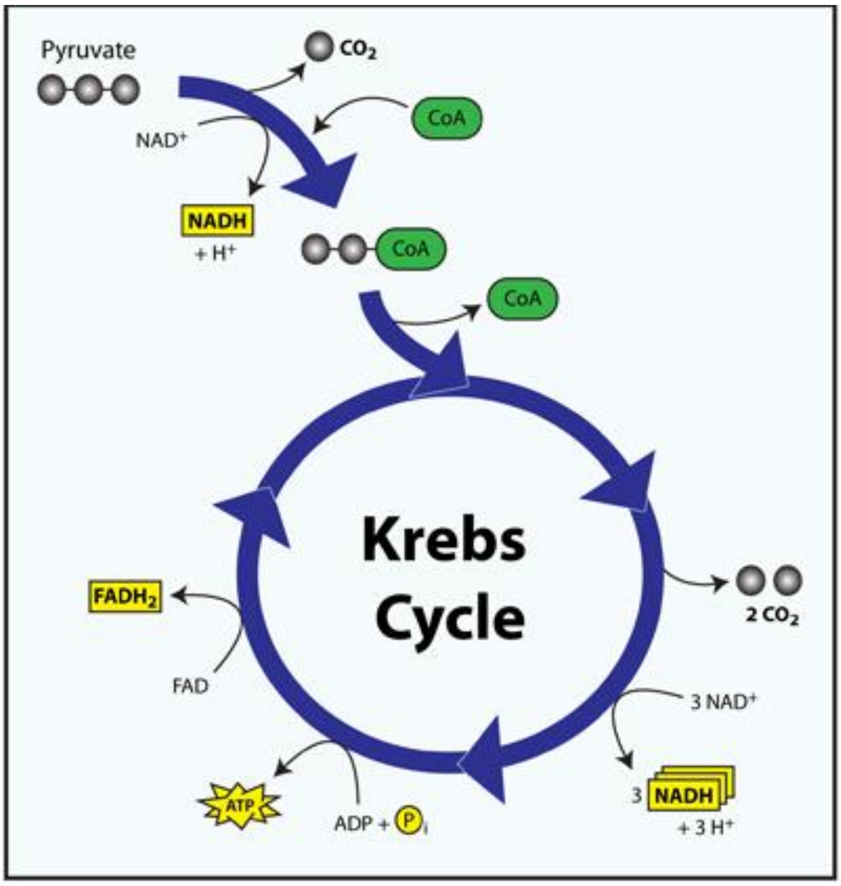


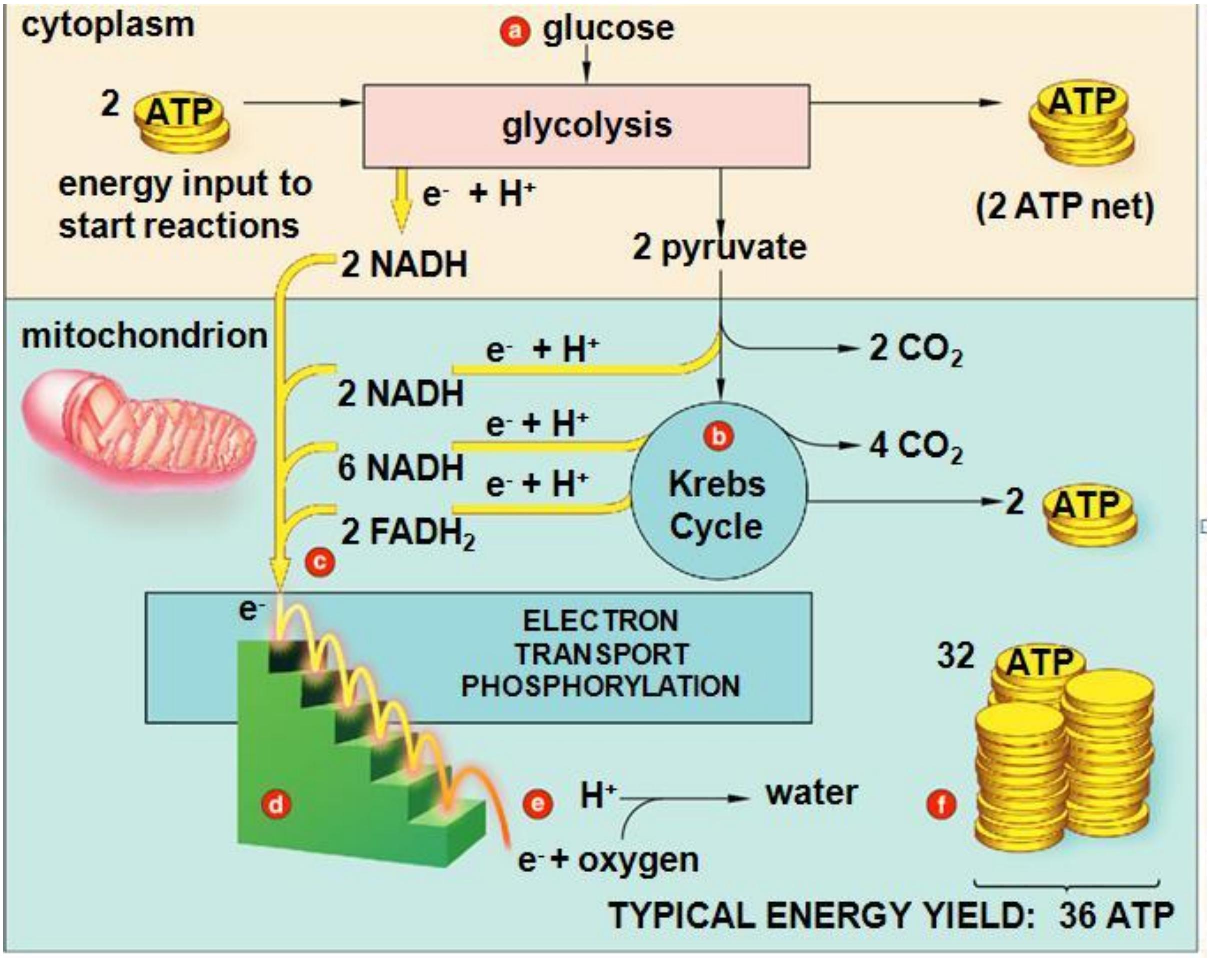
7. Cellular Respiration

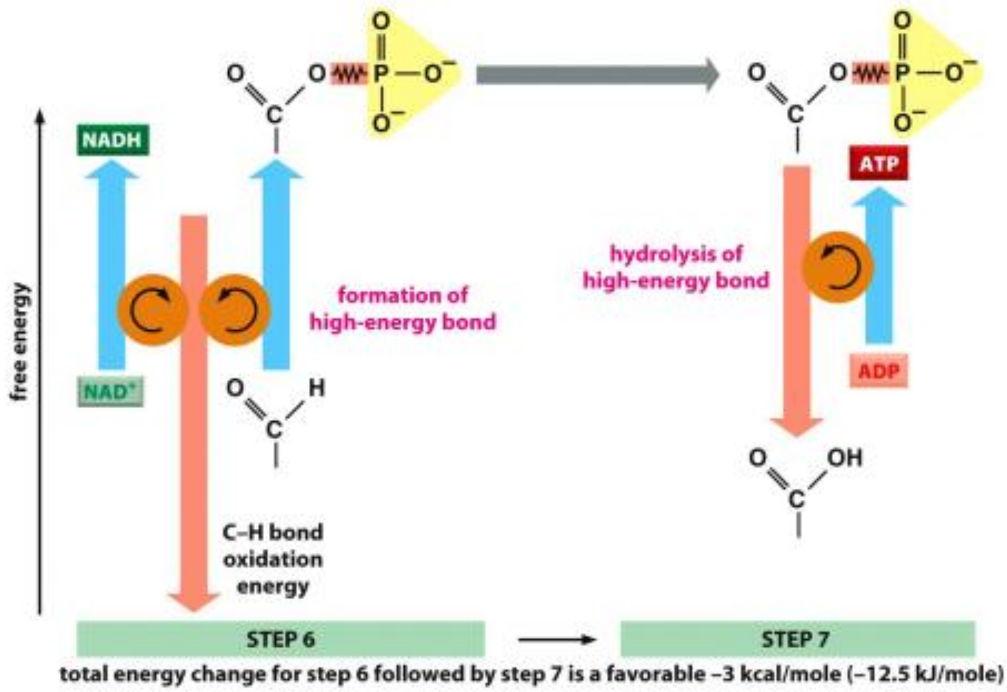
$6CO_2$ Carbon dioxide + $6H_2O$ Water $\xrightarrow{\text{Light}}$ $C_6H_{12}O_6$ Sugar + $6O_2$ Oxygen



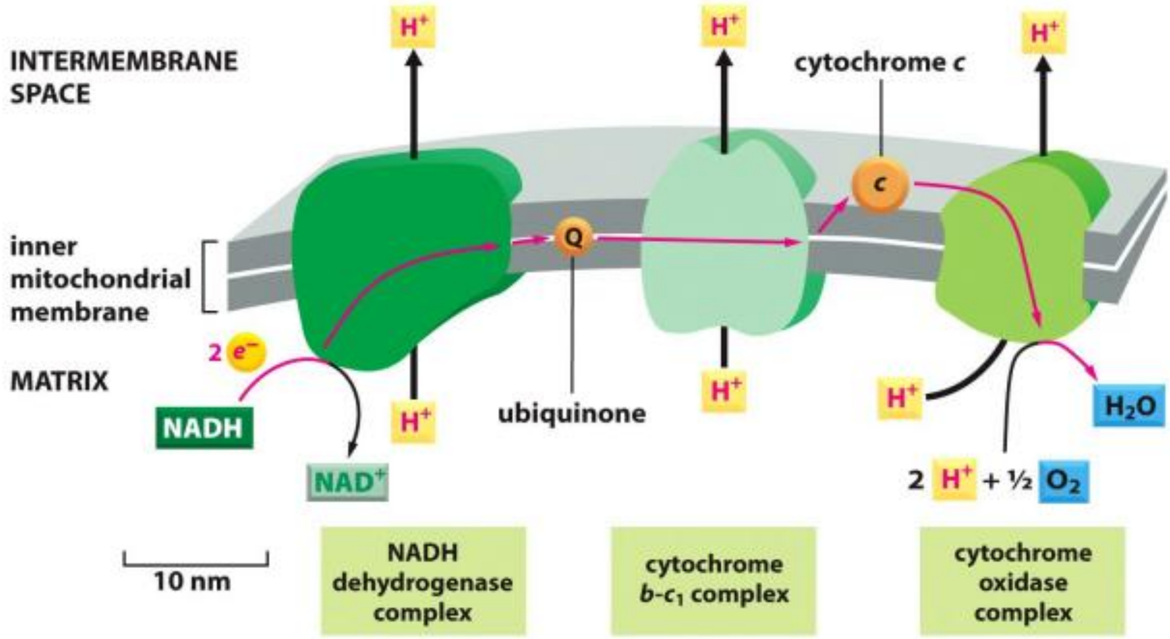

Glycolysis
Citric acid cycle
Oxidative phosphorylation: electron transport and chemiosmosis
ATP
ATP
ATP
Inner mitochondrial membrane
Intermembrane space
Inner mitochondrial membrane
Mitochondrial matrix
Protein complex of electron carriers
H+
H+
H+
H+
H+
Cyt c
Q
I
II
III
IV
NADH + H+
(carrying electrons from food)
NAD+
FADH2
FAD
2 H+ + / O2
H2O
ATP synthase
ADP + P
ATP
Electron transport chain
Electron transport and pumping of protons (H+), which create an H+ gradient across the membrane
Chemiosmosis
ATP synthesis powered by the flow of H+ back across the membrane
Oxidative phosphorylation


Pyruvate
CO2
NAD+
CoA
NADH
+ H+
CoA
CoA
Krebs Cycle
2 CO2
FADH2
FAD
3 NAD+
3 NADH
+ 3 H+
ATP
ADP + P

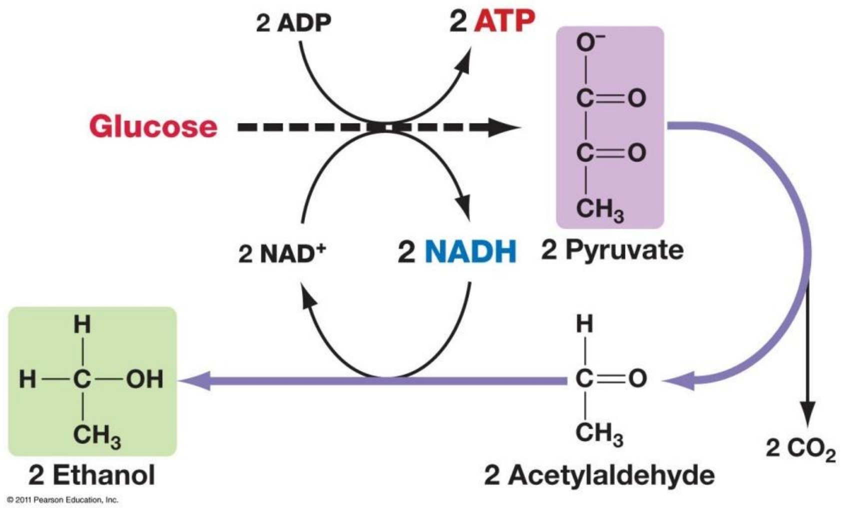

cytoplasm
glucose
2 ATP
glycolysis
ATP
energy input to start reactions
e- + H+
(2 ATP net)
2 NADH
2 pyruvate
mitochondrion
e- + H+
2 CO2
2 NADH
e- + H+
4 CO2
6 NADH
e- + H+
Krebs Cycle
2 ATP
2 FADH2
ELECTRON TRANSPORT PHOSPHORYLATION
32 ATP
H+
water
e- + oxygen
TYPICAL ENERGY YIELD: 36 ATP


free energy
NADH
NAD+
formation of high-energy bond
hydrolysis of high-energy bond
ATP
ADP
C-H bond oxidation energy
STEP 6
STEP 7
total energy change for step 6 followed by step 7 is a favorable –3 kcal/mole (–12.5 kJ/mole)

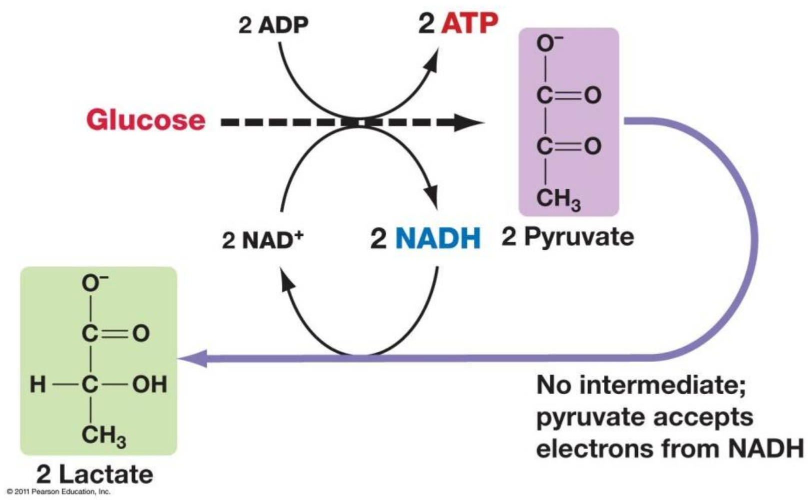
The Electron-Transport Chain Pumps Protons Across the Inner Mitochondrial Membrane



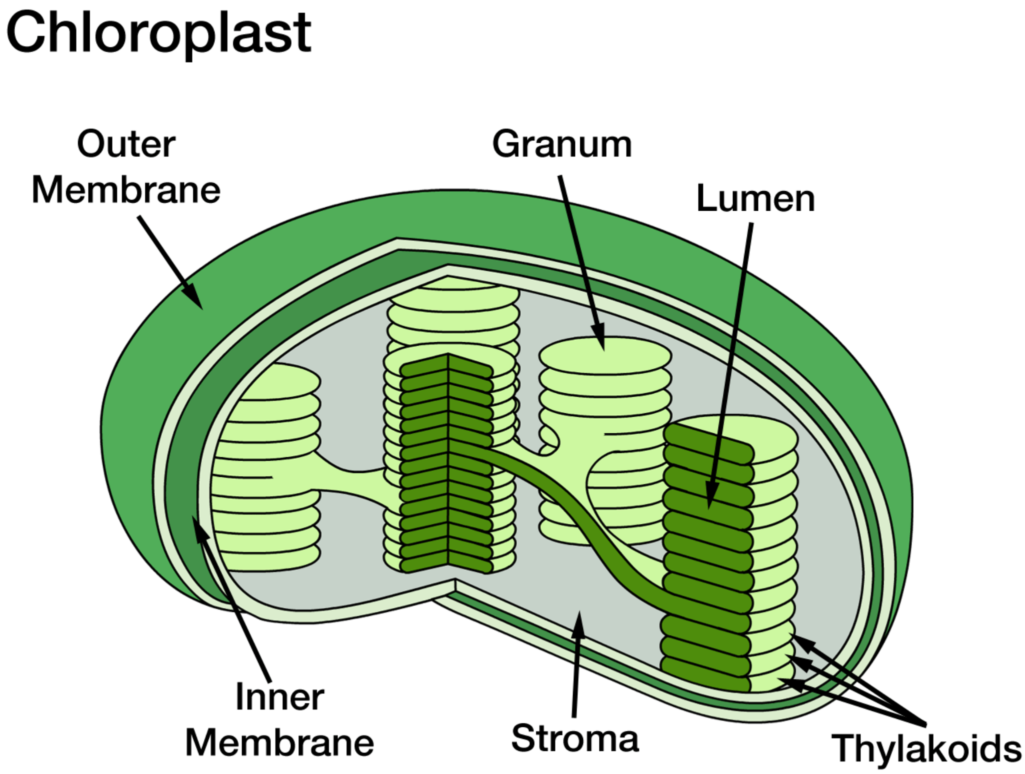
(b) Alcohol fermentation occurs in yeast.



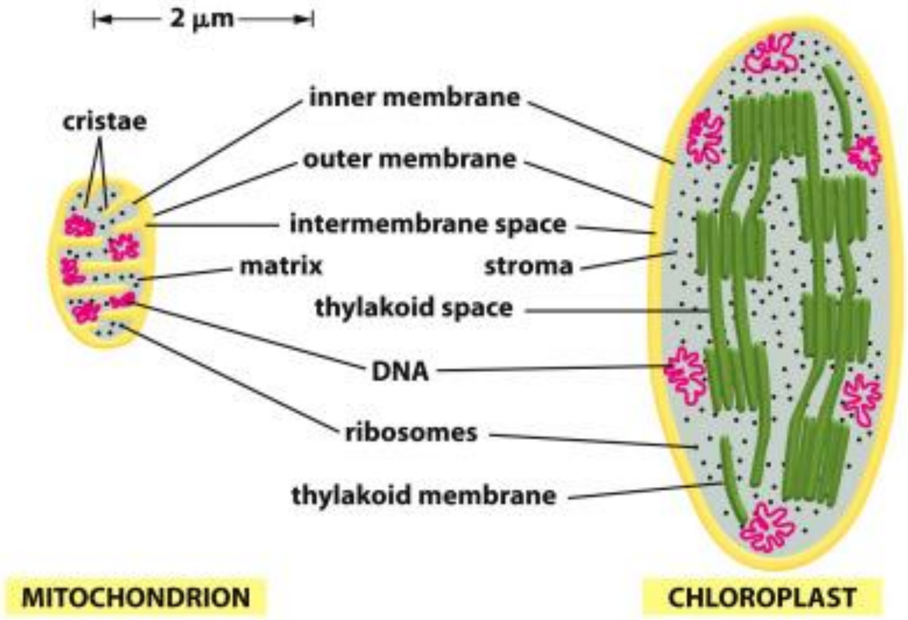
(a) Lactic acid fermentation occurs in humans.



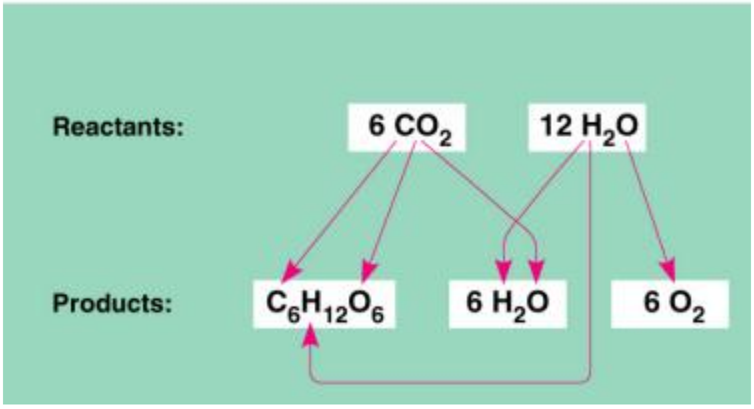
8. Photosynthesis

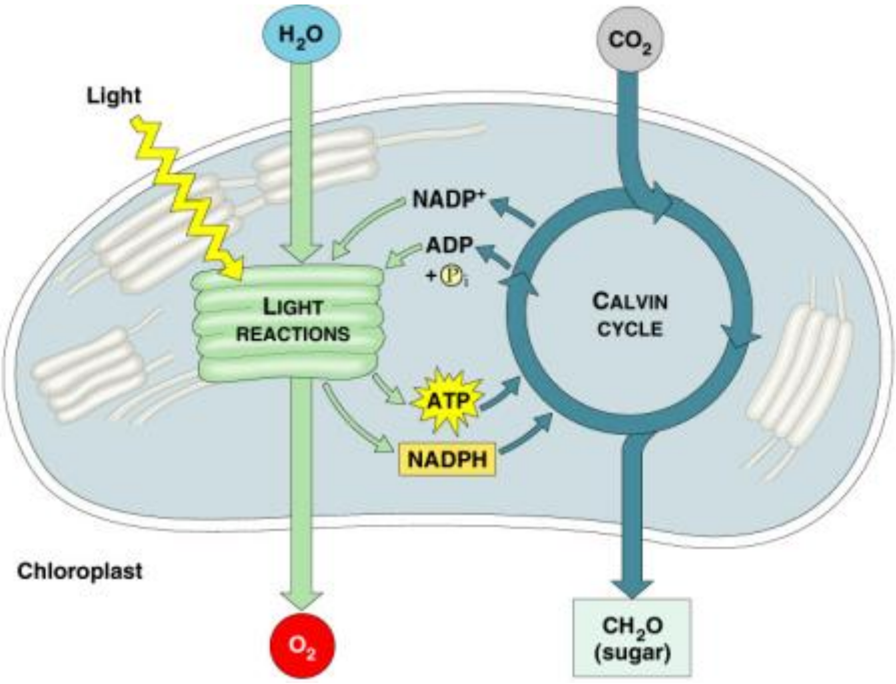


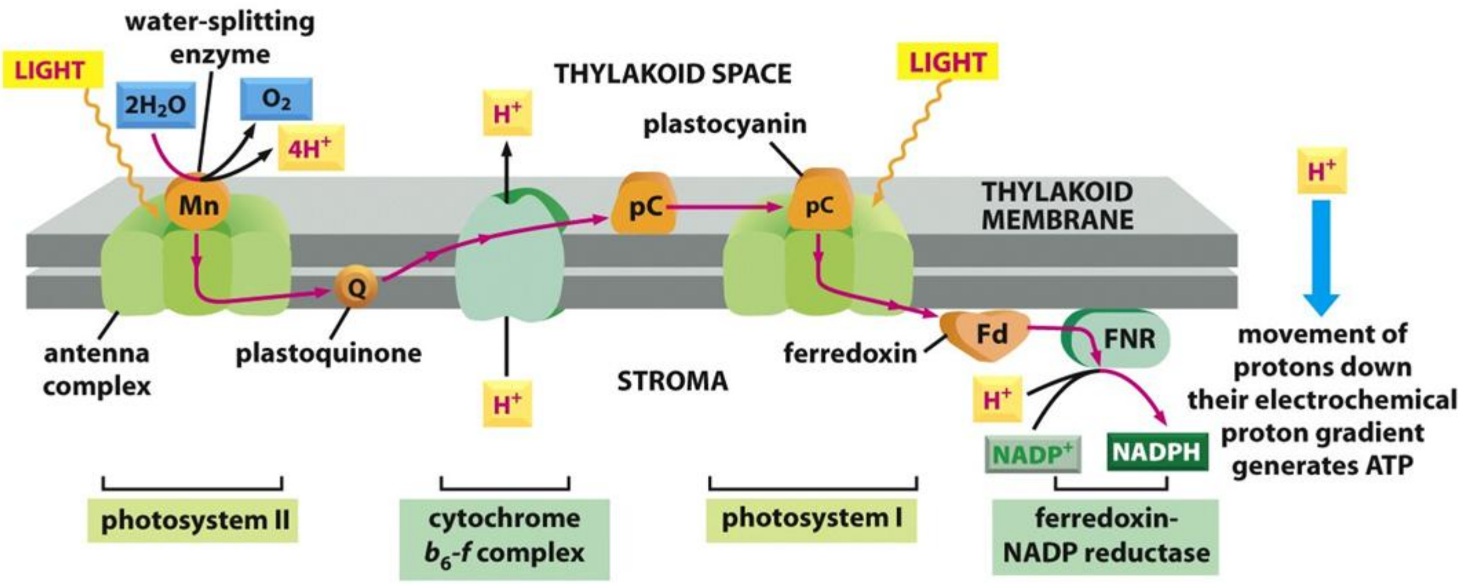
Structural similarities/differences

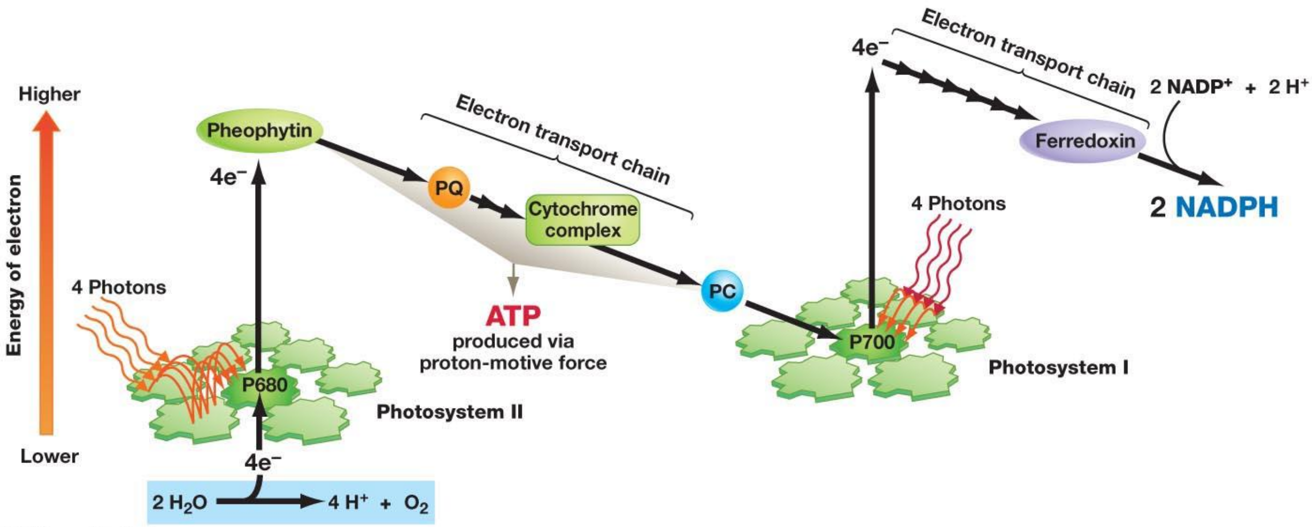


Key thing to note is that the evolved O_2 does NOT come from carbon dioxide!!

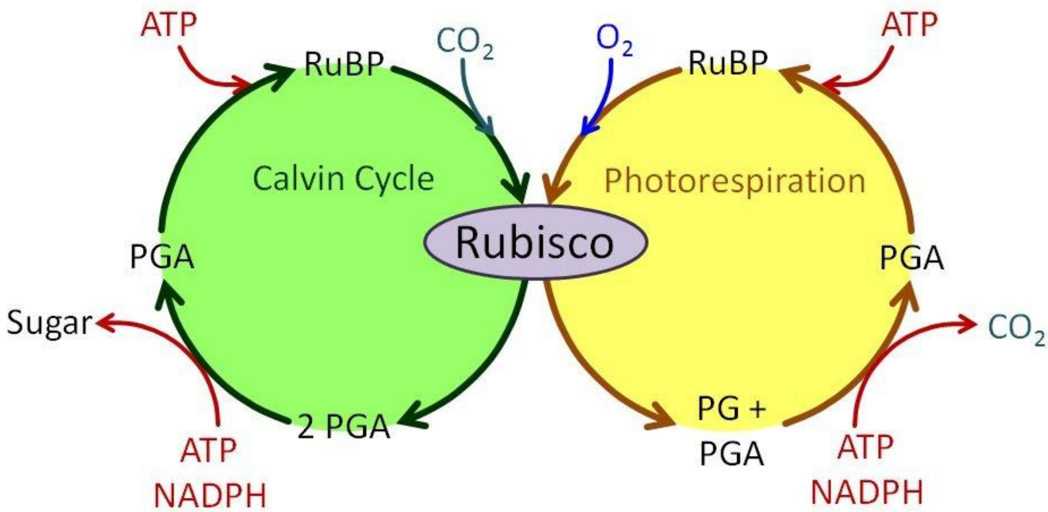




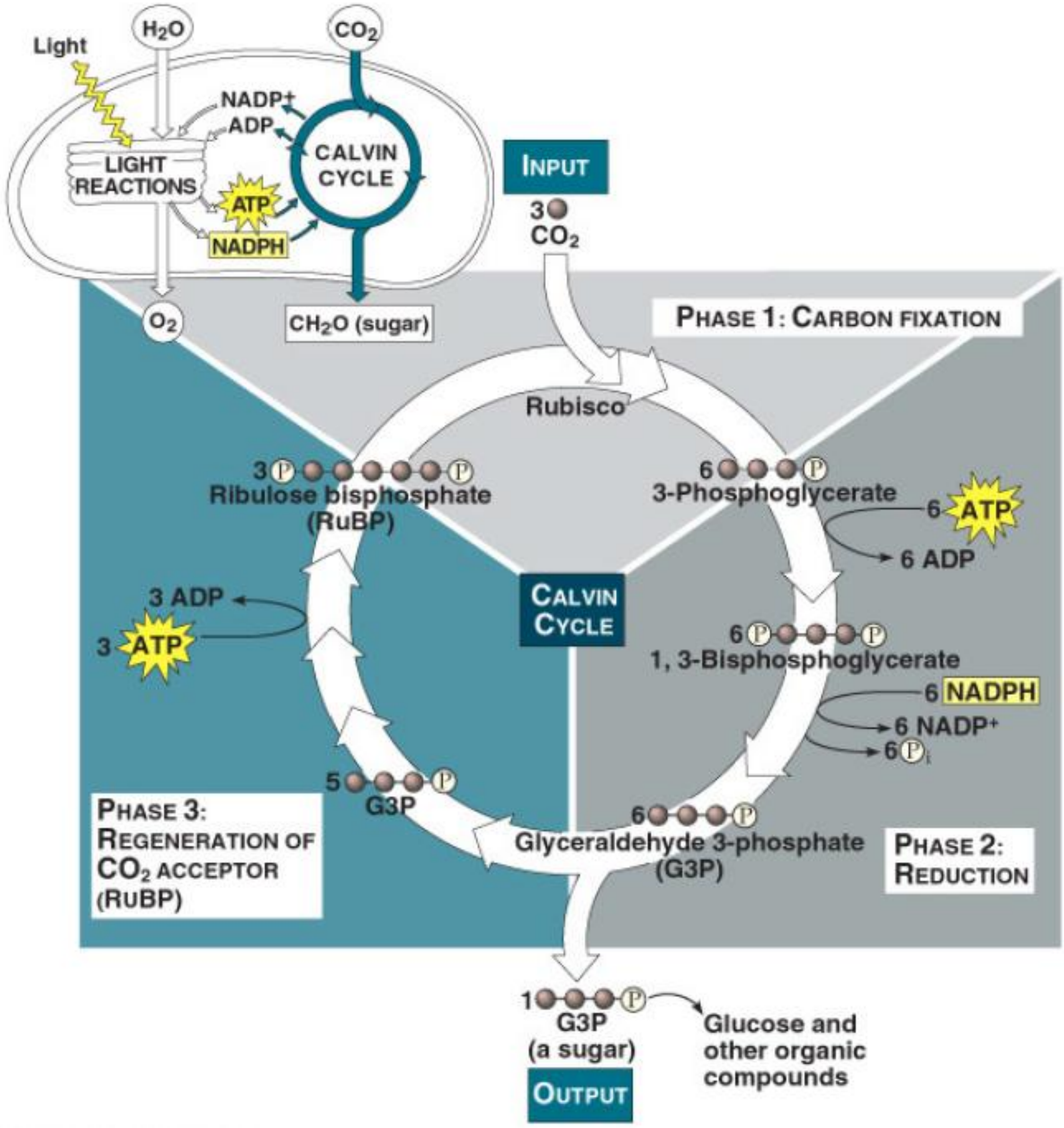




Higher
Energy of electron
Lower
Pheophytin
4e⁻
4 Photons
P680
Photosystem II
4e⁻
2 H2O → 4 H+ + O2
Electron transport chain
PQ
Cytochrome complex
ATP
produced via proton-motive force
PC
P700
Photosystem I
4 Photons
4e⁻
Electron transport chain
Ferredoxin
2 NADP+ + 2 H+
2 NADPH

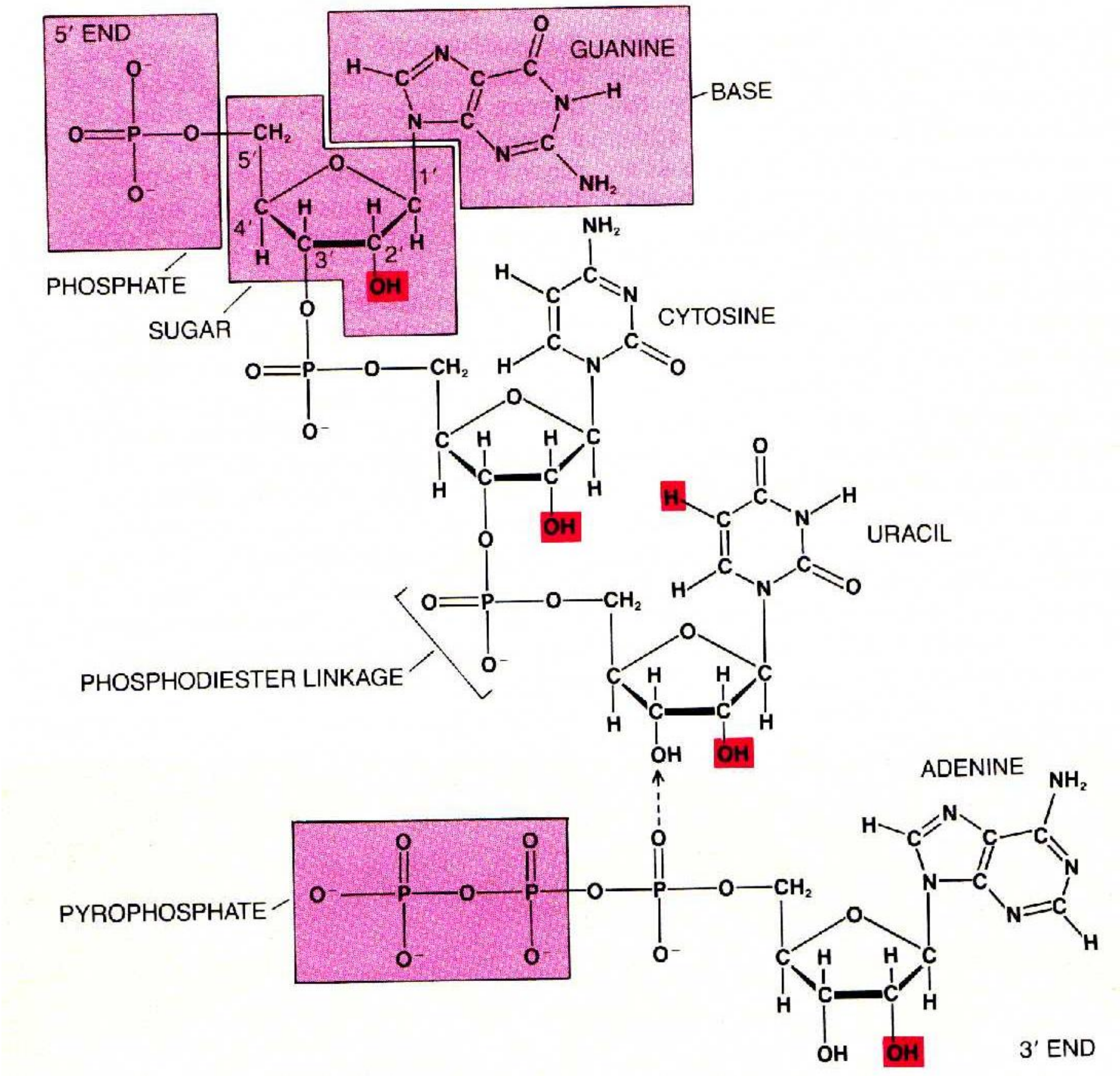


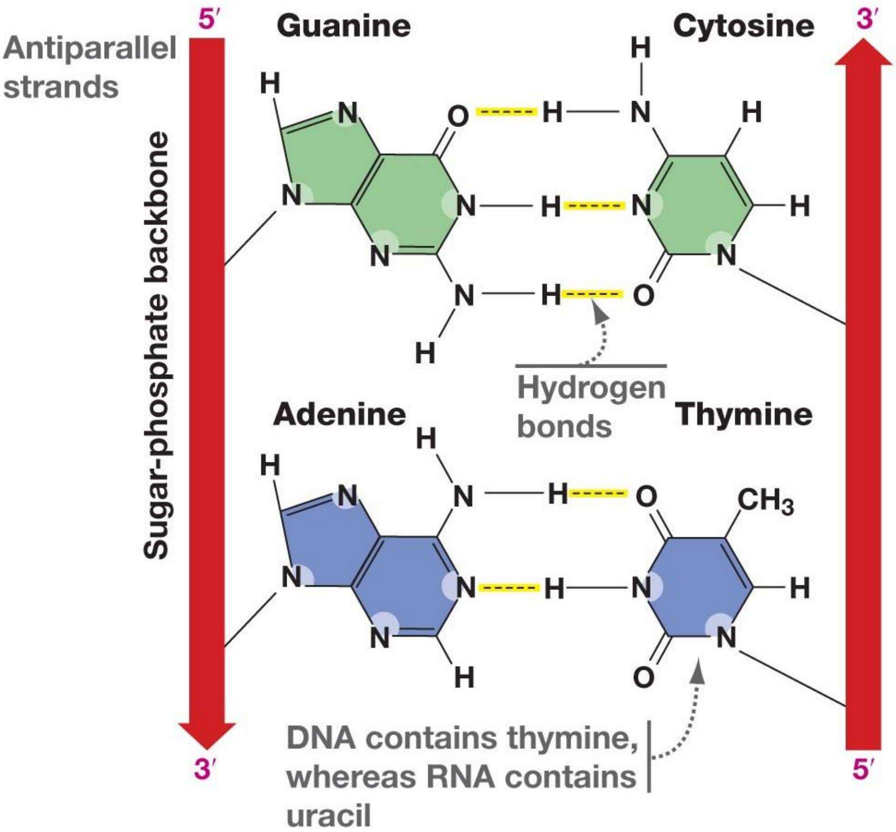
ATP
RuBP
CO2
Calvin Cycle
PGA
Sugar
2 PGA
ATP
NADPH
Rubisco
O2
RuBP
ATP
Photorespiration
PGA
CO2
PG +
PGA
ATP
NADPH

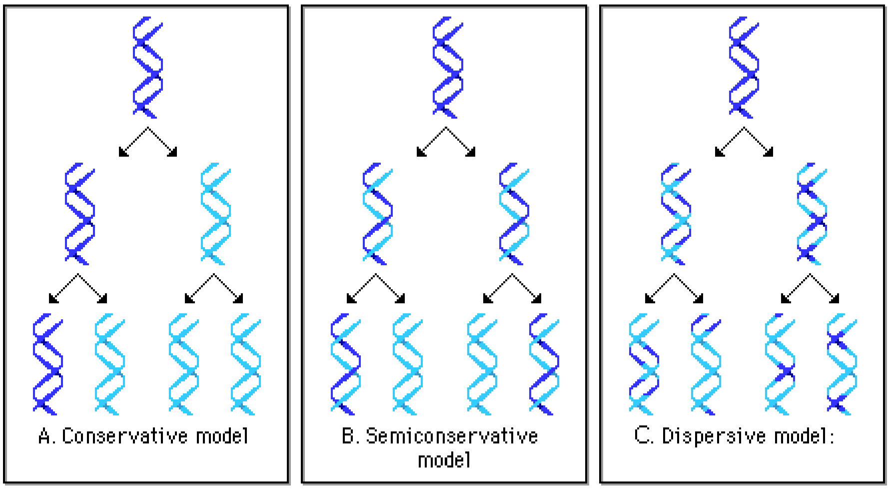


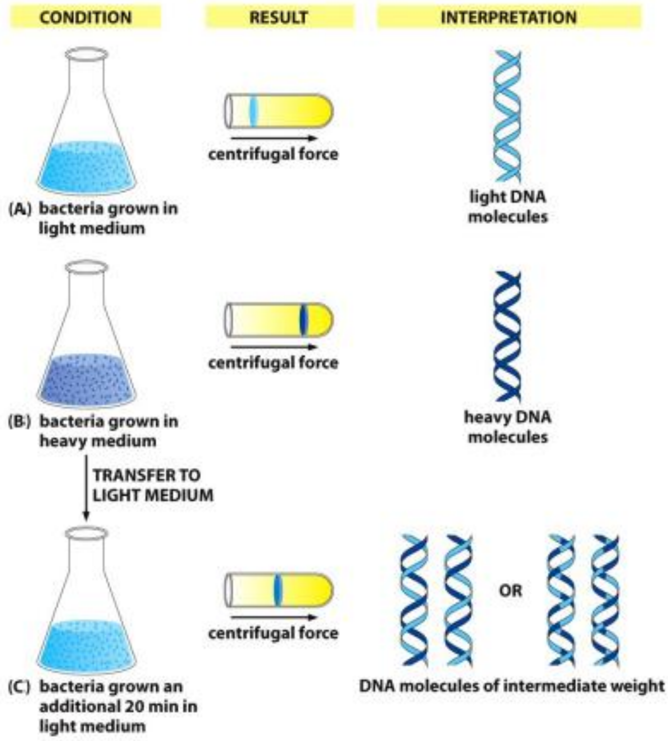
Light
H_2O
CO_2
NADP+
ADP
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
O_2
CH_2O (sugar)
INPUT
3
CO_2
PHASE 1: CARBON FIXATION
Rubisco
3
Ribulose bisphosphate (RuBP)
6
3-Phosphoglycerate
6 ATP
6 ADP
3 ADP
3 ATP
CALVIN CYCLE
6
1, 3-Bisphosphoglycerate
6 NADPH
6 NADP+
6 Pi
5
G3P
PHASE 3: REGENERATION OF CO_2 ACCEPTOR (RUBP)
6
Glyceraldehyde 3-phosphate (G3P)
PHASE 2: REDUCTION
1
G3P (a sugar)
OUTPUT
Glucose and other organic compounds

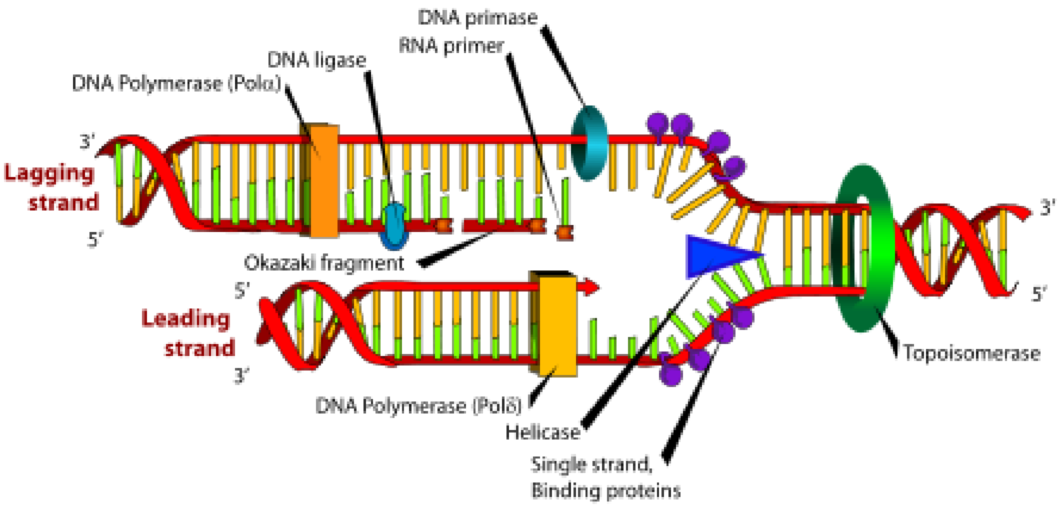
9. DNA Replication and Protein Synthesis

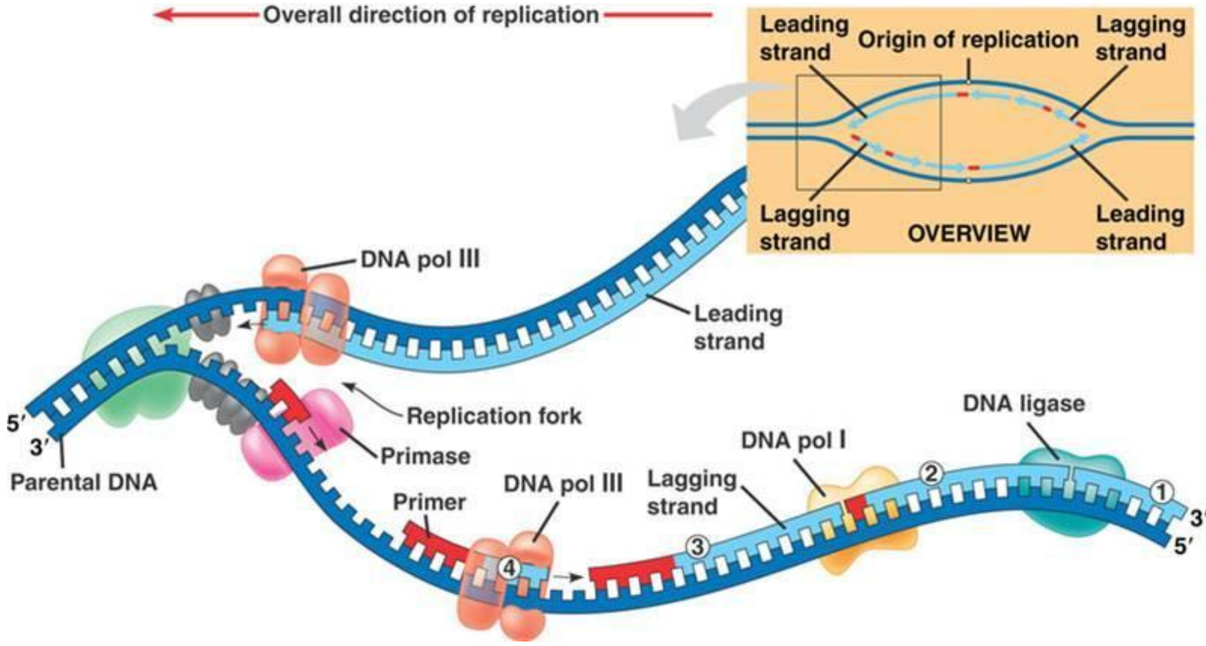


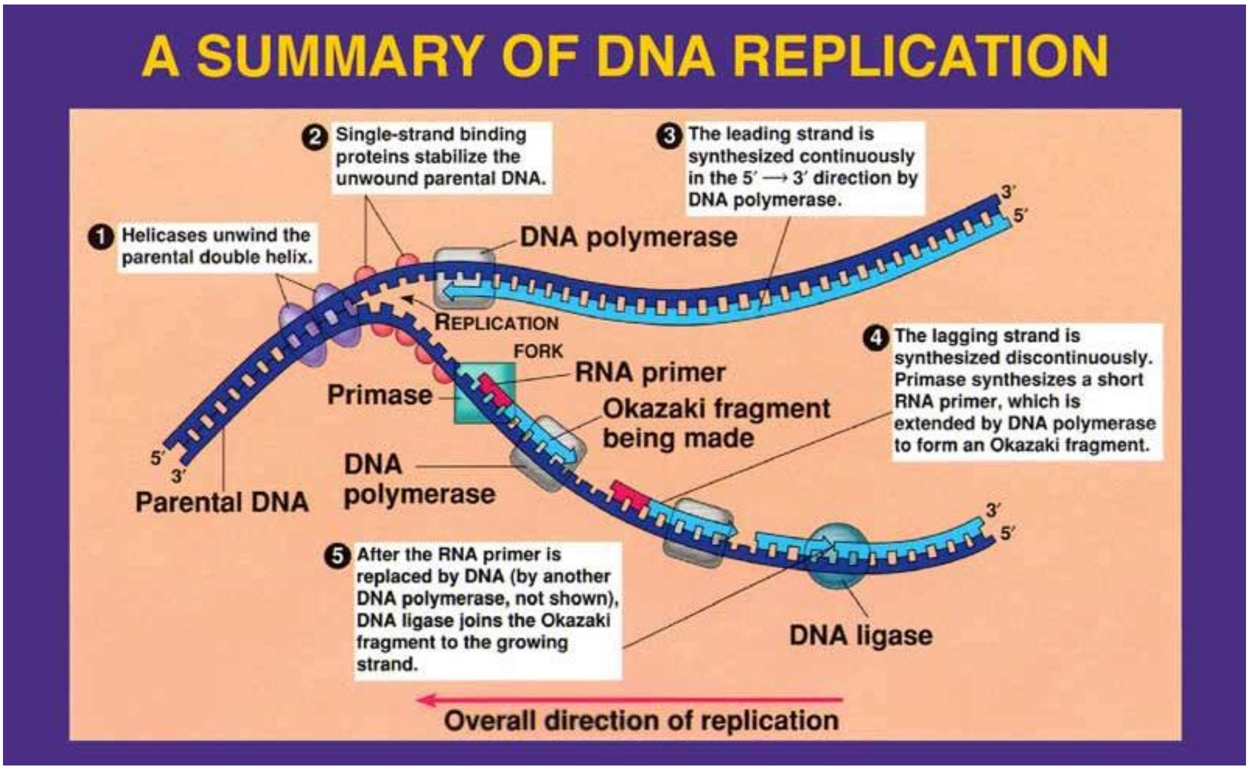



A. Conservative model
B. Semiconservative model
C. Dispersive model:


CONDITION
RESULT
INTERPRETATION
centrifugal force
(A) bacteria grown in light medium
light DNA molecules
centrifugal force
(B) bacteria grown in heavy medium
heavy DNA molecules
TRANSFER TO LIGHT MEDIUM
centrifugal force
(C) bacteria grown an additional 20 min in light medium
OR
DNA molecules of intermediate weight


DNA primase
RNA primer
DNA ligase
DNA Polymerase (Polα)
3'
Lagging strand
5'
Okazaki fragment
5'
Leading strand
3'
DNA Polymerase (Polδ)
Helicase
Single strand, Binding proteins
3'
5'
Topoisomerase

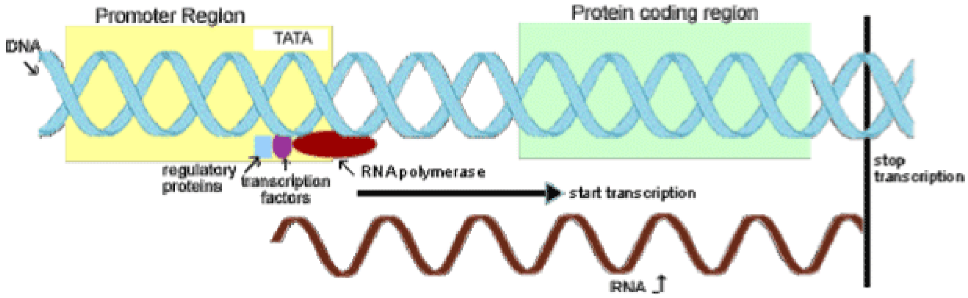


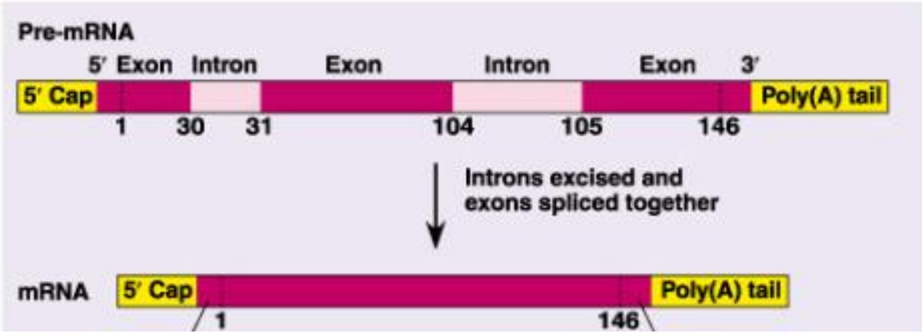


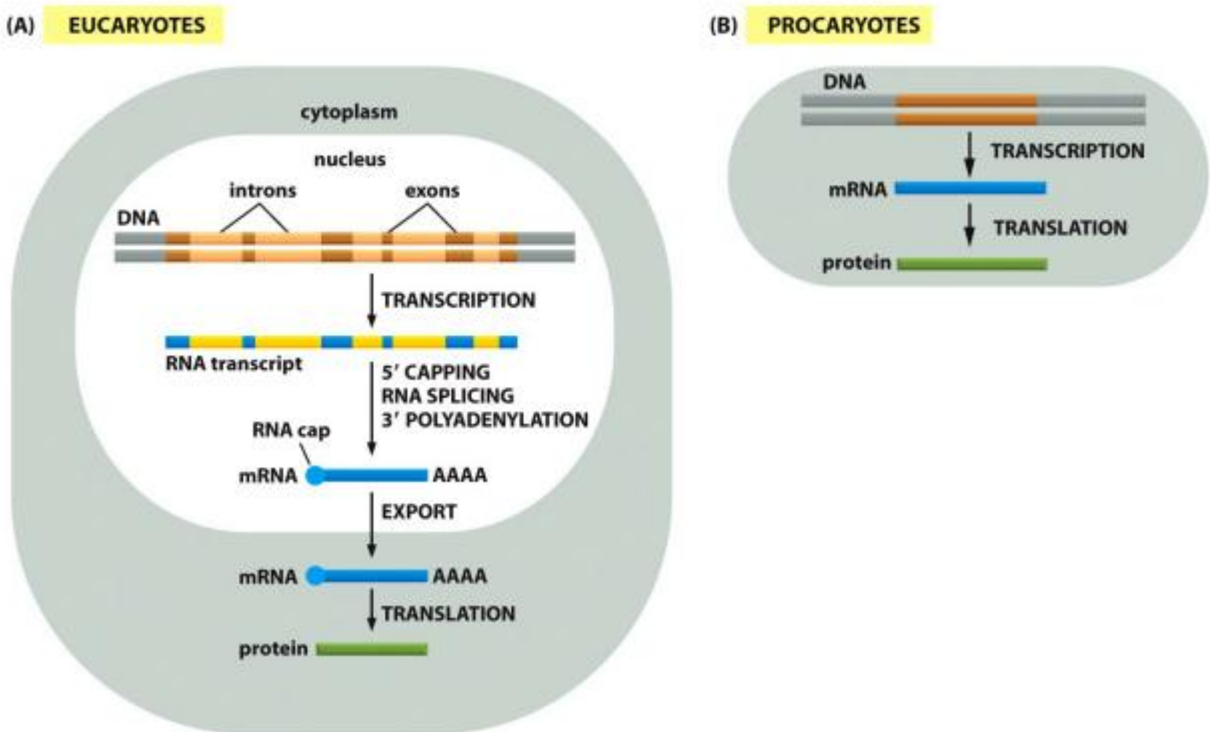
The Roles of Different Kinds of RNA

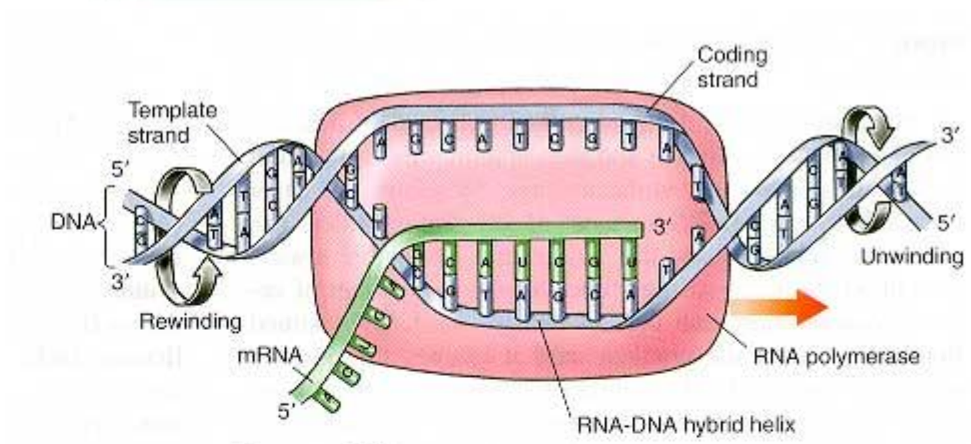
RNA Type	Size	Function
Transfer RNA	Small	Transports amino acids to site of protein synthesis
Ribosomal RNA	Several kinds—variable in size	Combines with proteins to form ribosomes, the site of protein synthesis
Messenger RNA	Variable	Directs amino acid sequence of proteins
Small nuclear RNA	Small	Processes initial mRNA to its mature form in eukaryotes
Small interfering RNA	Small	Affects gene expression; used by scientists to knock out a gene being studied
Micro RNA	Small	Affects gene expression; important in growth and development

Typical gene organization



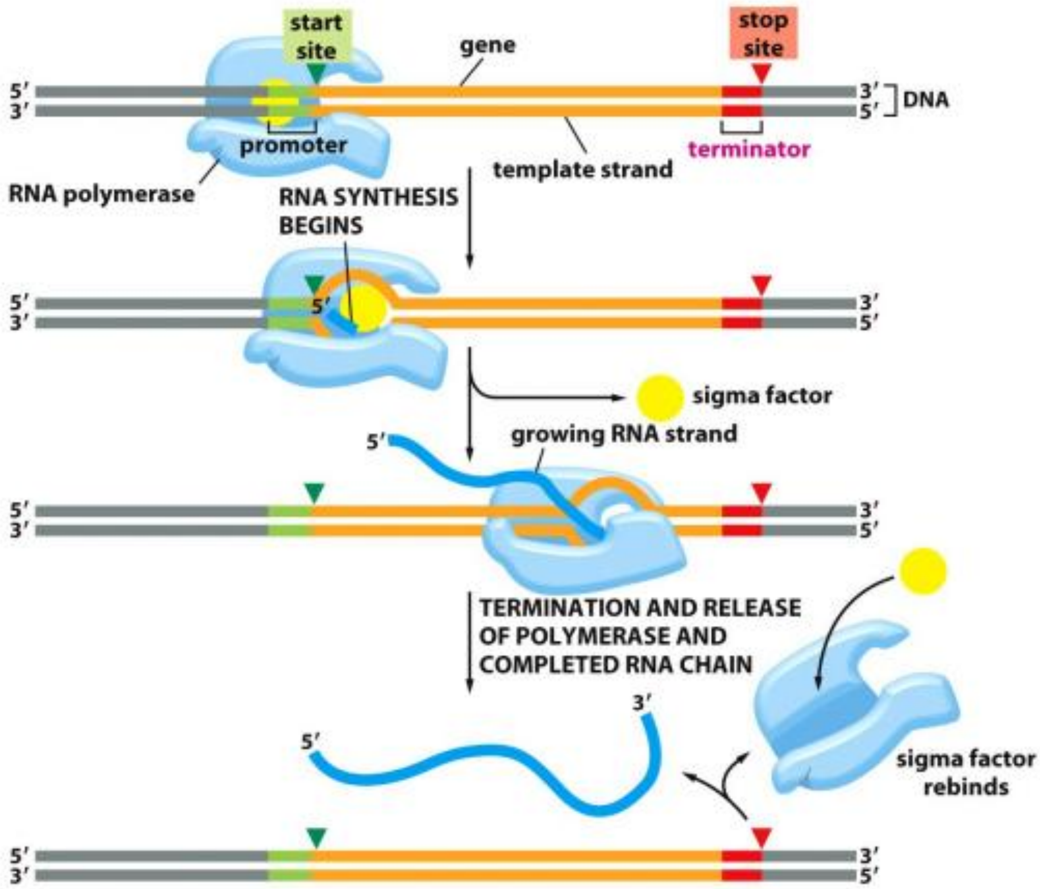






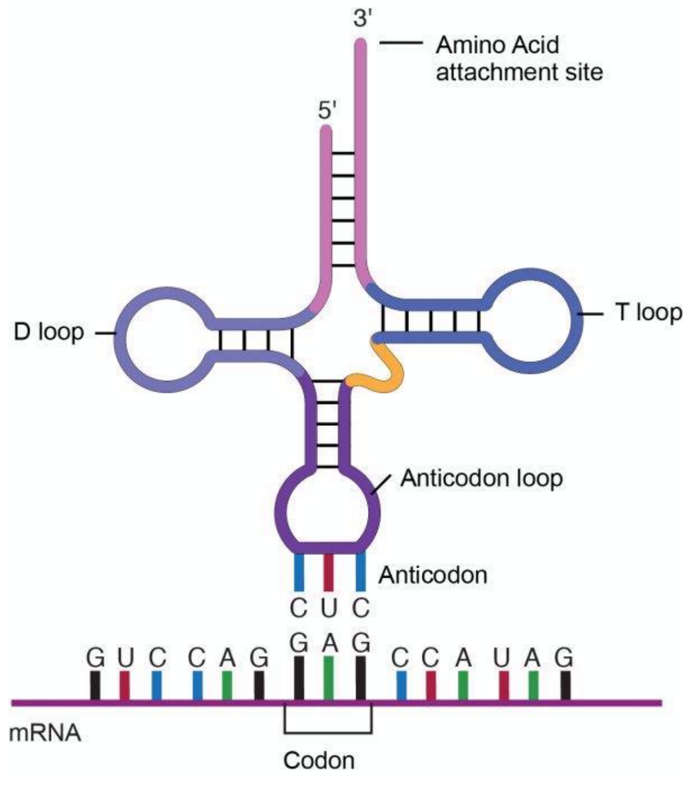
Transcription

One of the strands of DNA functions as a template on which nucleotide building blocks are assembled into mRNA by RNA polymerase as it moves down the DNA strand.

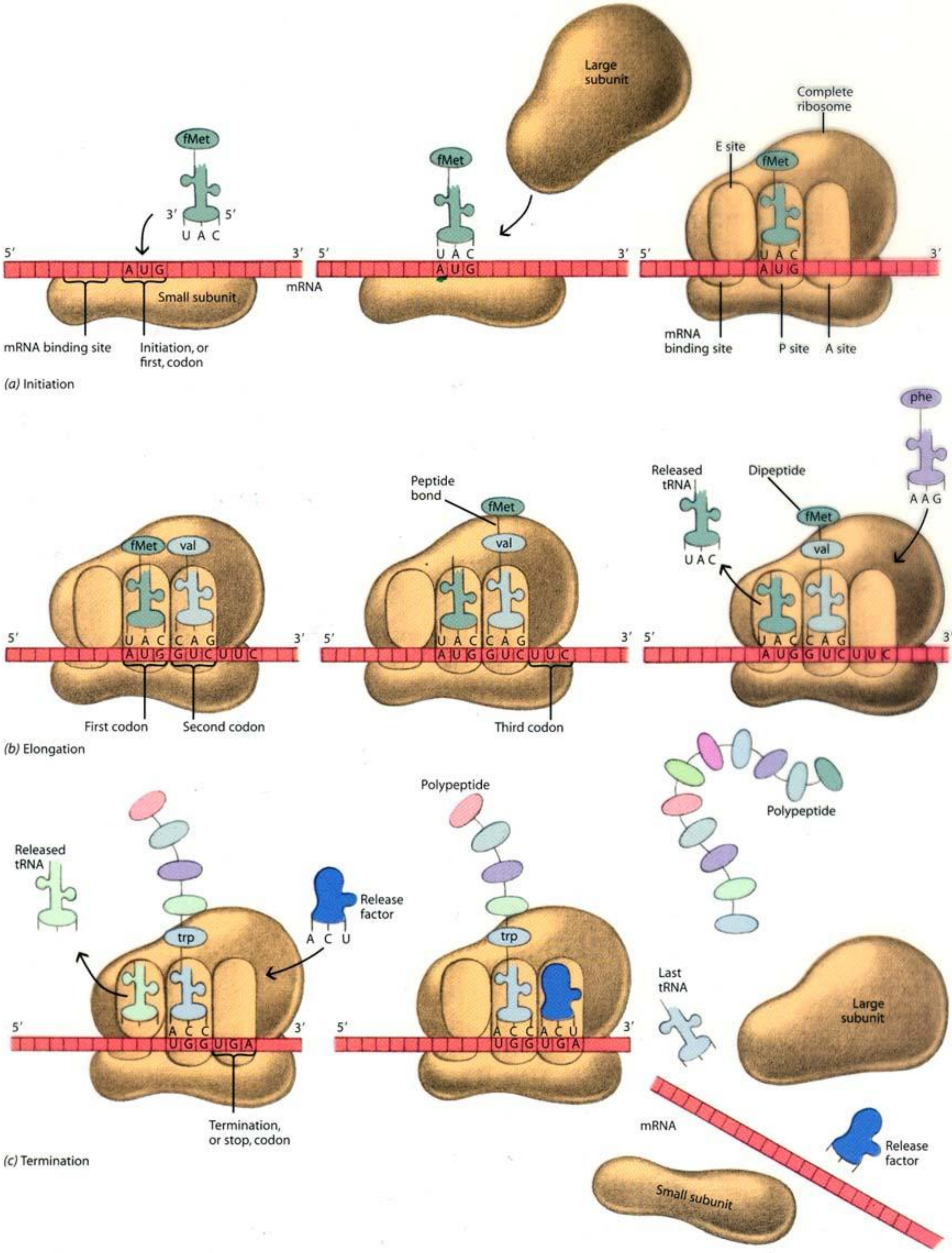


start site
gene
stop site
5′
3′
DNA
promoter
template strand
terminator
RNA polymerase
RNA SYNTHESIS BEGINS
sigma factor
growing RNA strand
TERMINATION AND RELEASE OF POLYMERASE AND COMPLETED RNA CHAIN
sigma factor rebinds

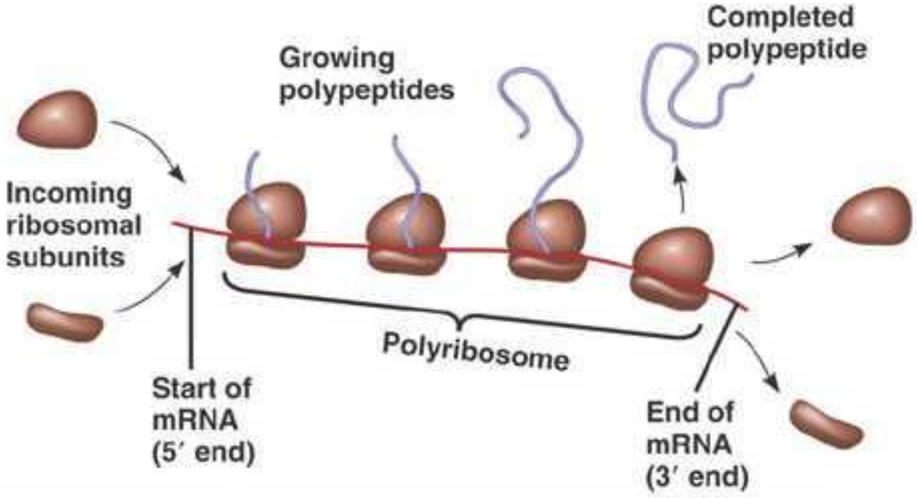
tRNA



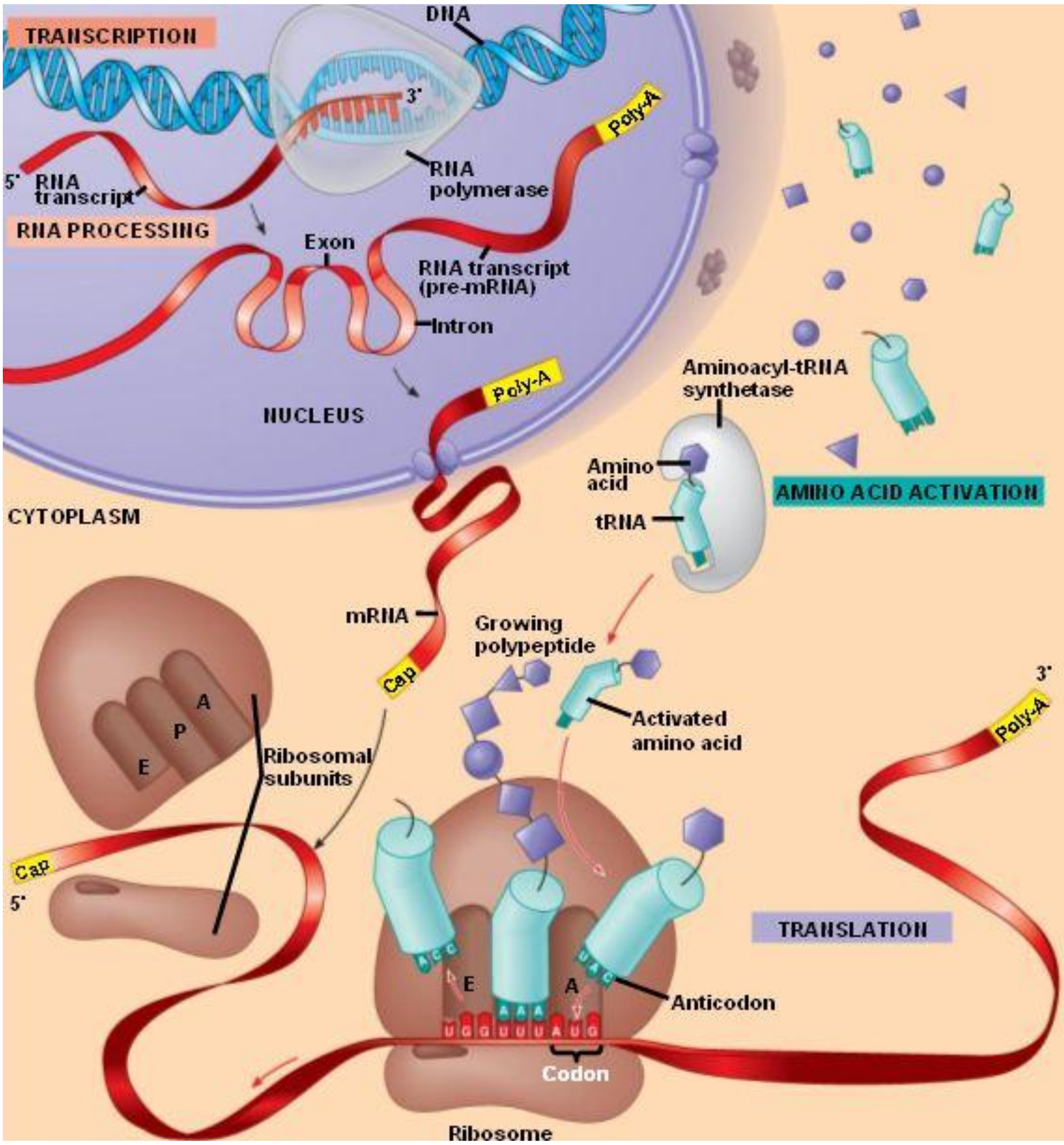
3′
Amino Acid attachment site
5′
D loop
T loop
Anticodon loop
Anticodon
C U C
G A G
G U C C A G G A G C C A U A G
mRNA
Codon



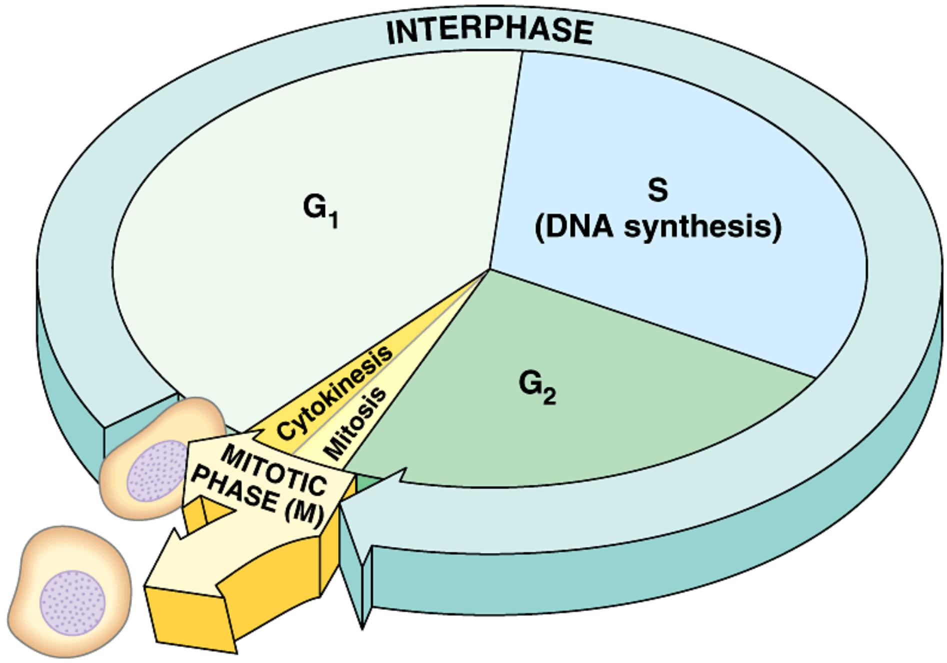
Large subunit
Complete ribosome
fMet
3′
5′
U A C
A U G
5′
3′
mRNA
Small subunit
mRNA binding site
Initiation, or first, codon
E site
P site
A site
mRNA binding site
(a) Initiation
val
phe
A A G
Peptide bond
Released tRNA
Dipeptide
C A G
G U C U U C
First codon
Second codon
Third codon
(b) Elongation
Polypeptide
Released tRNA
trp
Release factor
A C U
A C C
U G G U G A
Termination, or stop, codon
Last tRNA
mRNA
Small subunit
(c) Termination

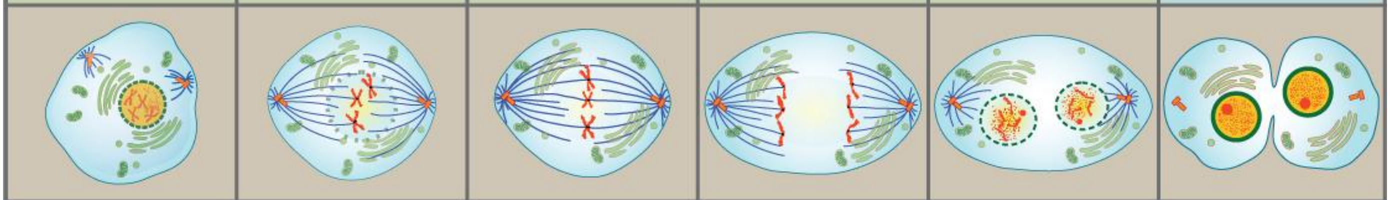


(a) An mRNA molecule is generally translated simultaneously by several ribosomes in clusters called polyribosomes.

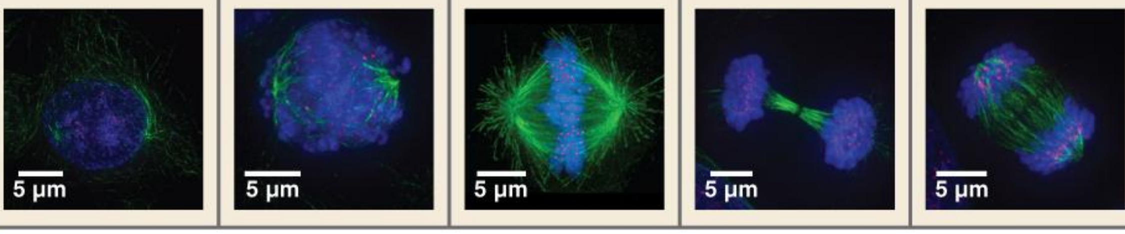


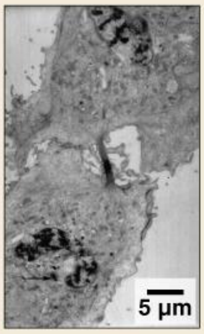
10. Cell Division



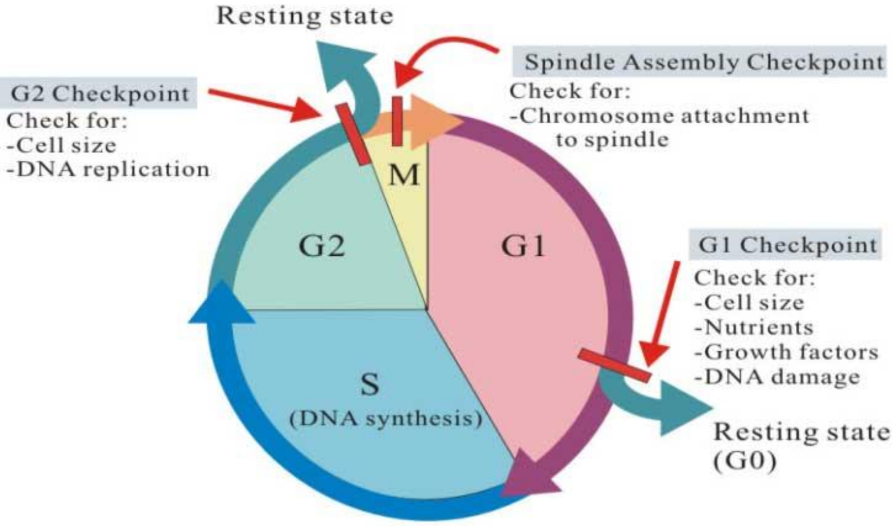


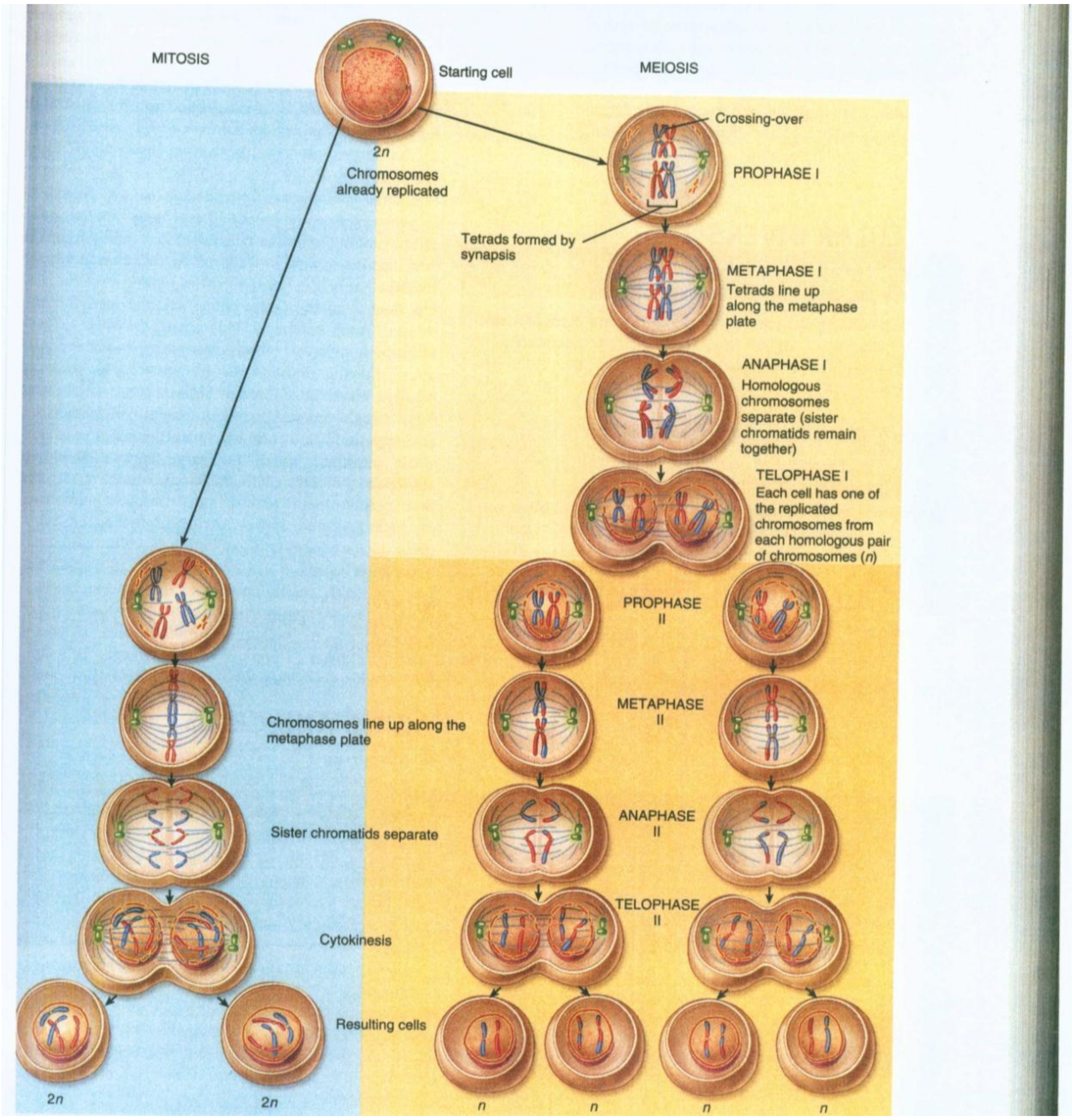
Prophase	Prometaphase	Metaphase	Anaphase	Telophase	Cytokinesis
• Chromosomes condense and become visible • Spindle fibers emerge from the centrosomes • Nuclear envelope breaks down • Centrosomes move toward opposite poles	• Chromosomes continue to condense • Kinetochores appear at the centromeres • Mitotic spindle microtubules attach to kinetochores	• Chromosomes are lined up at the metaphase plate • Each sister chromatid is attached to a spindle fiber originating from opposite poles	• Centromeres split in two • Sister chromatids (now called chromosomes) are pulled toward opposite poles • Certain spindle fibers begin to elongate the cell	• Chromosomes arrive at opposite poles and begin to decondense • Nuclear envelope material surrounds each set of chromosomes • The mitotic spindle breaks down • Spindle fibers continue to push poles apart	• Animal cells: a cleavage furrow separates the daughter cells • Plant cells: a cell plate, the precursor to a new cell wall, separates the daughter cells

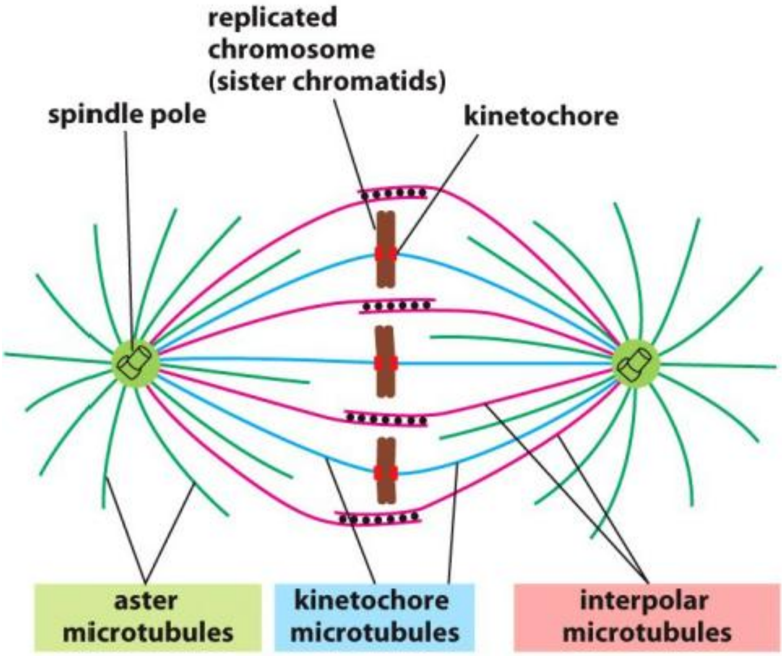


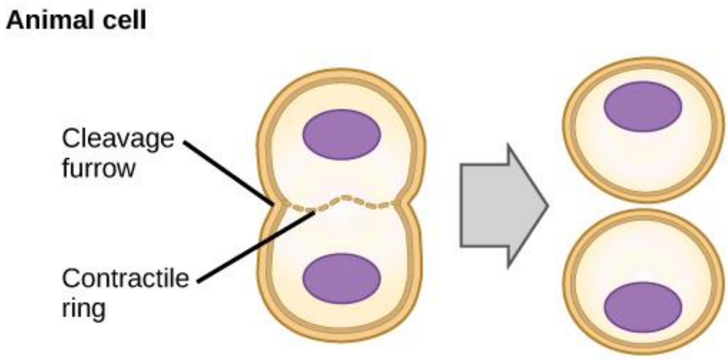


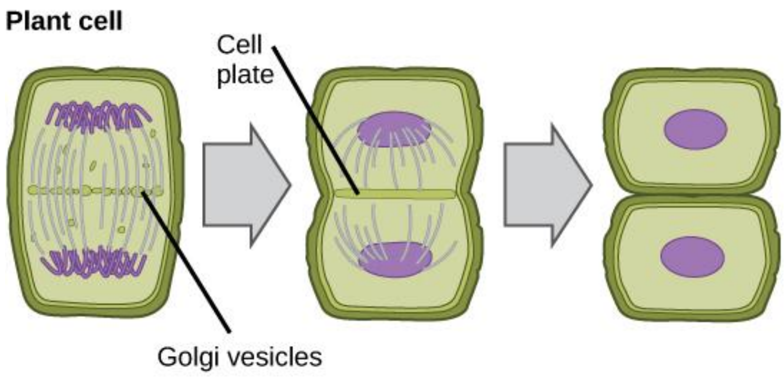
MITOSIS

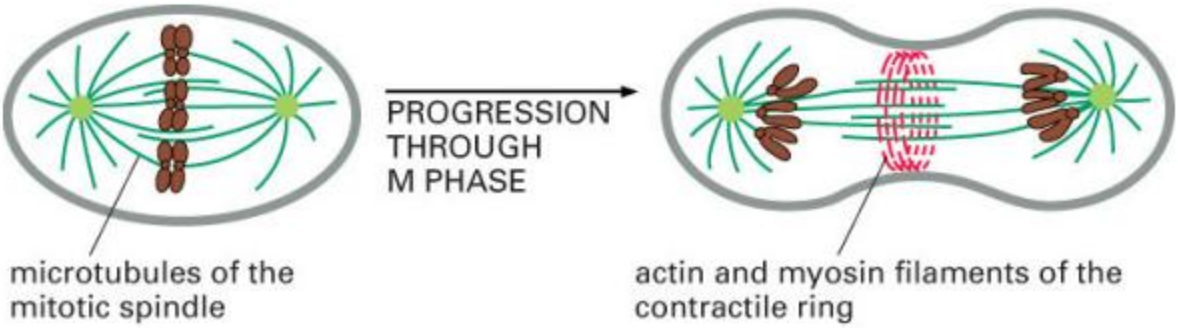

Resting state
Spindle Assembly Checkpoint
Check for:
-Chromosome attachment to spindle
G2 Checkpoint
Check for:
-Cell size
-DNA replication
M
G2
G1
G1 Checkpoint
Check for:
-Cell size
-Nutrients
-Growth factors
-DNA damage
S
(DNA synthesis)
Resting state
(G0)


MITOSIS
Starting cell
MEIOSIS
Crossing-over
2n
Chromosomes already replicated
PROPHASE I
Tetrads formed by synapsis
METAPHASE I
Tetrads line up along the metaphase plate
ANAPHASE I
Homologous chromosomes separate (sister chromatids remain together)
TELOPHASE I
Each cell has one of the replicated chromosomes from each homologous pair of chromosomes (n)
PROPHASE II
METAPHASE II
Chromosomes line up along the metaphase plate
ANAPHASE II
Sister chromatids separate
TELOPHASE II
Cytokinesis
Resulting cells
2n
2n
n
n
n
n


replicated
chromosome
(sister chromatids)
spindle pole
kinetochore
aster
microtubules
kinetochore
microtubules
interpolar
microtubules


Animal cell
Cleavage
furrow
Contractile
ring


Plant cell
Cell
plate
Golgi vesicles


PROGRESSION
THROUGH
M PHASE
microtubules of the
mitotic spindle
actin and myosin filaments of the
contractile ring