Biology 101

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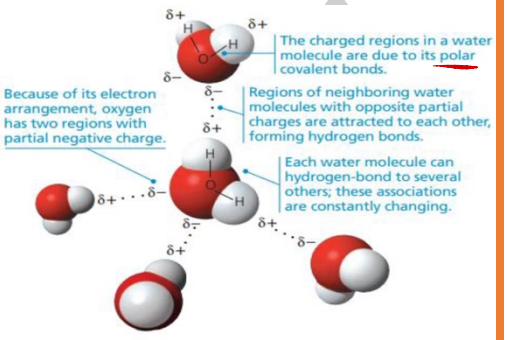
Chapter 3:

3.1: water molecule

- Polar covalent bonds in water molecules result in hydrogen bonding.
- H2O is a polar molecule **because** it is shaped like a wide V and Oxygen is more electronegative than hydrogen.
- Different water molecules are held together by **Hydrogen bonds**.
- These are formed by the attraction between the partially positive hydrogen of one molecule and the partially negative oxygen in the nearby molecule.



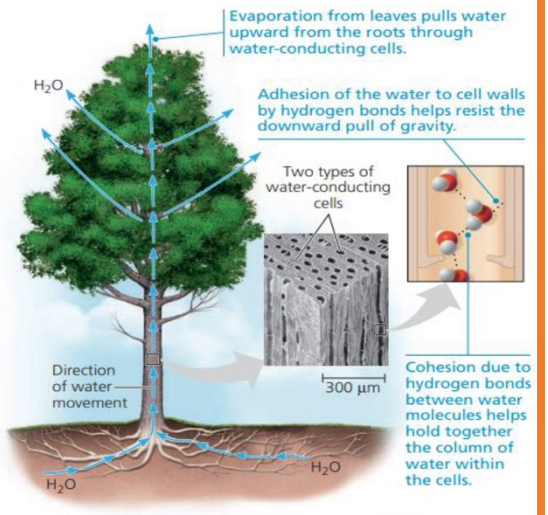
- in the liquid form, hydrogen bonds are relatively weak.
- They form, break, and re-form with great frequency.
- each water molecule can form hydrogen bonds with four other water molecules.

3.2: properties of water

hydrogen bonds are the reason in the extraordinary properties of water.

a) Cohesive behavior:

- Cohesion: the phenomenon of Hydrogen bonds holding water molecules together.
- Adhesion: the phenomenon of Hydrogen bonds holding water molecules to other substance.
- The application for these two phenomena is the transport of water and dissolved nutrients against gravity in plants which requires water to evaporate from the leaves then it's transported through a network of water-conducting cells.



Polar:	قطبي	Partially:	جزئيا	Surface tension:	توتر سطحي
Electronegativity:	كهرسلبية	Cohesion:	تماسك	Hydrogen bond:	رابطة هيدروجينية
Covalent bond:	رابطة تساهمية	adhesion:	تلاصق		

- surface tension: a measure of how difficult it is to stretch or break the surface of a liquid.
- Water has high surface tension, resulting from the collective strength of its **hydrogen bonds**.

b) Moderation of temperature

- Water absorb heat from air that is warmer and release the stored heat to the air that is cooler.
- Water is effective as a heat bank because it can absorb or release a relatively large amount of heat with only a slight change in its own temperature.

Some definitions:

- Kinetic energy: is the energy of motion.
- atoms and molecules are always moving randomly so they have kinetic energy that is called Thermal energy.
- The faster a molecule moves, the greater its kinetic energy.
- Temperature: the average kinetic energy of the molecules in a body of matter, regardless of volume.
- Thermal energy: the total kinetic energy in a body so it depends on volume.
- Ex: coffee pot vs swimming pool
- Heat: the transfer of thermal energy between different objects.
- Thermal energy passes from the warmer object to the cooler object until the two have the same temperature.
- The unit of heat is called calorie (Cal): amount of heat it takes to change the temperature of 1 g of water by 1°C.
- kilocalorie kcal= (1,000 Cal), Another unit is Joule (J)= 0.239 Cal // 1 Cal=4.2 J.
- The specific heat of a substance: the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1°C.
- The specific heat of water is high (1 cal) because of the hydrogen bonds.
- Water resists changing its temperature making it a good heat bank.
- Water also has high Heat of vaporization which is: the quantity of heat a liquid must absorb for 1 g of it to be converted from the liquid to the gaseous state.

	Swimming pool	Coffee maker
Temperature	low	high
Thermal energy	High	Low
Volume	Large	Small

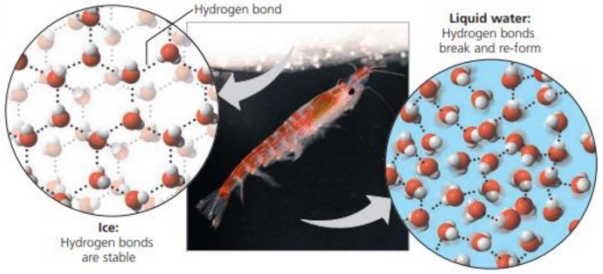
Applications:

- stabilize ocean temperatures, creating a favorable environment for marine life.
  moderate air temperatures in coastal areas.
- organisms are better able to resist changes in their temperature.
- Evaporative cooling: water evaporation cools down the surface beneath it.
  contributes to the stability of temperature in lakes and ponds.
  prevents organisms from overheating (sweat cools you down).

Kinetic energy:	طاقة حركية	Heat of vaporization:	حرارة التبخير
Thermal energy:	طاقة حرارية	Evaporative cooling:	التبريد بالتبخير
Specific Heat:	الحرارة النوعية	organism	كائن حي

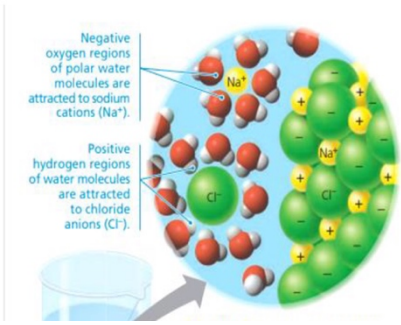
c) Expansion upon freezing

- Materials usually shrink and become denser when they solidify.
- water expands and becomes less dense (10 % less dense) due to hydrogen bonds.
- Above 4°C: water behaves like other liquids.
- At 4°C: water is the most dense.
- 4°C to 0°C: hydrogen bonds become stronger.
- At 0°C: molecules become locked into a crystalline form.
- The floating ice insulates the liquid water below, preventing it from freezing and allowing life to exist under the frozen surface.



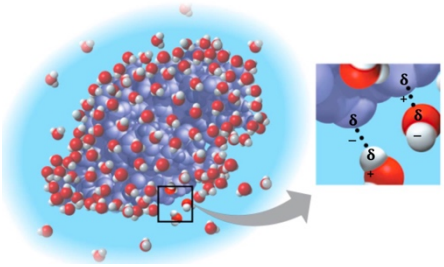
Applications:

- Allows Marine life to exist.
- Ice provides a solid habitat for some animals. (Threatened by global warming)



d) Water as a solvent

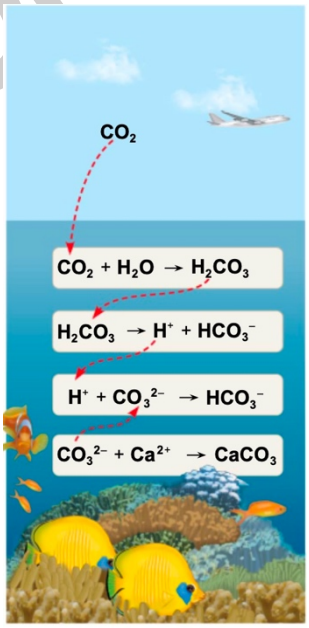
- Solution: A liquid that is a completely homogeneous mixture of two or more substances.
- Solvent: The dissolving agent of a solution
- Solute: the substance that is dissolved
- Aqueous solution: when water is the solvent.
- Because water is Polar; it is a very versatile solvent.
- partial charges in water molecules become attracted to each other due to their opposite charges.
- Hydration shell: water molecules surround the individual dissolved ions.



- Ionic, and non-ionic polar molecules (sugar) and large molecules as proteins can dissolve in water.
- Hydrophilic substances: have affinity for water (ionic and polar substances).
- Some hydrophilic substances don't dissolve in water like cotton which is made from cellulose sugar.
- Hydrophobic substances: do not have affinity for water because they cannot form hydrogen bonds. (non-ionic and nonpolar substances)

Solution:	محلول	Solute	مذاب
homogeneous	متجانس	Aqueous	مائي
Solvent	مذيب	versatile	متعدد الاستعمالات

3.3: Acidification:



- 25% of human-generated CO_2 is absorbed by the oceans.
- when CO_2 dissolves in seawater, it reacts with water to form carbonic acid, which lowers ocean pH. This process, known as ocean acidification.
- carbonic acid provides additional protons that react with carbonate ion (CO_3^{-2}) forming HCO_3^-.
- this decreases CO_3^{-2} levels that's needed for the production ($CaCO_3$) by many marine organisms to build their shells (calcification).

Past papers:

Q1: What bond between water molecules make them stick together?

A. Hydrogen bonds
B. Covalent bonds
C. Polar covalent bonds
D. Vander Waals forces
E. None of the above

Q2: Lakes and oceans, do not quickly fluctuate (change) in temperature. What is the reason for this phenomenon?

A. Water is an acid
B. Water is a versatile solvent
C. Water has a high specific heat
D. Water acts as a buffer
E. All of the above

Q3: Specific heat of water molecule contribute to the following, except:

A. Organisms resist changes in body temperature
B. Ice floating on top of liquid water
C. Stabilize Ocean temperature
D. Water heat of vaporization
E. None of the above

Q4: In water molecule, the atom in which electrons spend more time will have a …… charge, and the atom around which the electrons spend the least time will have ……. charge.

A. slightly negative, slightly positive
B. only positive charge
C. only negative charge
D. neutral charge
E. None of the above

Q5: The high heat capacity (specific heat) of water allows it to:

A. form additional hydrogen bonds
B. absorb large amounts of heat energy before the temperature changes
C. boil at higher temperatures than many liquids
D. B and C
E. None of the above

Q6: Oil does not dissolve in water because

A. Oil is a liquid
B. Oil is more dense than water
C. Oil molecules are non-polar
D. Oil is hydrophilic
E. None of the above

Q7: What is the property of water that help in transport of water against gravity from the roots in plants?

A. cohesion alone
B. adhesion alone
C. specific heat
D. adhesion and cohesion
E. water expansion

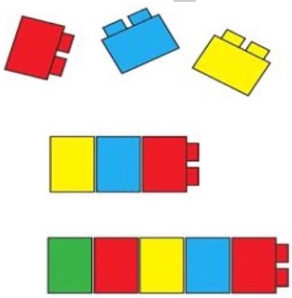
Q8: The high specific heat of water is responsible for the following, except:

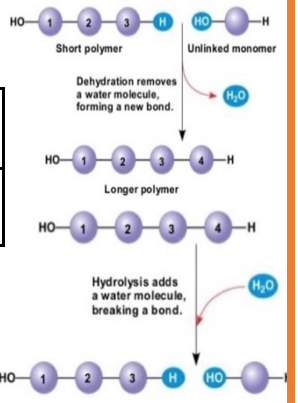
A. helps moderate earth's climate
B. stabilizes ocean temperature
C. enables organisms to resist changes in their own temperature
D. large amount of heat is required to raise the temperature of water
E. hydrogen bond formation between water molecules

chapter 5:

5.1: Macromolecules and Polymers

- Biological molecules: Carbohydrates Lipids Proteins Nucleic Acids
- Polymer: large molecule consisting of similar units linked by covalent bonds. (Macromolecules)
- They include the Biological molecules except lipids.
- Monomers: the repeating units that make a polymer.
- Polymers are diverse because of the monomer's: Number / Type / Order
- Polymerization: building polymers by covalently binding molecules to each other with the loss of a water molecule. A process called **Dehydration**
- Polymers are disassembled to monomers by adding a molecule of water (**hydrolysis**)
- **# Of H2O to breakdown a polymer = # of monomers -1**



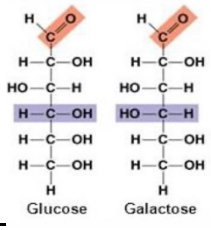


Dehydration	Build large molecules	Removing water	Spend energy	(photosynthesis)
Hydrolysis	Breakdown large molecules	Adding water	Produce energy	Cellular respiration

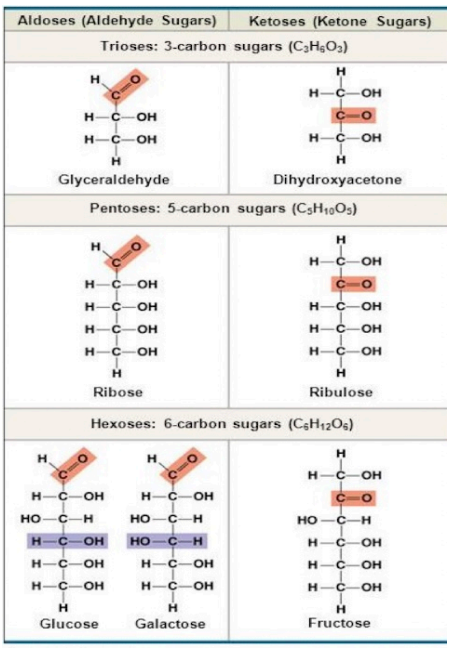
5.2: Carbohydrates

a) Monosaccharides:

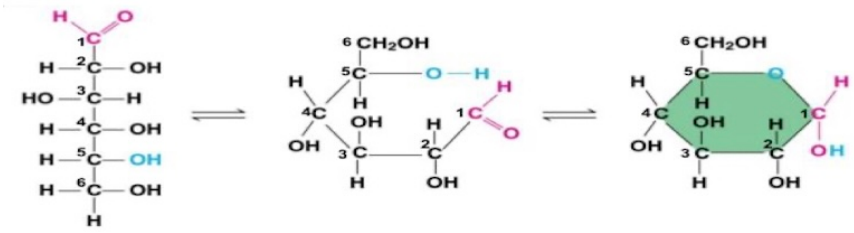
- molecular formula: multiples of CH_2O
- glucose is the most common ($C_6H_{12}O_6$)
- have a carbonyl (C=O) and hydroxyl groups (OH).
- Classification:

(C=O) location	Number of carbons	Asymmetric carbon
Aldose	Hexose (6)	
Ketose	Pentose (5)	
	Triose (3)	

- asymmetric carbon: is a carbon attached to 4 different atoms or group of atoms.
- In aqueous solution, glucose molecules as well as most other 5 and 6 carbon sugars form rings.



- the ring structure forms when the aldehyde group (at C1) reacts with the oxygen of the hydroxyl group attached to (C5).
- **Carbon number 1: below= alpha (α) / above= beta (β)**



Functions:

1. Nutrients for cells.
2. Raw material for synthesis of other materials.

b) Disaccharides:

- two monosaccharides joined by a covalent bond through dehydration reaction. (Glycosidic linkage)

Sugar	Components	Type of Glycosidic linkage
Maltose (Malt Sugar)	Glucose+ Glucose	α 1-4
Sucrose (Table Sugar)	Glucose+ Fructose	**α 1-2**
Lactose (Milk Sugar)	Glucose+ Galactose	α 1-4

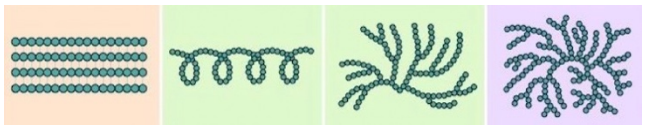
- Disaccharides must be broken down into monosaccharides to be absorbed.
- Lactose intolerance: is a common condition in humans who lack the enzyme lactase.

diverse	متنوع	Nutrients	مواد غذائية
Disassemblyy	تفكيك	Raw	خام
asymmetric	غير متجانس	Malt	شعير

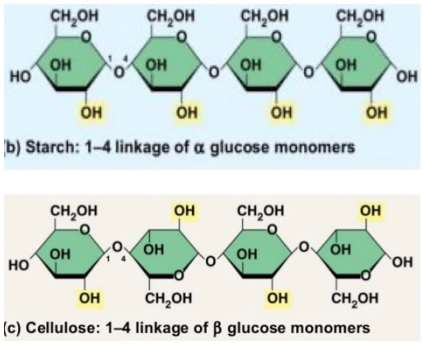
c) Polysaccharides

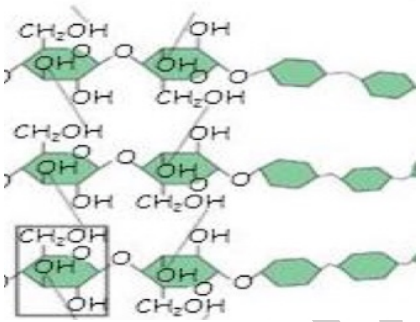
- polymers with a few hundreds to a few thousand monosaccharides joined by glycosidic linkages.
- **2 functions:**

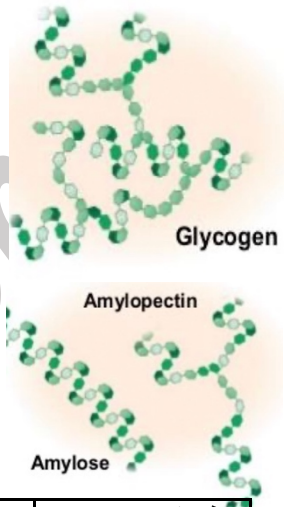
	Storage		Structural	
	Plant	**Animals**	**Plants**	**Not Plants**
Sugar	Starch amylose (unbranched) / amylopectin (branched)	Glycogen	Cellulose	Chitin
Components	α-glucose	α-glucose	β-glucose	β-glucose
Bond	▪ 1-4 glycosidic linkages ▪ 1-6 glycosidic linkages (branching)	▪ 1-4 glycosidic linkages ▪ 1-6 glycosidic linkages (branching)	1-4 glycosidic linkages	1-4 glycosidic linkages
Special characters	▪ Helical shape ▪ Stored in plastids	▪ Extensively branched	▪ Unbranched ▪ microfibrils	▪ Unbranched ▪ Has Nitrogen

		▪ Stored in liver and muscle cells	through H-bonds.	
Uses			▪ Building material ▪ Cell walls for plant	▪ exoskeletons for arthropods ▪ cell walls for fungi

- cellulose is present in cotton and paper.
- Animals can't digest cellulose; only prokaryotes and fungi can.

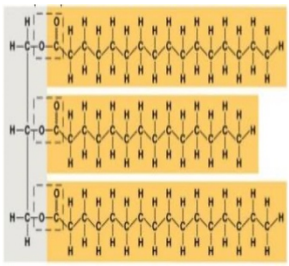






Starch	النشا	Exoskeleton	هيكل خارجي	Fungi	فطريات
branching	تفرع	arthropods	المفصليات	Prokaryotes	اوليات (بكتيريا)

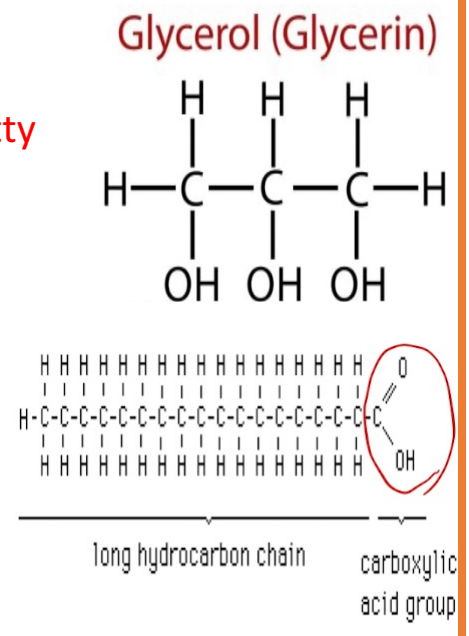
5.3: Lipids



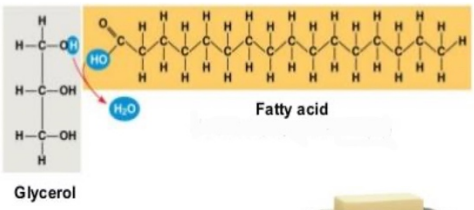
- Lipids are not polymers.
- They are not big enough to be considered macromolecules.
- Lipids are Hydrophobic because they consist of hydrocarbons that form non-polar covalent bonds.
- Types of lipids are: (1) fats (2) phospholipids (3) steroids.
- The covalent bond of the lipids is called ester bond.

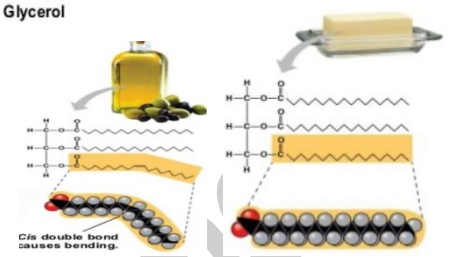
a) Fats:

- fat is constructed from 1 glycerol molecule and 3 fatty acids molecules.
- Glycerol: a 3-carbon alcohol with three OH groups.
- fatty acid: long carbon skeleton (16-18) that has a carboxyl group (COOH) at the end.
- fatty acids are joined with the glycerol at each (OH) group by an ester bond.
- Fats are hydrophobic because of the nonpolar C-H bonds in fatty acids.

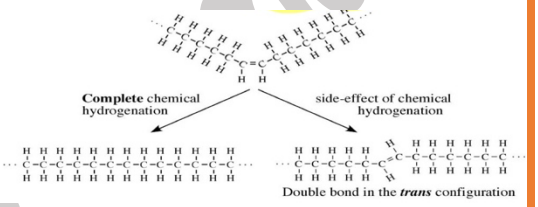


- Fatty acids can be either:
  1. Saturated: no double bonds
  2. Unsaturated: has double bonds
- Unsaturated fats have kinks with a cis double bond (naturally).
- These kinks prevent the molecules from solidifying at room temperature, so they are liquid, such as plant and fish oils.





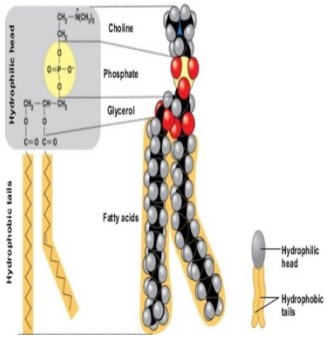
- Saturated fats are solid because they don't have kinks, like animal fats (butter).
- Hydrogenation: the process of converting unsaturated fats to saturated fats by adding hydrogen, it produces trans double bonds (atherosclerosis).

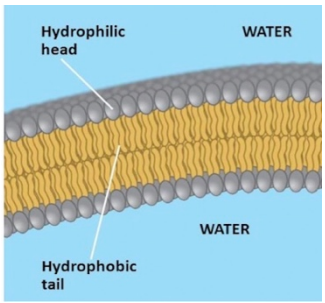


- Functions of fat are energy storing (twice as much of polysaccharides), cushioning organs, and insulating the body.

b) Phospholipids:

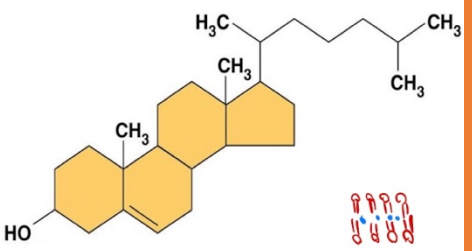
- They make cell membranes.
- consist of glycerol, two fatty acids and a phosphate group.
- a choline molecule can be linked to the phosphate group.
- The hydrocarbon tails are hydrophobic while the phosphate head is hydrophilic.
- When phospholipids are added to water, they self-assemble into a bilayer that shields their hydrophobic fatty acid tails from water.





c) Steroids:

- characterized by a carbon skeleton consisting of four fused rings.
- Cholesterol: is a type of steroid and is a crucial molecule in animals.
- Functions:
  It's a component of animal cell membrane.
  It is a precursor from which other steroids are synthesized, such as sex hormones.



- Cholesterol is made in the liver and is also obtained from the diet.
- high level of cholesterol in the blood may contribute to atherosclerosis.

Saturated fats, trans fats, and cholesterol cause atherosclerosis

Skeleton	هيكل	kink	انثناء
Saturated	مشبع	cushioning	يحمي ويبطن
Unsaturated	غير مشبع	atherosclerosis	تصلب الشرايين

5.4: Proteins

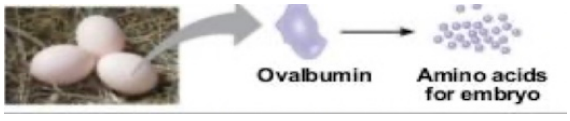
account for 50% of the dry mass of cells.

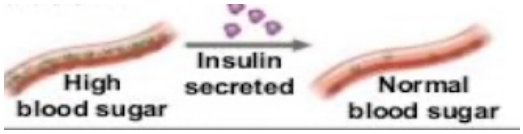
The enzymes are proteins that speed up chemical reactions (catalysts).

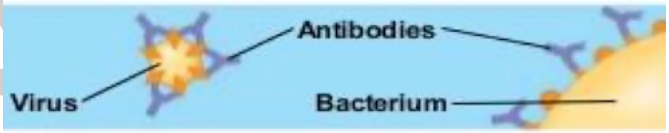
each protein has a unique 3D structure which gives it a specific function.

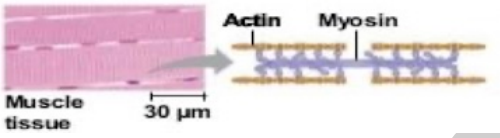
General functions:

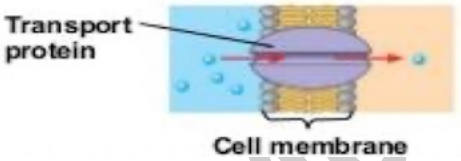
storage-hormonal-contractile-transport-enzymes-protection-receptors-structural

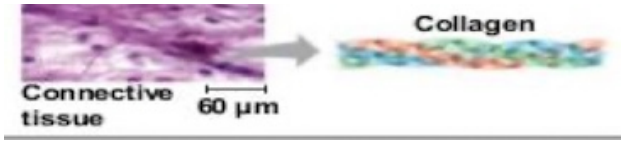




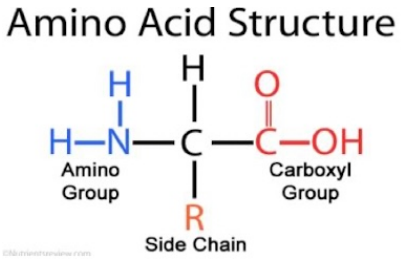






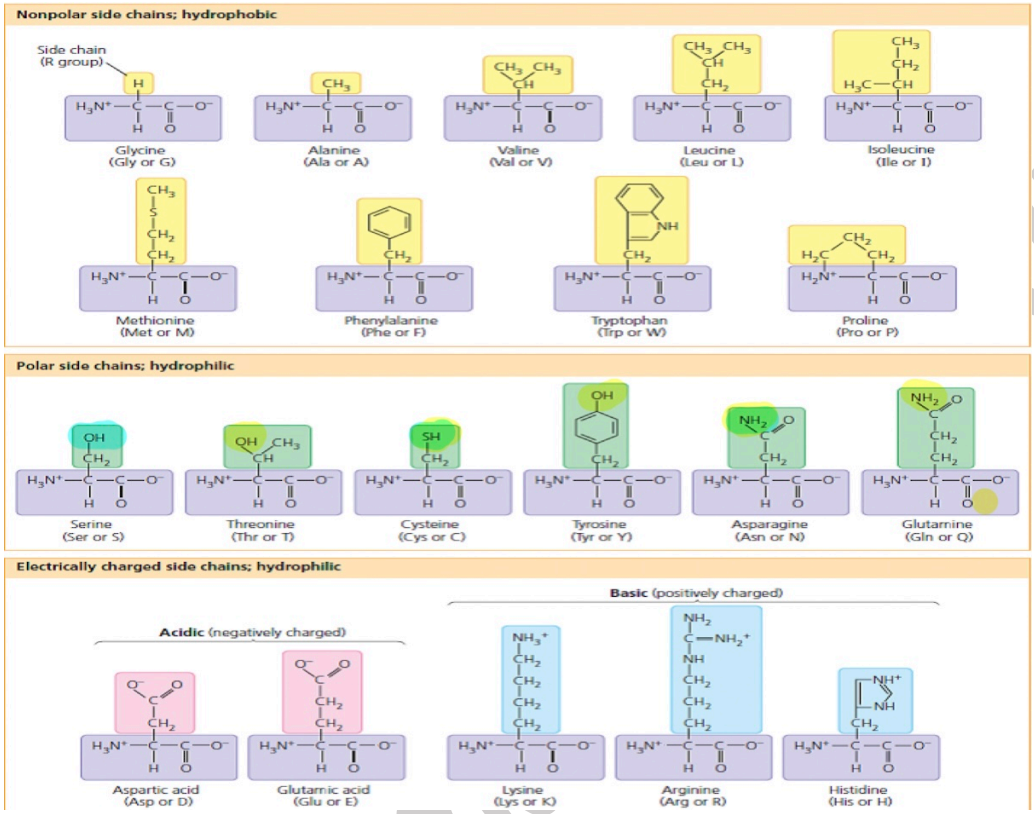


- a set of 20 amino acids are considered the monomers for proteins.
- They are bounded together by peptide bond.
- a polymer of amino acids is called a polypeptide.
- Protein: a biologically functional molecule made up of one or more polypeptides folded in a unique 3D structure.



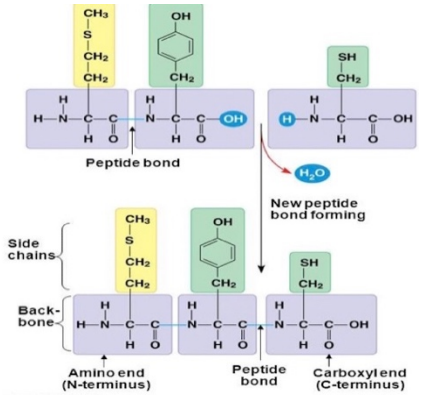
- amino acid: an organic molecule with both an amino group and a carboxyl group with a central asymmetric (α) carbon.
- 20 amino acids make thousands of different proteins.
- **(α) carbon's attachments: Amino/carboxyl/hydrogen/ and side chain.**

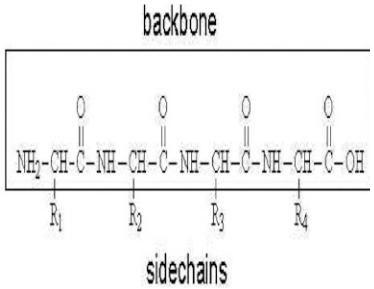
- properties of the side chain determine the unique characteristics of an amino acid affecting its role in a polypeptide.
- Types of Amino acids:

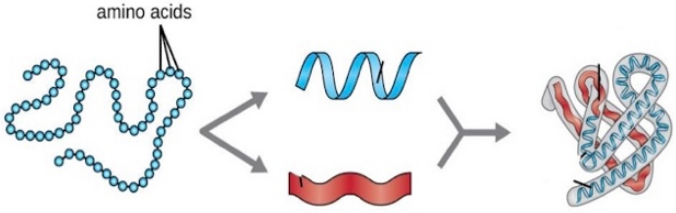


Polypeptides:

- repeating sequence of amino acids in a polypeptide is called the backbone.
- Side chains(R) extend from the backbone.
- polypeptides have an amino end (N-terminus) and a carboxyl end(C-terminus).
- chemical nature of the protein **determined by the kind and the sequence of the side chains.**
- Polypeptides are folded into a 3D protein which is studied using X-ray crystallography, Nuclear magnetic resonance (NMR), and bioinformatics.
- Proteins have 2 main shapes: Fibrous and Globular.

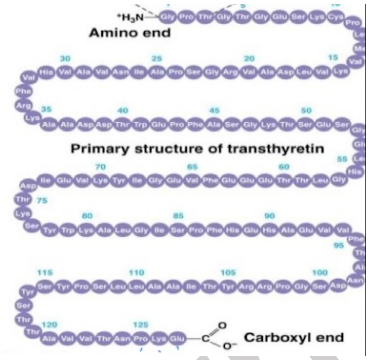




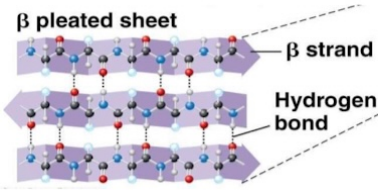


4 levels of protein structure:

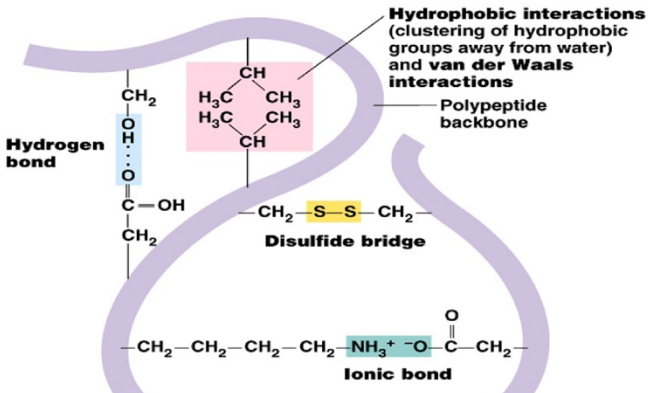
1. **Primary**:
   - linear sequence of amino acids.
   - determined by genetic information.
   - **dictates secondary and tertiary structure**.
   - **Only peptides bonds**.



2. **Secondary**:
   - Stabilized by hydrogen bonds between atoms of the **backbone only**.
   - Has two types: Alpha helix Beta sheets



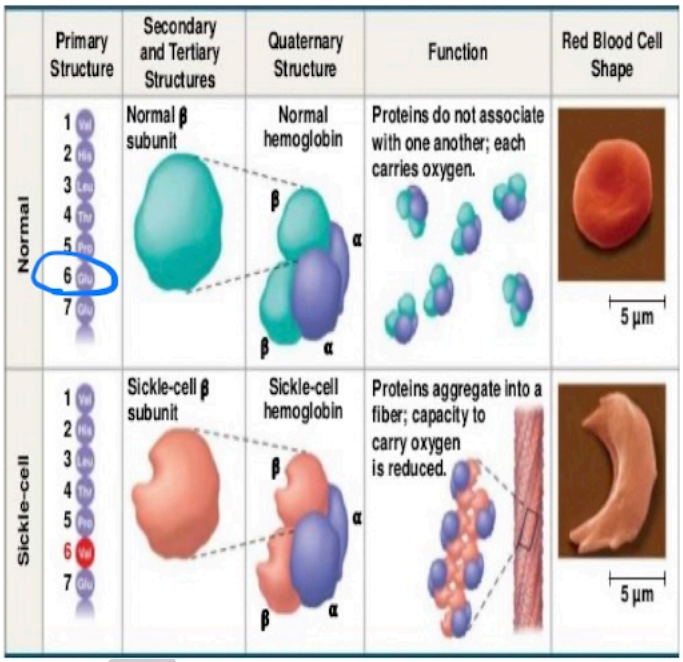
3. **Tertiary**:
   - It is the 3D structure of the polypeptide.
   - Stabilized by **interactions between side chains**.
   - These interactions include:
     a) hydrophobic interaction: the hydrophobic amino acids hide from water in the core of protein while hydrophilic amino acids will be facing the aqueous solution.
     b) van der Waals: interactions between non-polar amino acids.
     c) hydrogen bonds: between polar side chain.
     d) ionic bonds: between positively and negatively charged side.
     e) Disulfide bridges: Covalent bonds between 2 Cysteine monomers which have SH group on their side chain.



   - All are considered weak; disulfide is the strongest.

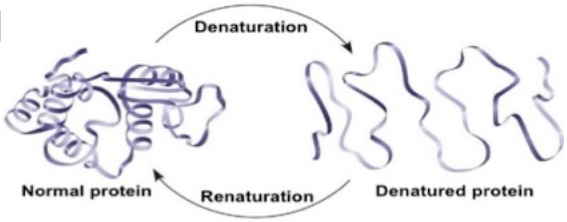
4. **Quaternary**:

- When a protein is made up from more than one polypeptide.
- Not all proteins have this level.
- Examples: Transthyretin collagen Hemoglobin
- Sickle cell disease is an inherited blood disorder Caused by the change of the normal Glutamine to Valine at the amino acid number 6.



Protein final structure depends on:

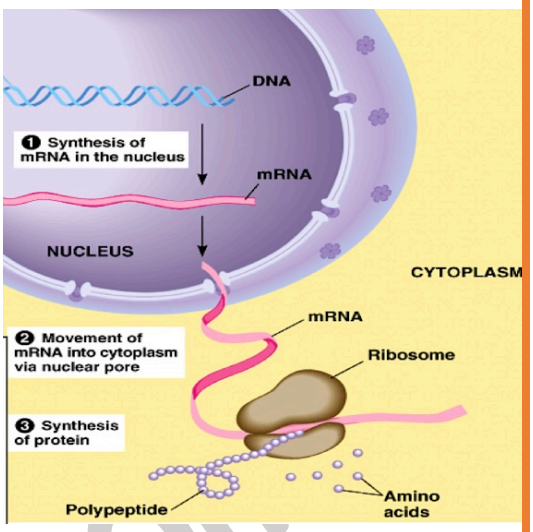
- Mainly, the sequence of amino acids and interactions that creates secondary and tertiary structures.
- Physical and chemical conditions in the protein's environment like pH, temperature, and salts.
- **Denaturation**: destruction of the functional shape of a protein due to loss of the weak bonds and interactions as result of change in environment.



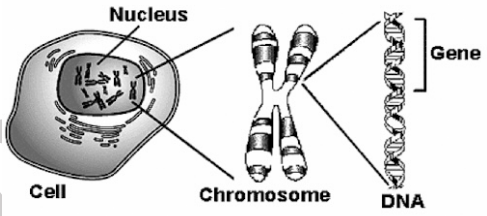
- denatured proteins are biologically inactive.
- denatured proteins can **sometimes** return to its functional shape when the denaturing agent is removed.
- Those agents can be:
  Transferring proteins to a nonpolar solvent.
  Chemicals that disrupt the bonds.
- Heat that breakdown weak bonds.
- The amino acid sequence of a polypeptide (primary structure) is programmed by a unit of inheritance known as a gene.

catalysts	محفز كيميائي	Fibrous:	من الألياف	Sickle cell:	الأنيميا المنجلية
sequence:	تسلسل	Globular:	كروي	Inherited:	وراثية
Dictates:	يحدد ويجبر	helix:	لولبي الشكل	Denaturation:	خراب الشكل

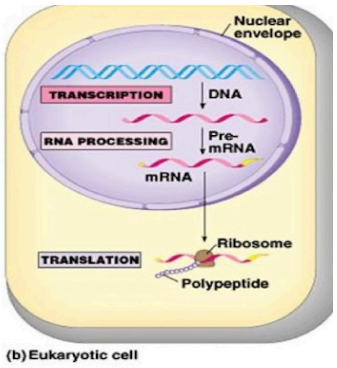
5.5: Nucleic Acids

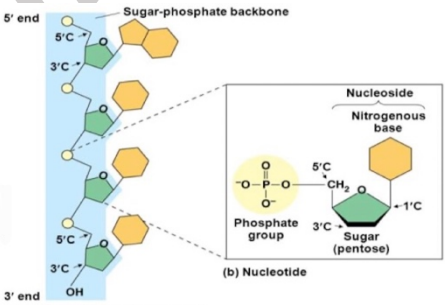


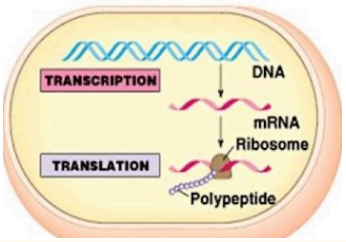
- deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)
- They are macromolecules that exist as polymers of nucleotides. (polynucleotide).
- DNA is found in the nucleus as chromosomes.
- Each chromosome is made of one long DNA molecule, carrying several genes.
- DNA can replicate by itself and is responsible for gene expression: the process of synthesizing mRNA that translates to a protein.
- Prokaryotic cells lack nuclei but still use mRNA for gene expression.
- DNA is the genetic material that organisms inherit from their parents.

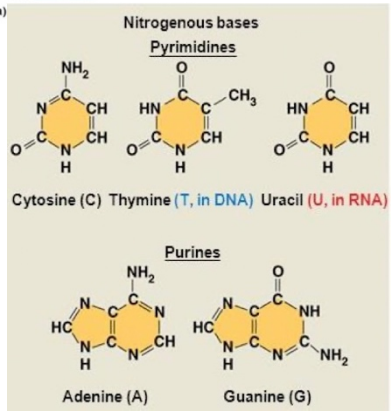


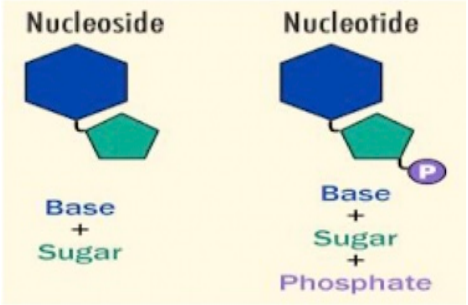
- Proteins are required to implement genetic programs that DNA provides (through gene expression).
- Each gene along DNA molecule directs synthesis of a messenger RNA (mRNA).
- **Backbone of nucleic acid strand: sugar + phosphate**
- **Nucleotides consist of:**
  a) five-carbon sugar (pentose).
  b) Nitrogenous base.
  c) (1-3) phosphate groups.
- 1'C: Nitrogenous base
- 5'C: Phosphate group
- 3'C: OH group.
- In RNA: the sugar is ribose. In DNA: the sugar is deoxyribose on 2'C.

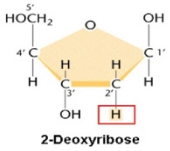


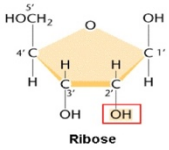










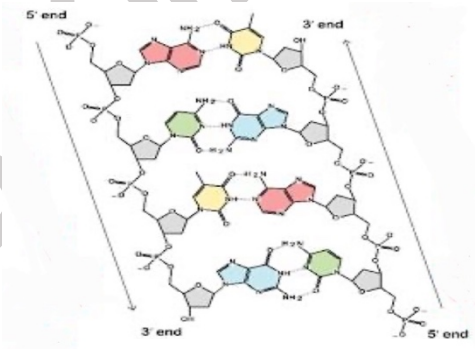


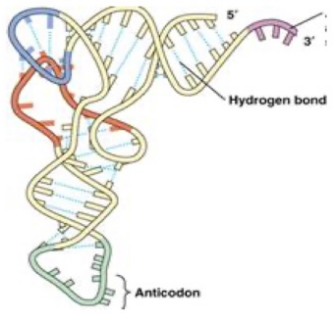
Nucleic acid synthesis:

- Adjacent nucleotides are joined by a dehydration reaction forming a covalent bond between a phosphate group of one nucleotide and the 3'C of another nucleotide; it's called **a phosphodiester bond**.
- nucleotides can be added only at the 3' end. (5' to 3')

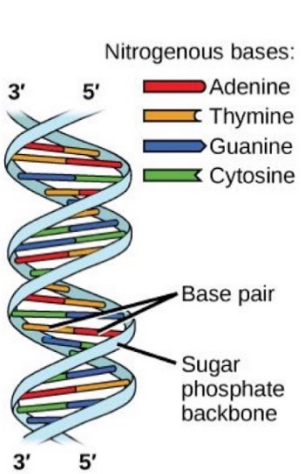
DNA	RNA
Deoxyribose	Ribose
Double stranded	Single stranded
Has Thymine	Has Uracil

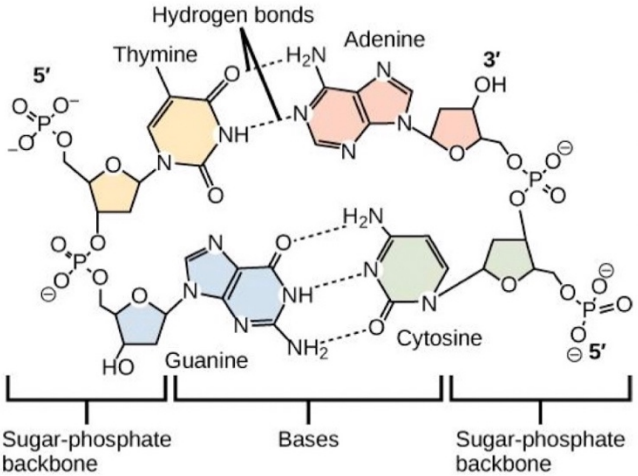
- DNA is described as double helix.
- It is made of two strands that are complementary to each other through nitrogen base-pairing**. (A=T) (G≡C).**
  The two strands are Antiparallel, they run in opposite directions; if one strand runs from 5' to 3', the opposite strand runs from 3' to 5'.
  Example: 5'-ATGC-3' with 5'-GCAT-3'





- Complementary base pairing can occur between regions of two RNA molecules or even between two stretches of nucleotides in the same RNA molecule. (tRNA)





synthesizing	يصنع
Adjacent	مجاور
complementary	مكمل

Past papers:

Q1) Which of the following properties is shared by starch and cellulose?

A. Digested by humans
B. Polymers of glucose
C. Structural carbohydrates
D. Branched carbohydrates
E. None of the above

Q2) How many molecules of water are needed to completely hydrolyze a 25-monomer long polypeptide?

A. 35
B. 24
C. 50
D. 25
E. Zero

Q3) Aldoses and ketoses differ in:

A. The position of the carbonyl group
B. The position of the hydroxyl groups
C. The number of carbon atoms
D. The number of oxygen atoms
E. The position of carbon atoms

Q4) A saturated fatty acid contains more…… atoms than unsaturated fatty acid?

A. Carbon
B. Oxygen
C. Nitrogen
D. Phosphate
E. Hydrogen

Q5) Which of the following molecules is a not a polysaccharide?

A. Amylose
B. Glycogen
C. Cellulose
D. Chitin
E. Collagen

Q6) Which is false about proteins?

A. Protein's specific structure determines how it works.
B. Functional protein is not just a polypeptide chain.
C. The bond linking amino acids is noncovalent.
D. Polypeptide backbone is the same in all polypeptides.
E. The R group of amino acid monomers differs from one amino acid to another

Q7) Which level of protein organization is due to interactions between amino acid side chain groups?

A. Primary
B. Secondary
C. Tertiary
D. Quaternary
E. all of the above

Q8) In a double -stranded DNA molecule, phosphodiester linkage consists of a phosphate group that links:

A. cytosine to guanine
B. the sugars of two nucleotides
C. thymine to adenine
D. ribose to a nitrogenous base
E. deoxyribose to a nitrogenous base

Q9) Which pair is mismatched?

A. Amino acids polymer————— protein
B. alpha Glucose polymer————glycogen
C. Beta Glucose polymer————cellulose
D. Purine————— thymine
E. Fatty acid————— hydrophobic

Q10) Which characteristic could be shared by the primary and tertiary structures of protein?

A. Both could have hydrogen bonds between the repeating constituents of the polypeptide backbone
B. Both have peptide bond between the amino acids
C. Both are functional proteins
D. Both could have disulfide bridge
E. Both must contain glycerol molecule

Q11) A double-stranded DNA molecule contains 20 purines and 20 pyrimidine should be composed of:

A. 20 adenine and 20 thymine
B. 20 thymine and 20 uracil
C. 40 cytosine
D. 40 cytosine and 40 guanine
E. 20 adenine and 20 guanine

Chapter 7

7.1: Microscopes

- Organisms are either unicellular or multicellular.
- Microscopes are used to study cell structure.

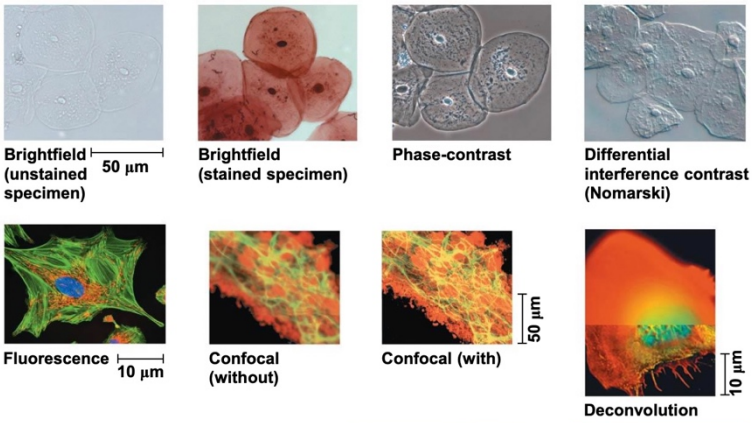
Important terms:

a) Magnification: ratio of an object's image size to its real size.

b) Resolution: the minimum distance two points can be separated and still be distinguished (clarity).

c) Contrast: difference in brightness (light and dark).

- staining and labeling cell components are used to enhance contrast.



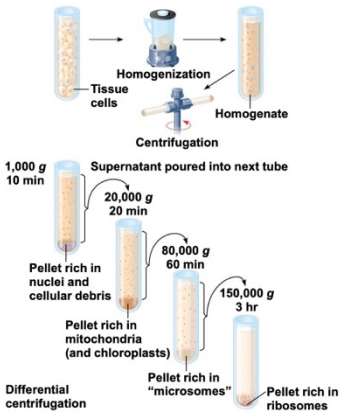
2 types of:

a) Light Microscope (LM):

- Magnification = 1000 times.
- visible light is passed through the specimen and then through glass lenses to be magnified.
- Used to study living cells.
- Has multiple types.
- Confocal and deconvolution=3D images.

b) Electron Microscope (EM):

- focuses a beam of electrons instead of light through the specimen (TEM) or onto its surface (SEM).
- Has high resolution that allows us to study organelles.
- Two types only:



Scanning Electron Microscope (SEM)	Transmission Electron Microscope (TEM)
surface (topography)	Internal structure
Specimen is coated with gold	Needs very thin section
3D images	Stained with heavy metals

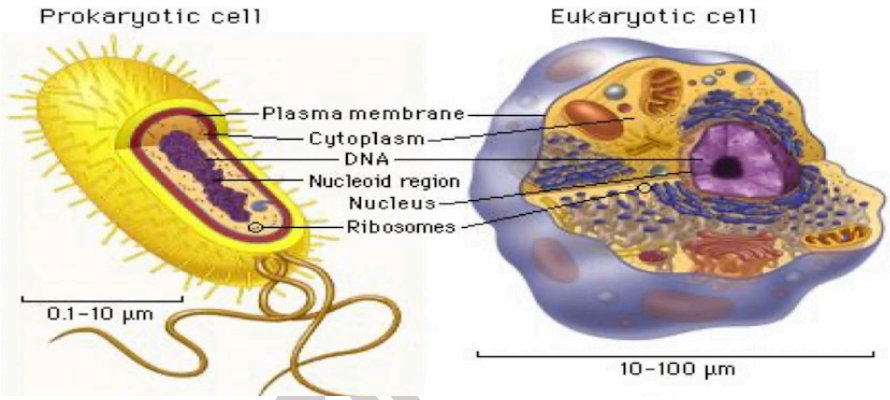
- Cell fractionation: a technique for studying cell structure and function, which separates organelles from one another.

- Larger components precipitate first: nuclei/mitochondria+chloroplasts/plasma membrane/ribosome.

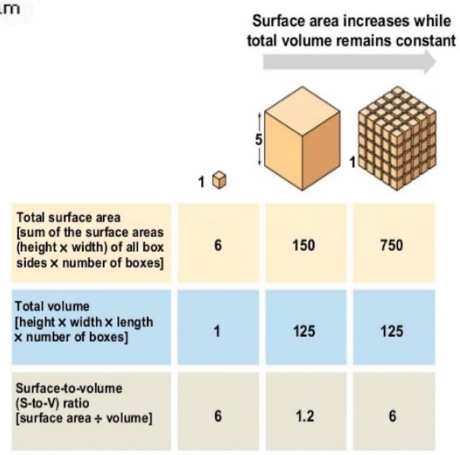
7.2: Eukaryotes

- We have two types of cells:

Prokaryotes	Eukaryotes
bacteria and archaea	Protists, fungi, animals, and plants
plasma membrane, cytosol, chromosomes, and ribosomes (smaller)	plasma membrane, cytosol, chromosomes, and ribosomes (larger)
DNA: in a nucleoid	DNA: in the nucleus.
Smaller (1-5 µm)	Larger (10-100 µm)
Fimbriae, cell wall, glycocalyx and flagella	Has organelles that are bounded by a phospholipid bilayer (cytoplasm)



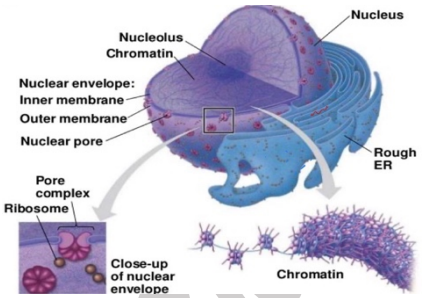
- A high surface area-to-volume ratio facilitates the exchange of materials between a cell and its environment.
- smaller objects have greater ratio of surface area to volume than the bigger objects.
- Larger organisms do not generally have larger cells than smaller organisms, they have more cells.



Animal cell	Plant cell	Bacteria
Nuclear membrane	Nuclear membrane	No nuclear membrane
No cell wall	Cell wall (cellulose)	Cell wall (peptidoglycan)
Multiple chromosomes	Multiple chromosomes	Single circular chromosome
Small vacuoles	Large vacuoles	No vacuoles
Lysosomes	No lysosomes	No lysosomes

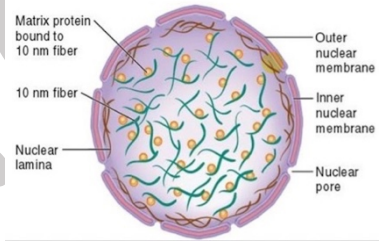
Mitochondria	Mitochondria	No mitochondria
No chloroplasts	Chloroplasts	No chloroplasts

7.3: Genetic Control of Eukaryotes



the nucleus and ribosomes are involved in gene expression.

The nucleus contains most of the genes in the eukaryotic cell; some are in the mitochondria and chloroplasts.



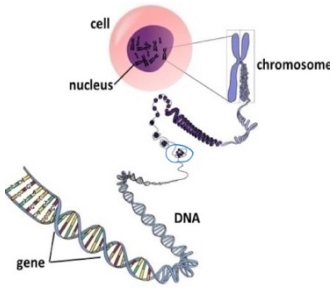
Nuclear envelope: a double membrane structure with a space between the membranes.

It has pores where the inner and outer membranes fuse together.

Pore complex: a protein structure lines each pore and regulates the entry and exit molecules.

The nuclear lamina: a netlike structure of intermediate filaments that lines the nuclear side of the membrane and maintains the shape of the nucleus by mechanically supporting the nuclear envelope.

The nuclear matrix: a framework of protein fibers extending throughout the nuclear interior.



Chromosomes: one long DNA molecule associated with many proteins (some proteins reduce the length of the DNA molecule allowing it to fit into the nucleus).

The complex of DNA and proteins making up chromosomes is called chromatin.

When a cell prepares to divide, the chromosomes, become coiled and can be distinguished.

Each eukaryotic species has a characteristic number of chromosomes.

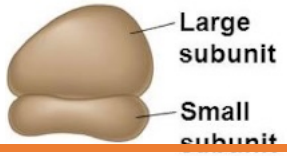
Nucleolus: is a prominent structure within the non-dividing nucleus.

Functions: **ribosomes synthesis**. (rRNA+ proteins).

large and small subunits exit the nucleus through pores to the cytoplasm, where they assemble into a functional ribosome.

Sometimes there are two or more nucleoli; the number depends on the species and the stage in the cell's reproductive cycle.

Ribosomes are protein synthesis factory.



They are not membrane bound (**not organelles**).

Located In:

cytosol (free ribosomes): intracellular proteins.

RER and nuclear envelop (bound): secretory and membrane proteins.

7.4: Endomembrane system

- Is composed of:

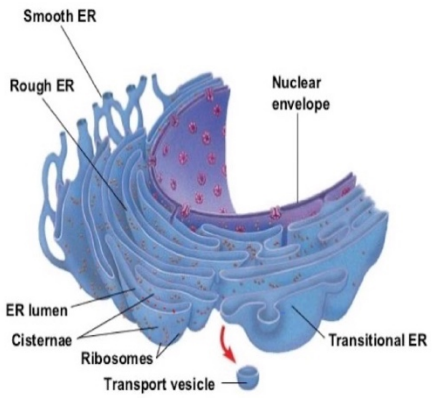
  Golgi apparatus Plasma membrane Nuclear envelope
  Endoplasmic reticulum Lysosomes Vesicles Vacuoles

- functions:

  1. Protein synthesis and transport 2. Lipid metabolism and movement
  3. Detoxification of poisons

- Detoxification: Adding hydroxyl groups to drug molecules, making them more soluble and easier to flush from the body.
- the endomembrane system components are in direct physical continuity with each other through vesicles.

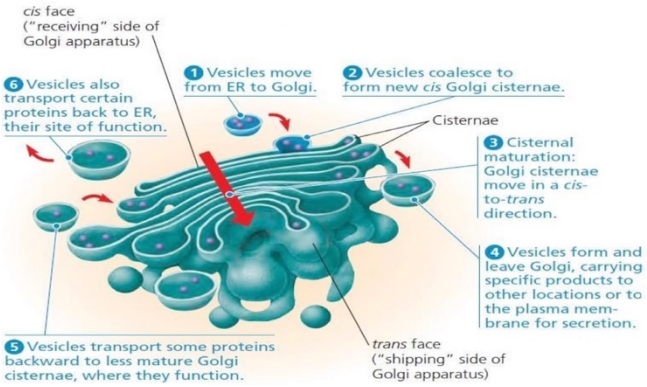
Endoplasmic reticulum:



- network of membranous tubules and sacs called cisternae.
- ER membrane separates the internal compartment of the ER (lumen) or cisternal space, from the cytosol.
- ER is either smooth with no bound ribosomes or it is rough (bound ribosomes).
- SER functions: Lipid synthesis Detoxification Storage of calcium
  Metabolism of carbohydrates.
- RER functions:

a) Secretory proteins Synthesis: bound ribosome- peptide into the lumen- folding of the peptide- carbohydrates addition (glycoproteins)-transport vesicles from transitional ER.

b) synthesizing membrane proteins and phospholipids.



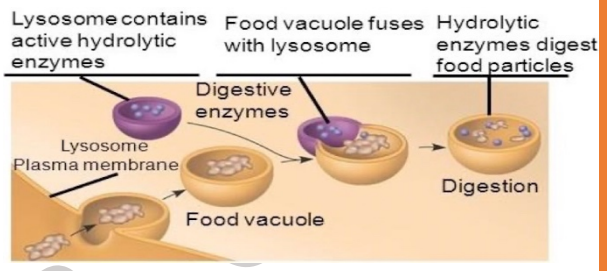
Golgi apparatus:

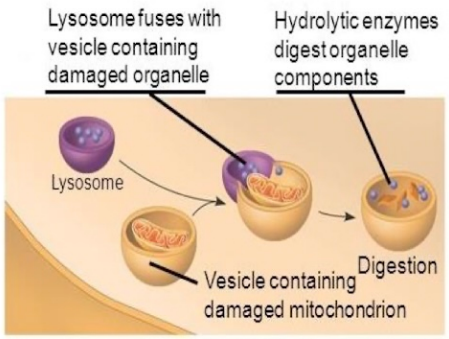
- shipping (trans) and receiving center (cis).

- where products of the ER are modified and sorted and then sent to other destinations such as plasma membrane, back to Golgi, and back to ER.
- consists of a group of associated separated cisternae.
- It modifies proteins, alters membrane phospholipids, and manufactures some macromolecules.

Lysosome:

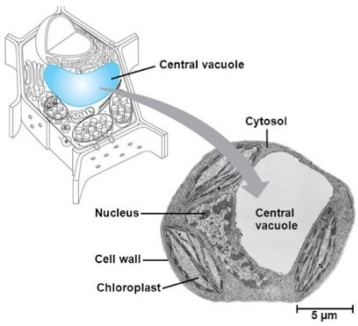
- It is a Membranous sac of hydrolytic enzymes that many eukaryotic cells use to digest (hydrolyze) macromolecules.
- Lysosomal enzymes and membrane are made by RER.
- It has acidic pH that is suitable for the enzymes.
- Intracellular digestion:
  a) Phagocytosis: Amoebas and macrophages.
  b) Autophagy: recycling the cell's own organic material. (Double membrane)
- Inherited lysosomal storage diseases: hydrolytic enzymes are not functional.





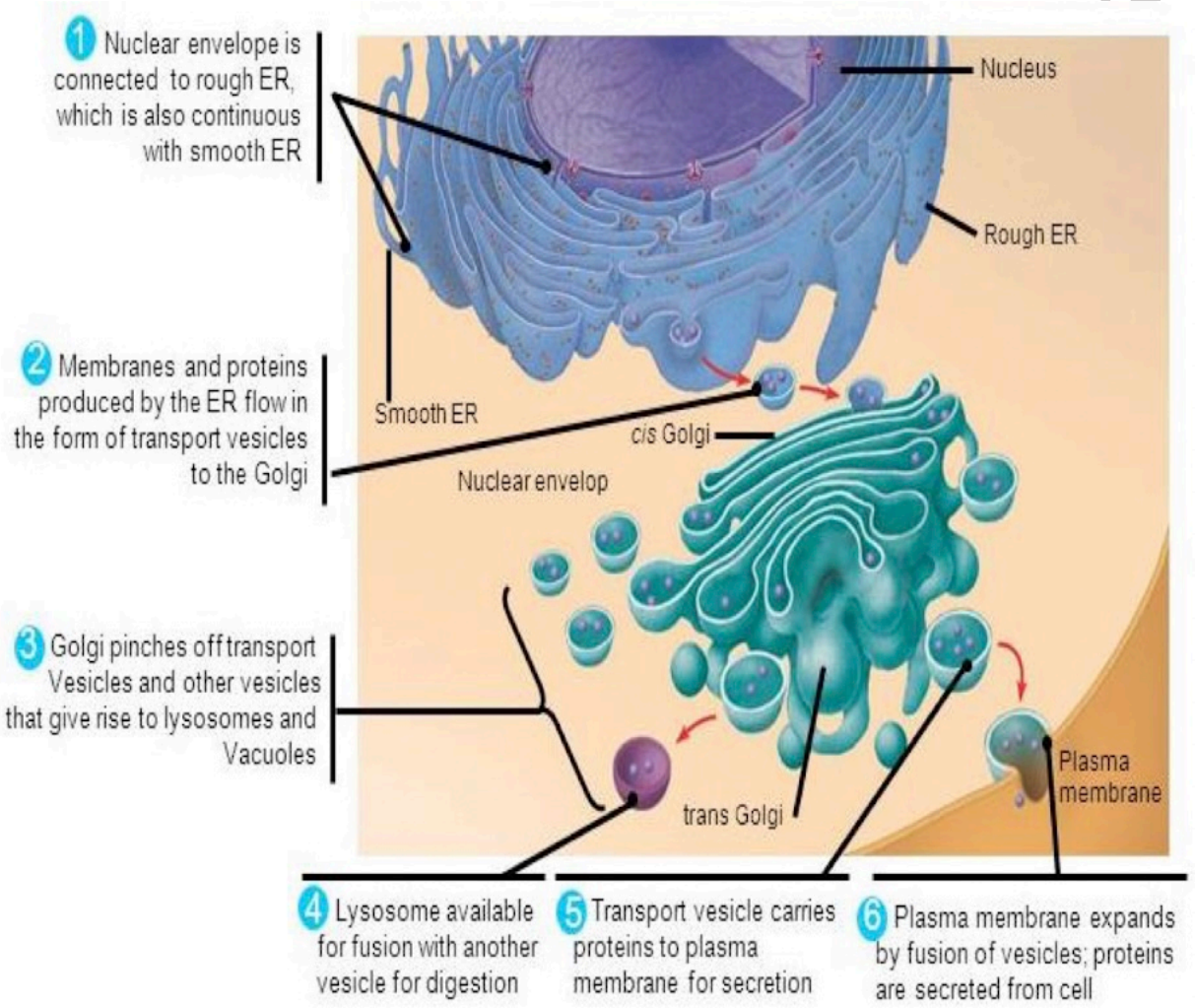
Vacuoles:

- They are large vesicles derived from the ER and Golgi apparatus with a selective membrane for transporting solutes.
- Vacuoles perform different kinds of functions in different kinds of cells.
  Food vacuole: formed by phagocytosis.
  Contractile vacuole: pumps excess water out of the cell (in unicellular eukaryotes).
  Hydrolytic vacuoles: found in plants and fungi; they carry out enzymatic hydrolysis (like lysosomes in animal cells).
  Central vacuoles: found in mature plant cells which develop by the coalescence of smaller vacuoles; it contains cell sap (storage of inorganic ions) and helps in cellular growth; the cell enlarges as the vacuole absorbs water.



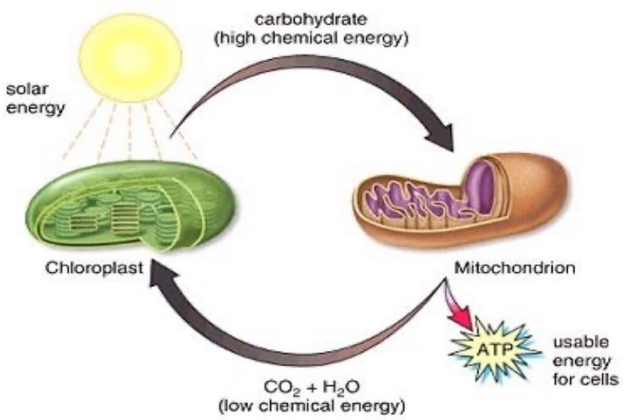
Small vacuoles: can hold reserves of important organic compounds, such as the proteins in seeds. They may also protect the plant from herbivores by storing poisons. some contains pigments, that help attract insects to flowers.

summary of endomembrane system:

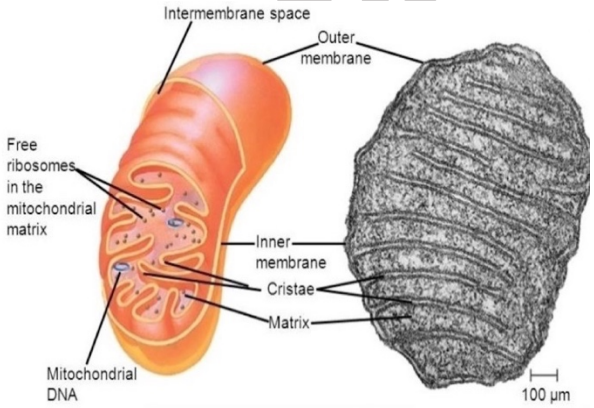


Fractionation:	تكسير	distinguish:	يميز	vesicles:	حويصلات
pores:	ثقوب	assemble:	يتجمع	lumen:	تجويف
coiled:	ملتف	Detoxification:	إزالة السموم	sac:	كيس
Pigments:	صبغات				

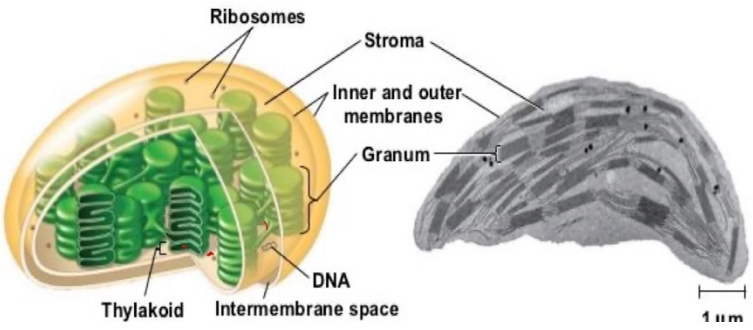
7.5: Mitochondria and Chloroplasts



- the organelles that convert energy to forms that cells can use for work.
- Mitochondria: the sites of cellular respiration, which uses oxygen to drive the generation of ATP by the breakdown of sugars and other molecules.
- Found in Eukaryotes only; maybe more than one in each cell according to the level of metabolic activity.



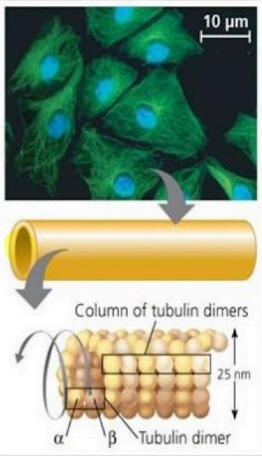
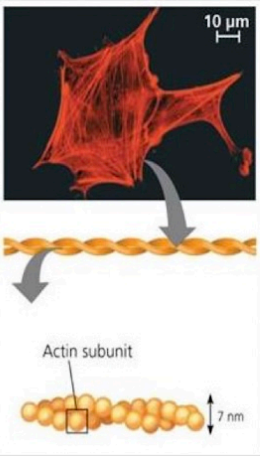
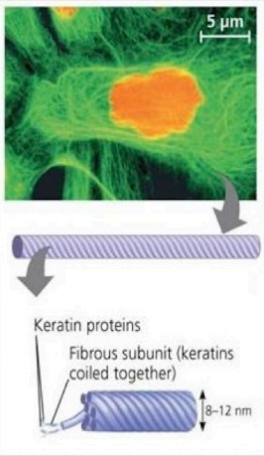
- Mitochondria is surrounded by two phospholipid bilayer membranes with different proteins.
- The outer membrane is smooth, but the inner membrane has infoldings called cristae which are important for increasing surface area which is important for cellular respiration.
- inner membrane divides the mitochondrion into:
  a) intermembrane space.
  b) mitochondrial matrix which is enclosed by the inner membrane and contains enzymes, DNA, and Ribosomes.
- enzymes found in the matrix catalyze some of the steps of cellular respiration and some are built into the inner membrane.
- Mitochondria move, change their shapes, and fuse or divide into two.
- Chloroplasts are the sites of photosynthesis; they convert solar energy to chemical energy by absorbing sunlight and using it to synthesize organic compounds.



- contain the green pigment chlorophyll, along with enzymes for the photosynthetic production of sugar.
- found in leaves and other green organs of plants and in algae.

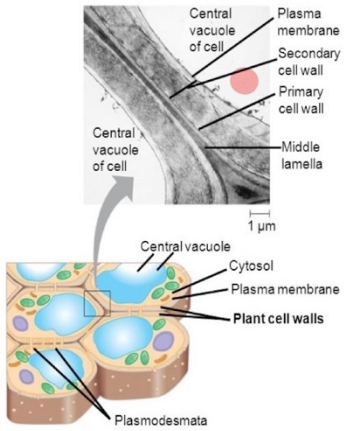
- Surrounded by two phospholipid bilayer membranes with a space in between.
- inside the chloroplast is another membranous system in the form of flattened, interconnected sacs called thylakoids.
- When thylakoids are stacked together; each stack is called a granum.
- fluid outside the thylakoids is the stroma. It contains DNA, Enzymes, and ribosomes.
- **Plastids** are divided into chloroplasts, amyloplast (colorless organelle that stores starch, and chromoplasts (which have pigments that give fruits and flowers their orange and yellow colors).
- Peroxisomes: a specialized metabolic organelle that is bounded by a single membrane.
- They contain enzymes that remove hydrogen atoms from various substrates and transfer them to oxygen (O_2), producing hydrogen peroxide (H_2O_2).
- Functions:
  a) Breakdown fatty acids into smaller molecules that are transported to Mitochondria and used as fuel for cellular respiration.
  b) In the liver detoxify alcohol and other harmful compounds.
  c) Specialized Peroxisomes called Glyoxysomes are found in the fat-storing tissues of plant seeds.

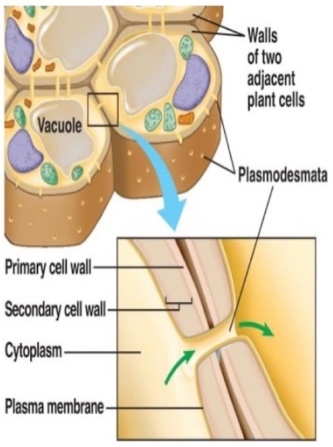
7.6: Cytoskeleton

Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes	Two intertwined strands of actin	Fibrous proteins coiled into cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins (such as keratins)
Main functions	Maintenance of cell shape (compression-resisting "girders"); cell motility (as in cilia or flagella); chromosome movements in cell division; organelle movements	Maintenance of cell shape (tension-bearing elements); changes in cell shape; muscle contraction; cytoplasmic streaming in plant cells; cell motility (as in amoeboid movement); division of animal cells	Maintenance of cell shape (tension-bearing elements); anchorage of nucleus and certain other organelles; formation of nuclear lamina
Fluorescence micrographs of fibroblasts. Fibroblasts are a favorite cell type for cell biology studies. In each, the structure of interest has been tagged with fluorescent molecules. The DNA in the nucleus has also been tagged in the first micrograph (blue) and third micrograph (orange).			

7.7: Extracellular components

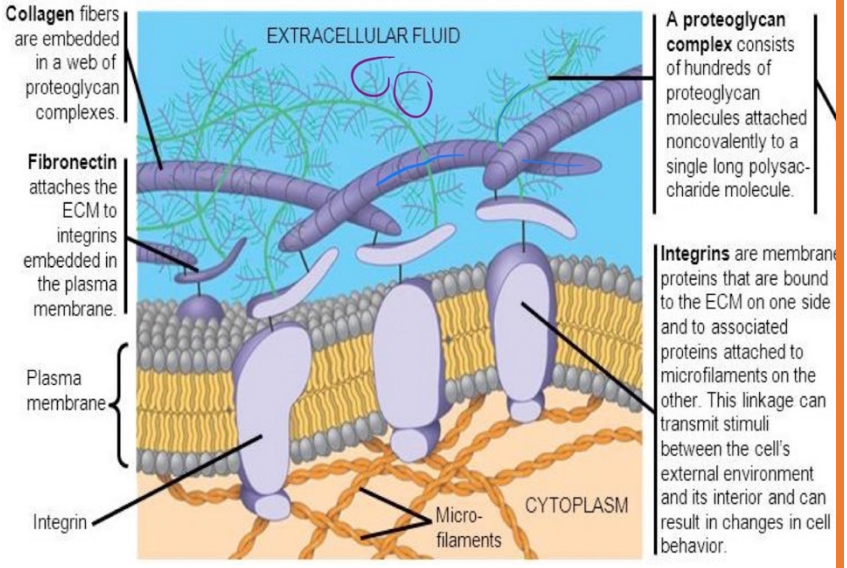
- Plant cell wall: an extracellular structure of plant cells that functions in: protecting the plant cell, maintaining its shape, preventing excessive uptake of water.
- Prokaryotes, fungi, and some unicellular eukaryotes also have cell walls.
- Plant cell walls are made of cellulose fibers.
- Cellulose microfibrils are synthesized by an enzyme called cellulose synthase.
- In the extracellular space, they become embedded in a matrix of other polysaccharides and proteins that is called Ground Substance.
- A young plant cell first secretes a thin and flexible wall called the primary cell wall.
- Between the primary walls of adjacent cells is the middle lamella, a thin layer rich in sticky polysaccharides called pectin.





- The middle lamella glues adjacent cells together.
- When the cell matures and stops growing, it strengthens its wall, by secreting hardening substances and adding secondary cell walls between the plasma membrane and the primary wall.
- The secondary wall has several layers and a strong matrix that protects and supports the cell.
- Plant cell walls usually have channels between adjacent cells called plasmodesmata.

- ECM of animal cells is made of glycoproteins and other carbohydrate-containing molecules secreted by the cells.
- The most abundant glycoprotein is collagen which is embedded in a network of proteoglycans secreted by cells.
- A proteoglycan molecule



consists of a small core protein plus many carbohydrate chains.

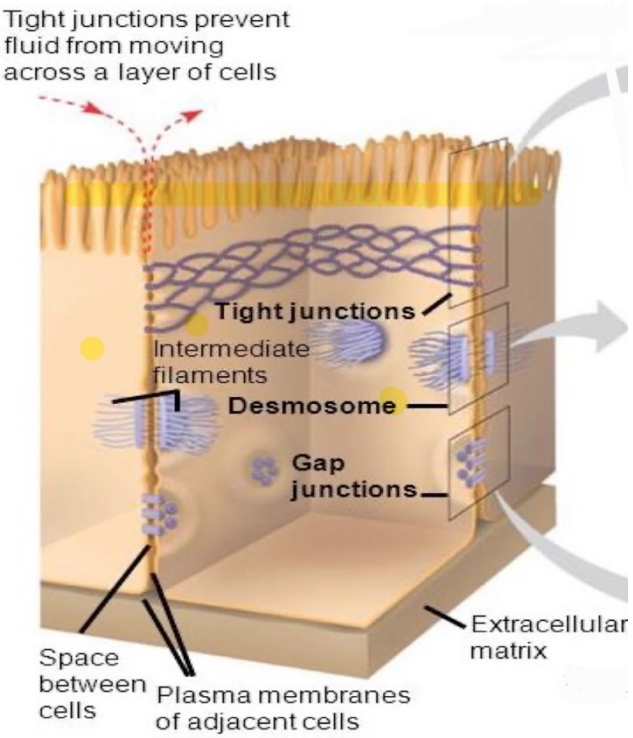
- Cells are attached to the ECM by glycoproteins such as fibronectin.
- Fibronectin and other ECM proteins bind to cell-surface receptors called integrins.
- Integrins span the membrane and bind on their cytoplasmic side to associated proteins attached to microfilaments of the cytoskeleton.

Functions of the ECM include:

a) Regulating the cell's behavior by communicating with a cell through integrins.
b) Influencing the activity of genes in the nucleus.

Cell Junctions: Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact.

- plasmodesmata channels: cytosol pass through these channels joining the internal chemical environments of adjacent cells.
- The plasma membranes of adjacent cells line these channels.



in animal cells:

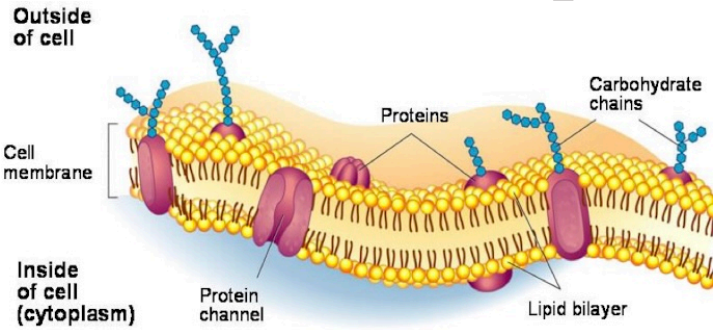
1. Gap junctions: provide channels between cells like plasmodesmata in plants but aren't surrounded by a membrane. They consist of membrane proteins that surround a pore.
2. Tight junctions: tighten the plasma membranes of neighboring cells; they form continuous seals around the cells and prevent leakage of fluid between cells.
3. Desmosomes: function like nails, holding cells together into strong sheets. Intermediate filaments anchor desmosomes in the cytoplasm.

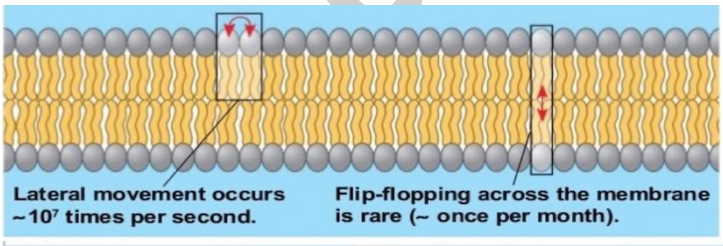
cellular respiration	التنفس الخلوي	photosynthesis:	البناء الضوئي	lamella:	صفيحة
infoldings	ثنيات	algae:	طحالب	span:	يخترق
Chloroplasts	بلاستيدات خضراء	Tubules:	أنيبات	adhere:	يلتصق
Pigments:	صبغات	Adjacent:	مجاور	Nails:	مسامير

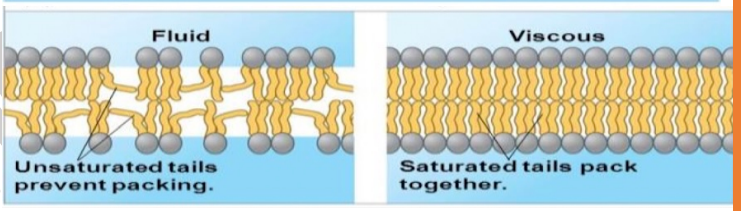
Chapter 8

8.1: Cell Membrane Structure

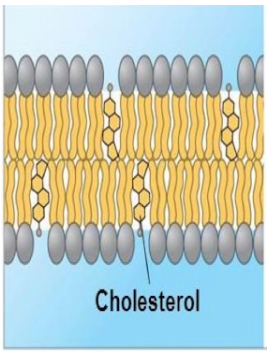
- Plasma membrane: is the boundary that separates the living cell from its surroundings and controls traffic into and out of the cell.
- it is made of lipids (mostly phospholipids), proteins and few carbohydrates.
- Membrane lipids are described as amphipathic structures, having both hydrophilic and hydrophobic region.
- Most membrane proteins are also amphipathic.
- The fluid mosaic model: the membrane is a mosaic of protein molecules embedded in a fluid bilayer of phospholipids.
- Phospholipids form the main fabric, but proteins determine most of the cellular functions.
- A membrane is held together by weak hydrophobic interactions.





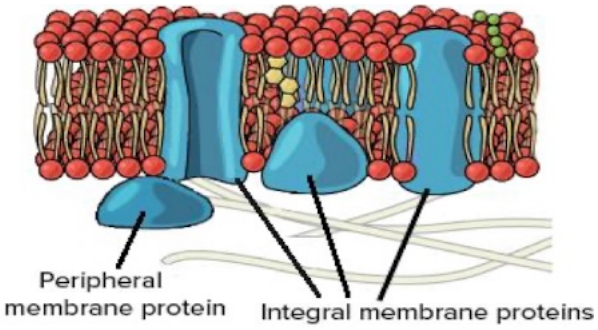


Membrane fluidity:



- Membranes are not static, Phospholipids in the plasma membrane can move within the bilayer.
- Movement can be: A) Lateral B) flip-flop
- membranes remain fluid as temperature decreases until the phospholipids settle into a closely packed arrangement and the membrane solidifies.
- Factors affecting fluidity:-
  Saturation: phospholipids with unsaturated fatty acids are more fluid.
  Cholesterol: at moderate-high temperatures cholesterol makes the membrane less fluid, at cool temperatures it maintains fluidity.
- The fluidity of membranes affects both its permeability and proteins movement to where their function is needed.

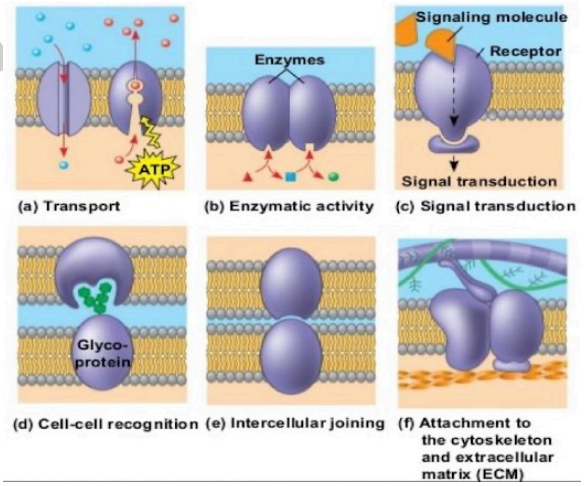
- Membrane proteins:
  1) Integral proteins are embedded in the phospholipid bilayer (transmembrane proteins).
     - hydrophobic regions consist of one or more stretches of nonpolar amino acids coiled into α helices.
     - hydrophilic parts of the molecule are exposed to the aqueous solutions on either side of the membrane and in hydrophilic channels.



  2) Peripheral proteins are loosely bound to the surface of membrane, some are attached to the cytoskeleton, and some are attached to fibers of the ECM.
- Carbohydrates are attached to membrane proteins forming glycoproteins or to lipids forming glycolipids.

Major functions of membrane proteins:

A. Transport
B. Enzymatic activity
C. Signal transduction
D. Cell-cell recognition (glycoproteins)
E. Intercellular joining
F. Attachment to the cytoskeleton and extracellular matrix



- cell-cell recognition: important for sorting of cells into tissues and organs in an animal embryo, and the immune system and response.
- Blood types (A,B,AB,O) are examples of it.
- Sidedness of plasma membrane: membranes have distinct inside and outside faces because of the asymmetrical arrangement of proteins, lipids, and their associated carbohydrates.
- It is determined by ER and Golgi.

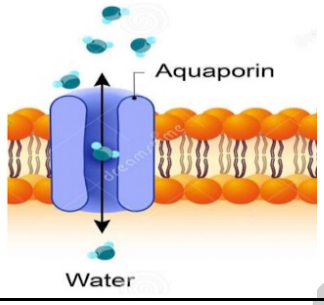
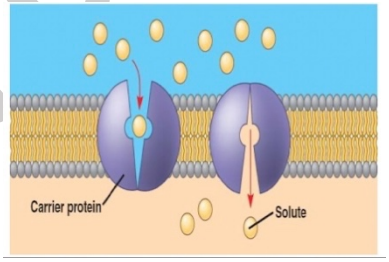
8.2: Membrane Permeability

Cell membranes are selectively permeable meaning the cell can take up some small molecules and ions and exclude others.

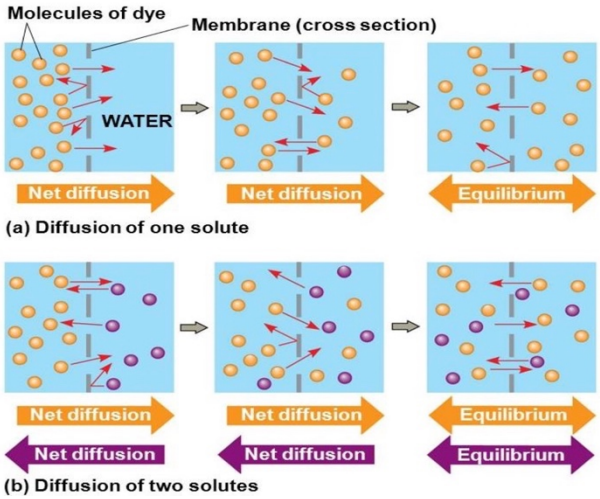
Non-polar hydrophobic molecules can dissolve in the lipid bilayer of the membrane and cross it easily, without the aid of membrane proteins.

Ions and polar hydrophilic molecules can't cross through the hydrophobic interior of the membrane.

So, they need the help of transport proteins:

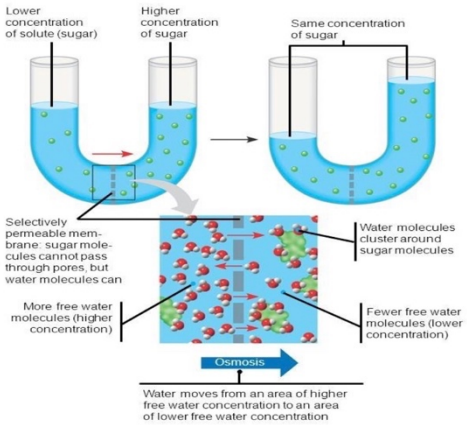
Channel proteins	Carrier proteins
Hydrophilic channel	Change its shape to transport
Very selective to water and ions	specific for the substance it moves
Aquaporins Ion channels 	Glucose transporter 

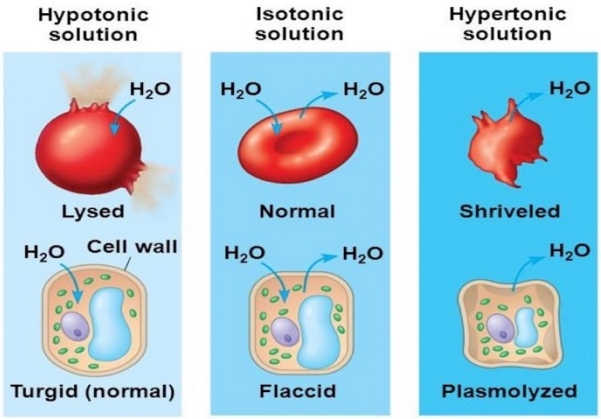
8.3: Passive Transport



- Diffusion: the movement of particles into the available space.
- a substance will diffuse from where its more concentrated to where its less concentrated. (Down its concentration gradient)
- diffusion is a spontaneous process, needing no input of energy.
- Dynamic Equilibrium: After a substance has diffused completely molecules will still be moving, but there will be no net movement of the number of molecules from one area to another.
- Passive transport: is the diffusion of molecules down their concentration gradient without the consumption of energy.
- Hydrophobic substance: simple diffusion.
- Hydrophilic substance: facilitated diffusion (needs transport proteins).

- Osmosis is the diffusion of water across a membrane.
- **Direction**: from higher water concentration to lower water concentration or from lower solute concentration to higher solute concentration.
- **Tonicity**: the ability of a surrounding solution to cause a cell to gain or lose water.
- It's affected by membrane permeability and concentration of non-penetrating solutes.
- **tonicity for animal cells: Isotonic**
- **tonicity for plant cells: hypotonic**





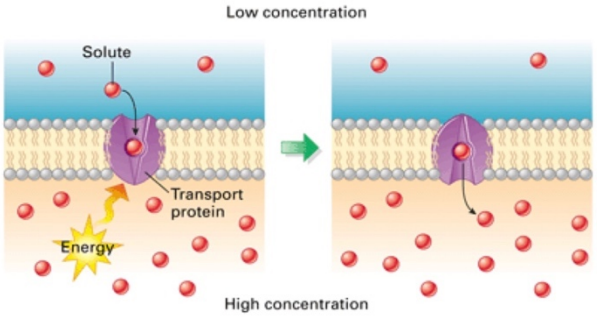
8.4: Active transport

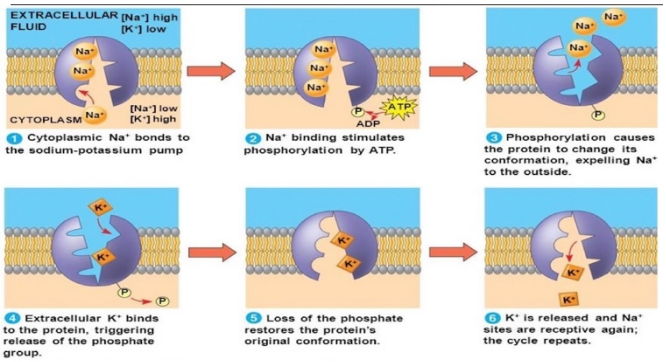
- the movement of a solute across a membrane against its concentration gradient with the use of energy.
- the transport proteins for active transport are all carrier proteins.
- Active transport enables a cell to maintain unique internal concentrations of small solutes. (Sodium-potassium pump)
- ATP supplies the energy for most active transport.
- because ions are charged molecules, there are two forces drive their diffusion across a membrane:

1) chemical: the ion's concentrations gradient.
2) Electrical: the effect of the membrane potential on the ion's movements.

When combined: electrochemical gradient

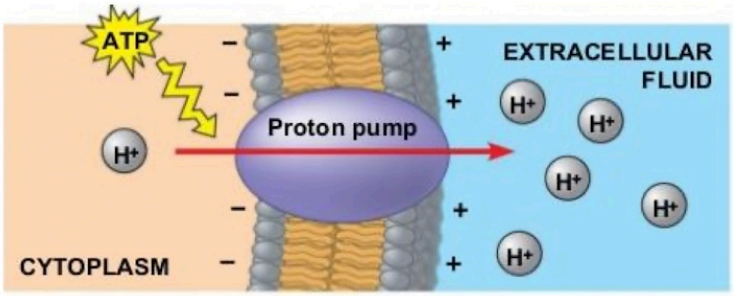
- The cytoplasmic side of the membrane is negative in charge relative to the extracellular side because of an unequal



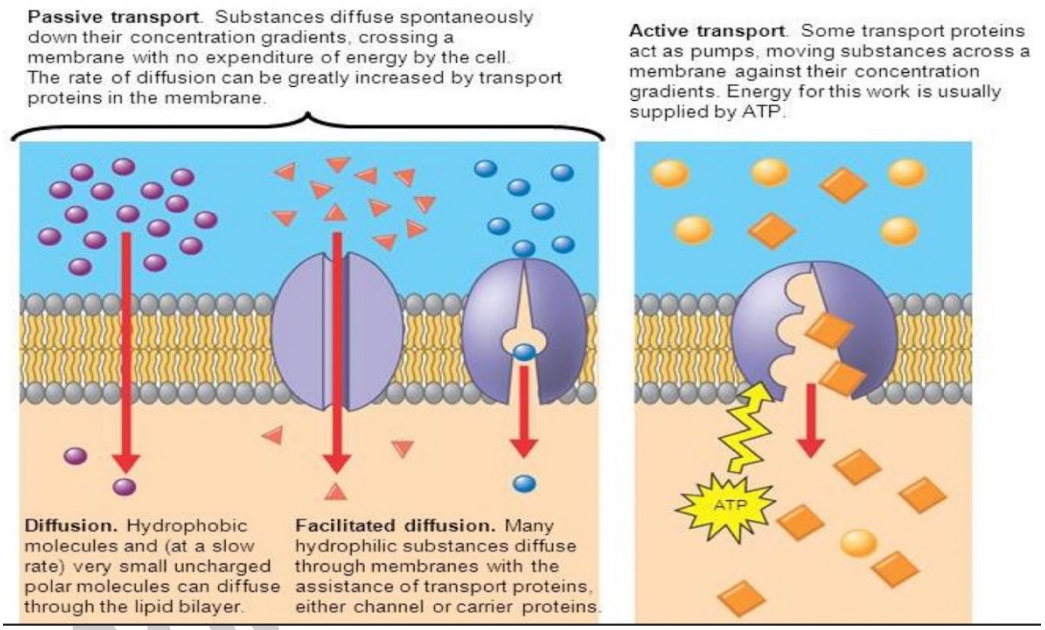


distribution of anions and cations on the two sides.

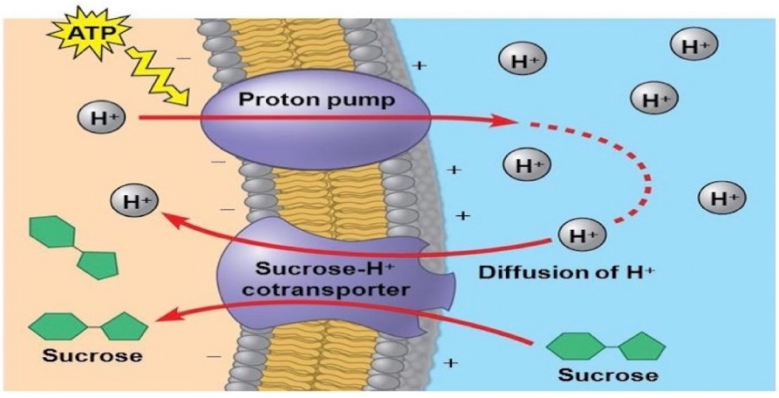
- This voltage is called membrane potential, it is a force that drives Cations into the cell and Anions out of it.
- Electro-Genic Pump: a transport protein that generates voltage across a membrane.
- Examples: Na+/K+ pump in animal cells, and H+ pump in plant cells, fungi, and bacteria.



Summary for passive and active transport:



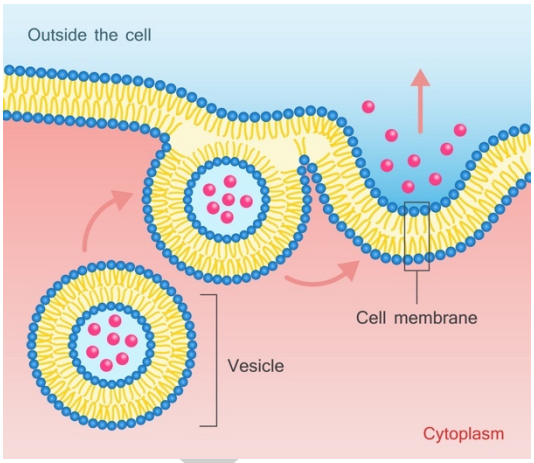
- Another type of active transport is Co-transport.
- Co- transporter protein couples the "downhill" passive diffusion of a substance to the “uphill” active transport of a second substance against its own concentration gradient.
- cotransport allows an ATP-powered pump to **indirectly** drive the active transport of a solute.
- H+/sucrose co-transporter is an



example in plant cells.

8.5: Endocytosis and Exocytosis

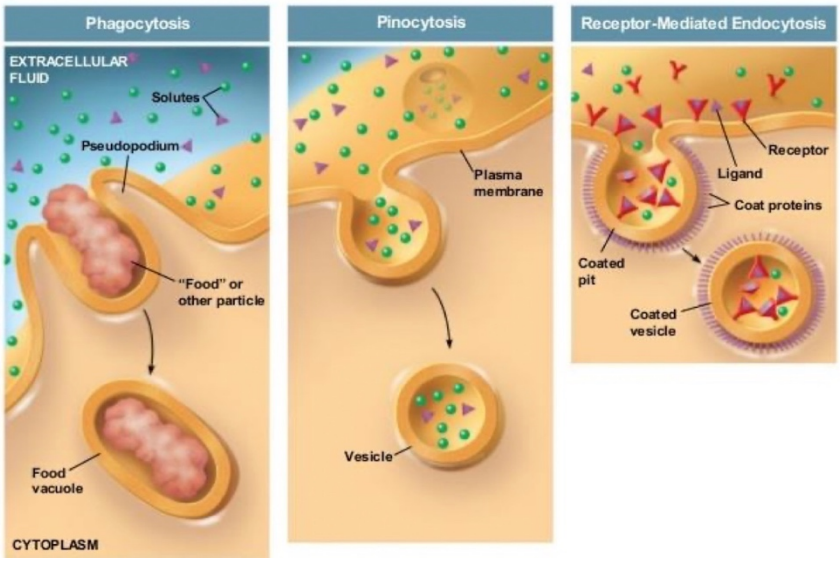
- Large molecules generally cross the membrane in bulk, packaged in vesicles and these processes require energy. (Active)
- Exocytosis: the cell secretes certain molecules by the fusion of vesicles with the plasma membrane.
- When the vesicles membrane and the plasma membrane come into contact, they fuse, and the vesicle contents spill out of the cell.
- The vesicle's membrane becomes part of the plasma membrane.
- Examples: insulin, neurotransmitters, cell walls.
- Endocytosis: the cell takes in molecules by forming new vesicles from the plasma membrane.



3 types of Endocytosis:

A. Phagocytosis: cell eating; pseudopodia of cell membrane engulf particles in a vesicle.

B. Pinocytosis: cell drinking; takes extracellular fluid with the molecules dissolved in it



C. Receptor mediated endocytosis: Bulk transport of specific molecules like cholesterol.

Boundary	حدود	Peripheral:	طرفي	bulk:	حزمة
mosaic	فسيفاء	Diffusion:	انتشار	pseudopodia:	أقدام كاذبة
embedded	مثبتة	Equilibrium:	اتزان	engulf:	يبتلع
transduction	نقل	Couples:	يدمج		

Chapter 6

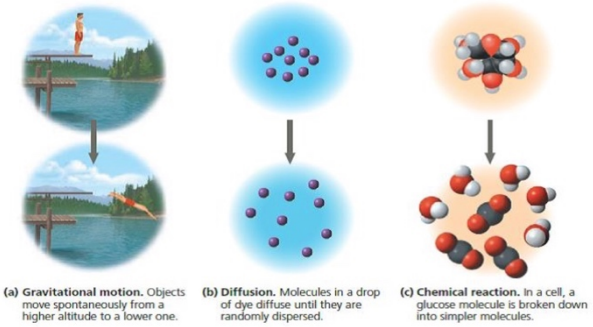
6.2: Free Energy

- It is the portion of a system's energy that can perform work when temperature and pressure are uniform throughout the system as in a living cell.
- It is a measure of a system's tendency to change to a more stable state.

$$\Delta G = \Delta H - T\Delta S \qquad \Delta G = G_{final} - G_{initial}$$

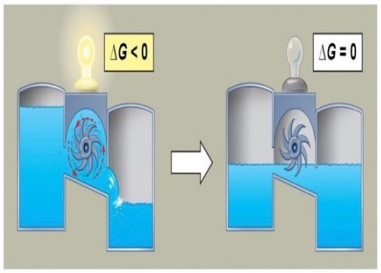
ΔG: free energy ΔH: Enthalpy ΔS: Entropy T: absolute temperature in (K)

- ΔG for a process can be used to predict whether the process will be spontaneous (negative) or if it needs energy (positive).
- ΔG can be negative only when the process involves a loss of free energy during the change from initial state to final state.
- Processes that have a positive or zero ΔG are never spontaneous.
- Unstable systems (higher G) tend to change in such a way that they become more stable (lower G).

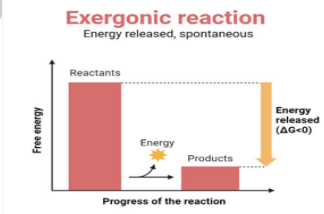
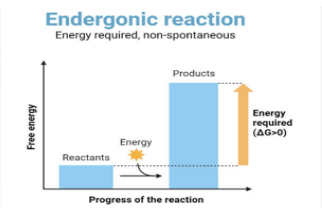


(a) Gravitational motion. Objects move spontaneously from a higher altitude to a lower one. **(b) Diffusion.** Molecules in a drop of dye diffuse until they are randomly dispersed. **(c) Chemical reaction.** In a cell, a glucose molecule is broken down into simpler molecules.

- chemical equilibrium of a reaction: when there is no further net change in the relative concentration of products and reactants.
- At equilibrium, ΔG is at its lowest possible value in that system (ΔG=0).

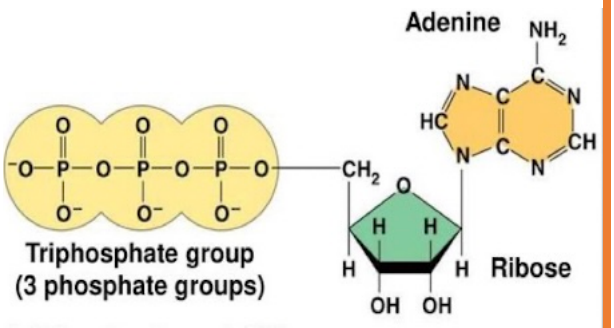


- **Living cells are never in equilibrium.**
- chemical reactions classification:

Exergonic Reactions	Endergonic Reactions
release of free energy	absorbs free energy
ΔG is negative	ΔG is positive
occur spontaneously	non spontaneous
Ex: Cellular respiration. ΔG= -686 kcal	Ex: photosynthesis ΔG= +686 kcal
	

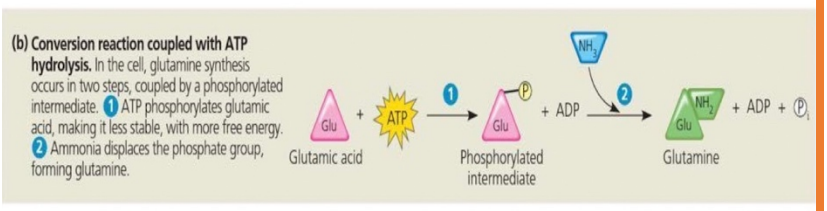
- If a chemical process is exergonic, then the reverse process must be endergonic.

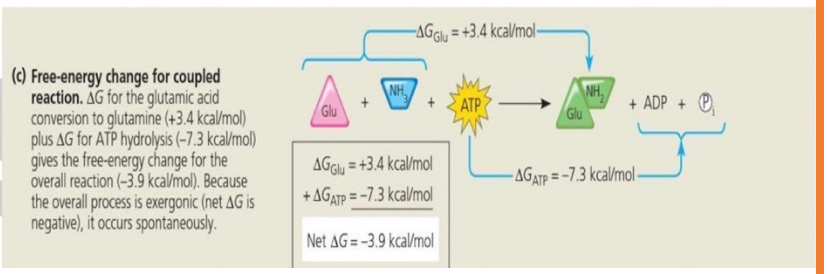
6.3: Energy Coupling through ATP



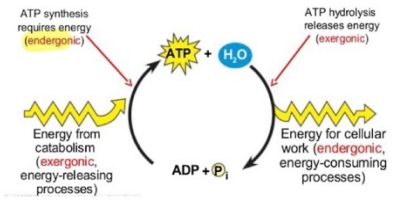
- Cellular work:
  1) chemical work: which pushes endergonic reactions that would not occur spontaneously.
  2) transport work: like pumping substances across membranes against the direction of spontaneous movement.
  3) mechanical work: such as the beating of cilia, the contraction of muscle cells, and the movement of chromosomes.

ATP:



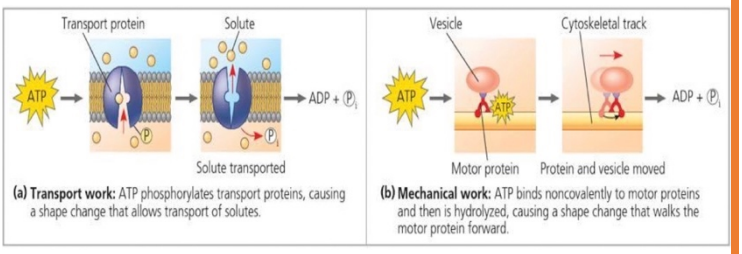


- ATP is responsible for mediating most energy coupling in cells.
- ATP (adenosine triphosphate nucleotide) consists of a ribose sugar, nitrogenous base (adenine), and three phosphate groups.
- a hydrolysis reaction breaks the terminal phosphate bond, and a molecule of inorganic phosphate is released.
- ATP hydrolysis is an exergonic reaction releasing 7.3 kcal of energy per mole of ATP hydrolyzed in standard conditions. (ΔG= -7.3 kcal)
- In the cell ΔG= -13 kcal.
- ATP is a renewable resource that can be regenerated by the addition of phosphate to ADP in an endergonic reaction.



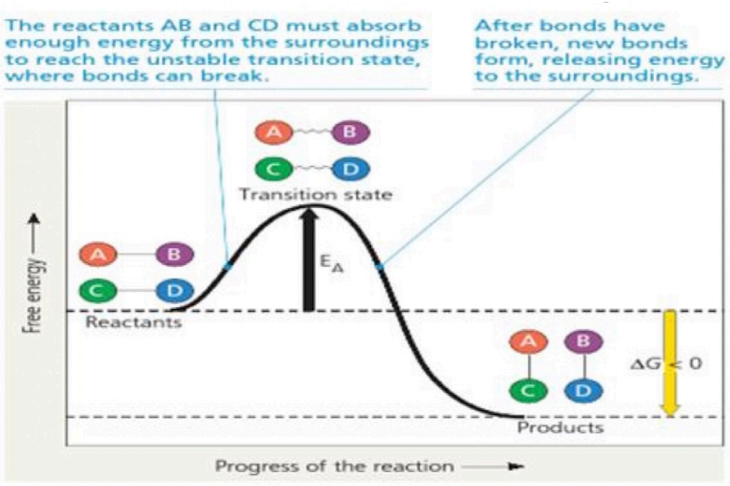
energy coupling:

- the use of an exergonic process to drive an endergonic one.
- If ΔG of an endergonic reaction is less in amount than the energy released by ATP hydrolysis, then the two reactions can be coupled so that, overall, the coupled reactions are exergonic.

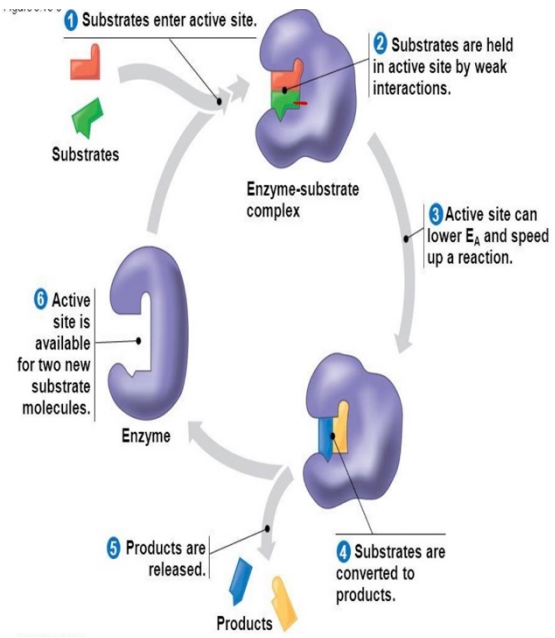


6.4: Enzymes

- A spontaneous chemical reaction occurs without any requirement for energy, **but it occurs slowly**.
- An enzyme is a macromolecule that acts as a catalyst; speeding up a reaction without being consumed. It can be a Protein or RNA (ribozyme).
- Activation energy EA: the initial investment (use) of energy for starting a reaction.
- EA is so high that the transition state is rarely reached, so the reaction will occur only if:
  1. Energy is provided, usually by heat. this would not work in cells because high temperature denatures proteins and it's not specific.
  2. catalytic agents are used, enzymes speed up reactions by lowering the EA barrier; enzymes do not change G_i, G_f, or ΔG; they cannot make an endergonic reaction exergonic.



- Active site: a pocket or groove on the surface of the enzyme where catalysis occurs formed by only a few of the enzyme's amino acids.
- As the substrate enters the active site, the enzyme changes shape slightly due to interactions between the substrate's chemical groups and chemical groups on the side chains (R groups) of the amino acids that form the active site. This is called induced fit.
- the more the substrate concentration, the more they access the active sites of the enzyme molecules, the more the reaction is catalyzed.



- When all the enzymes are occupied:

1. The enzyme is said to be saturated.
2. The rate of the reaction is determined by the speed at which the active site converts substrate to product (not the initial concentration of the substrate).
3. The only way to increase the rate of product formation is to add more enzymes.

Factors affecting Enzymes:

Temperature: when increased, the rate of the reaction increases until we reach the optimal temperature.

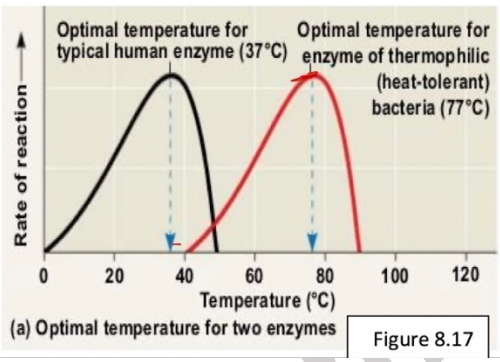
Above that temperature, the speed of the enzymatic reaction drops sharply.

Each enzyme has an optimal temperature at which its reaction rate is greatest.

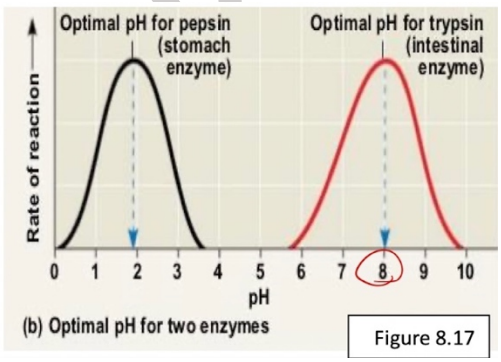
human enzymes: 35 - 40 °C. thermophile bacteria: 70°C or higher.

Each enzyme also has an optimal pH value at which it is most active:

most enzymes: pH=6-8 pepsin (stomach):pH=2 trypsin (intestine): pH=8



(a) Optimal temperature for two enzymes Figure 8.17



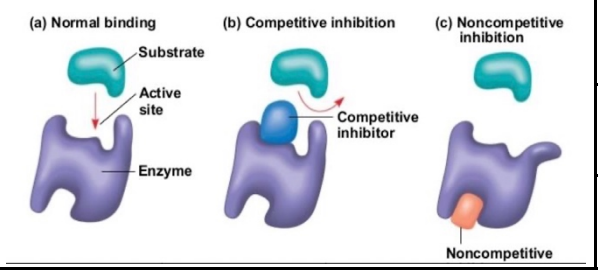
(b) Optimal pH for two enzymes Figure 8.17

Cofactors:

- They are non-protein helpers for catalytic activity for the enzymes.

Two types: inorganic (metals like zinc, iron), and organic cofactors which are called coenzymes (vitamins).

Enzyme inhibitors

irreversible	reversible	
Covalent bonds	weak interactions	
include toxins and poisons	**competitive**	**Noncompetitive**
	Bind the active site	Doesn't Bind the active site
	Looks like substrate	Doesn't Looks like substrate
	can be overcome by increasing substrate	Can't be overcome by increasing substrate

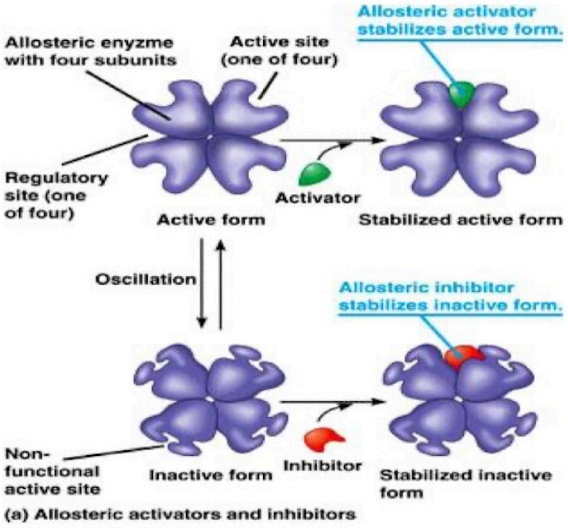
	concentration	concentration

- Many antibiotics are inhibitors of specific enzymes in bacteria. Penicillin blocks the active site of an enzyme that bacteria use to build their cell walls.

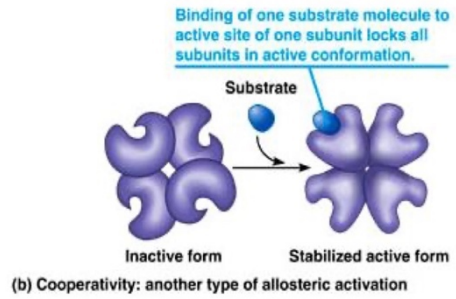
6.5: Regulation of enzyme activity

Allosteric regulation:

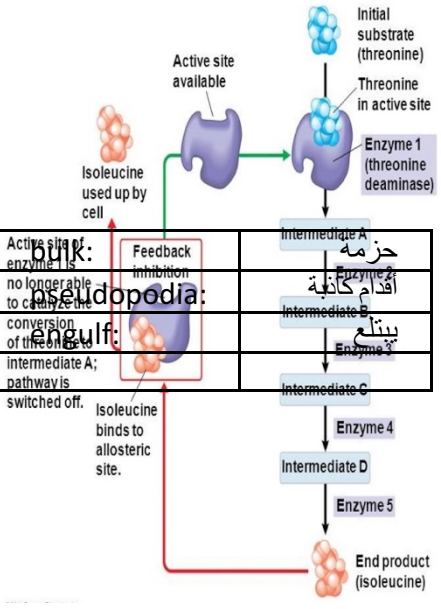
- Any case in which a protein's function at one site is affected by the binding of a regulatory molecule to a separate site.
- allosteric enzymes: are constructed from two or more subunits, and each subunit is composed of a polypeptide chain with its own active site.
- has two different shapes: Active and inactive



- The binding of an activator to a regulatory site stabilizes the shape that has functional active sites.
- binding of an inhibitor stabilizes the inactive form of the enzyme.
- A single activator or inhibitor molecule that binds to one regulatory site will affect the active sites of all subunits.



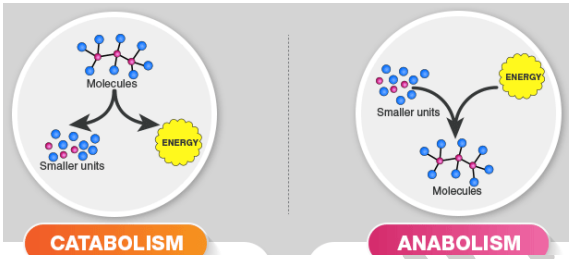
- Cooperativity: substrate molecule binding to one active site in a multi-subunit enzyme triggers a shape change in all the subunits. (hemoglobin)
- Feedback inhibtion: when a metabolic pathway is inhibited by the binding of its end product to an enzyme that acts early in the pathway.



portion	جزء	Exergonic	طارد للطاقة	bulk:	حزمة
tendency	قابلية	Endergonic	ماص للطاقة	pseudopodia:	أقدام كاذبة
Enthalpy	حرارة	regulatory:	تنظيمي	engulf:	يبتلع
spontaneous	تلقائي	Couples:	يدمج		

Chapter 10

10.1: Catabolic Pathways and Energy

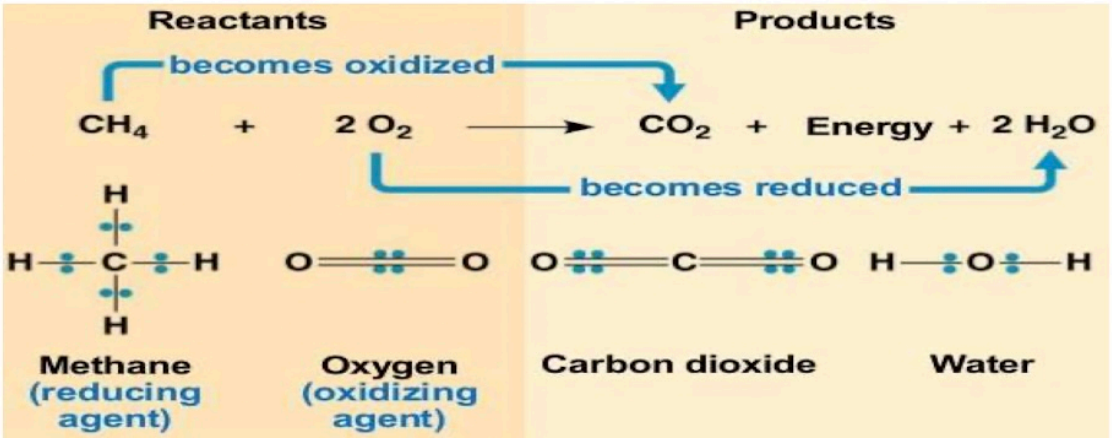


- Metabolism: catabolism + anabolism.
- Anabolic pathways: require energy to synthesize larger molecules. (endergonic)
- Catabolic pathways: release energy by breaking down large molecules. (exergonic)

Examples:

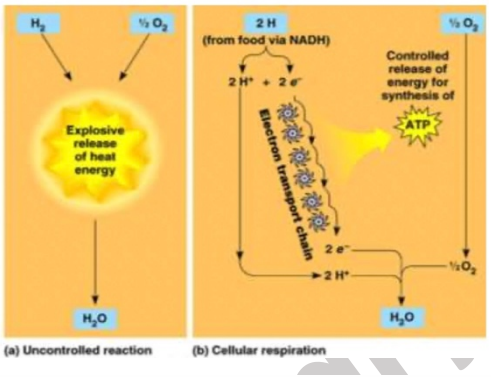
1. Fermentation: partial degradation of organic fuel without the use of oxygen.
2. Aerobic respiration: the most effective and in which oxygen is used.
3. Anaerobic respiration: like aerobic but with the use of substances other than oxygen.

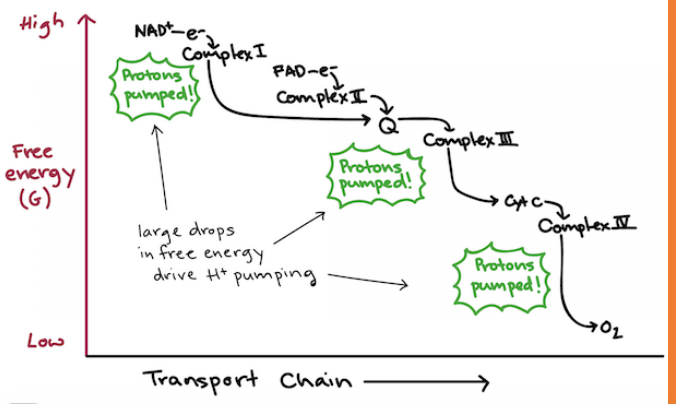
- Cellular respiration is a complicated process that includes both aerobic and anaerobic processes.
- However, it originated as a synonym for aerobic respiration.
- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy (ATP + heat) ΔG = -686 kcal/mol
- Catabolism is linked to work by (ATP), To keep working ATP must be regenerated from ADP and Pi.
- The relocation of electrons releases energy stored in organic molecules, and this energy is used to make ATP.
- oxidation and reduction reactions: a transfer of one or more electrons from one reactant to another.
- Oxidation: loss of electrons — Reduction: addition of electrons
- Reducing agent: electron donor — oxidizing agent: electron acceptor

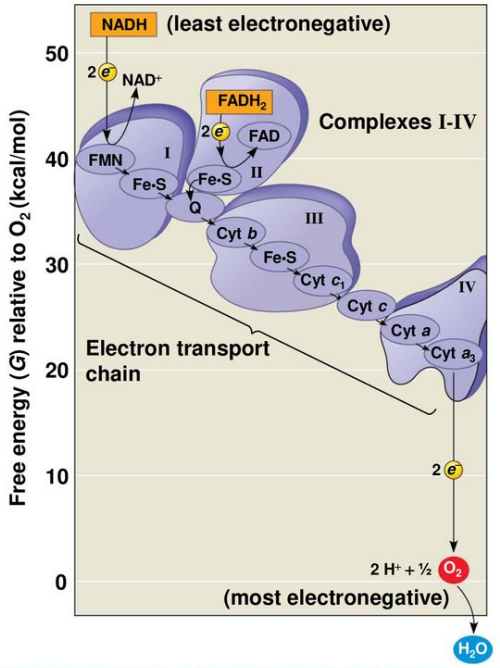


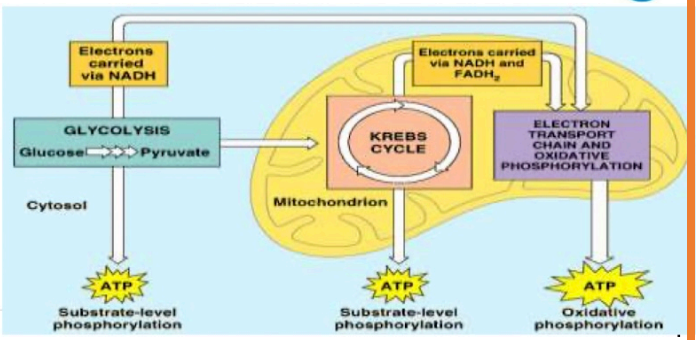
- an electron loses potential energy when it shifts from a less electronegative atom toward a more electronegative one.

- Cellular respiration doesn't oxidize glucose in a single explosive step.
- glucose is broken down in a series of steps, each catalyzed by a specific enzyme.
- The hydrogen atoms are passed to an electron carrier, a co-enzyme called nicotinamide adenine dinucleotide (NAD) before reaching oxygen.
- NAD can cycle easily between its oxidized form NAD^+ and its reduced form NADH.
- Enzymes called dehydrogenases remove a pair of hydrogen atoms (2 electrons and 2 H^+) from glucose to NAD^+ forming NADH.
- Electrons lose very little of their potential energy when they are transferred from glucose to NAD^+.
- This means that each NADH molecule formed during respiration represents stored energy that can be used to make ATP.
- Electron transport chain: consists of several molecules, mostly proteins, built into the inner membrane of the mitochondria of eukaryotic cells and the plasma membranes of prokaryotes.
- NADH shuttles the electrons removed from glucose (highest energy) down the chain from one carrier molecule to the next in a series of redox reactions, losing a small amount of energy with each step until they finally reach oxygen (lowest energy). ΔG = -53 kcal/mol.
- Each downhill carrier is more electronegative than, and thus capable of oxidizing its uphill neighbor, with oxygen at the bottom (most electronegative).

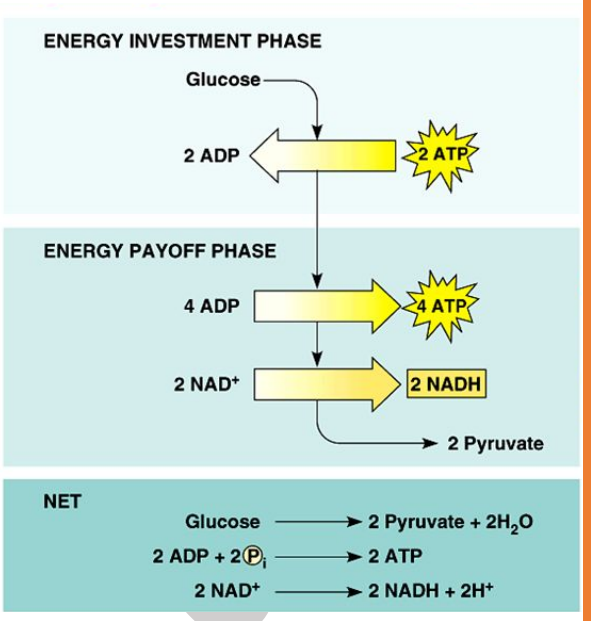




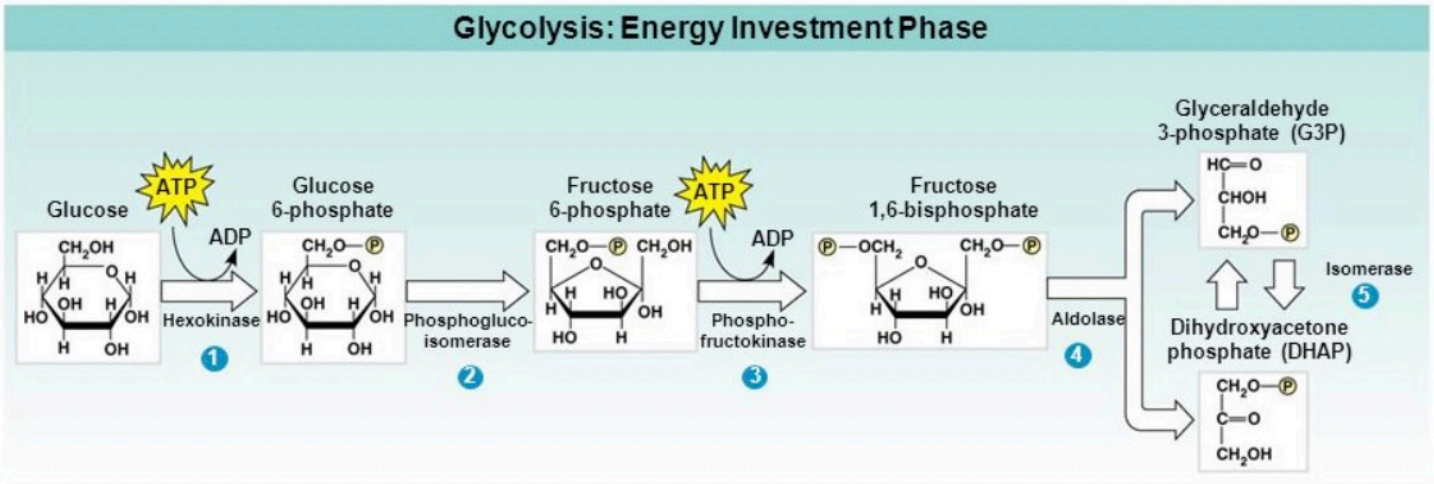


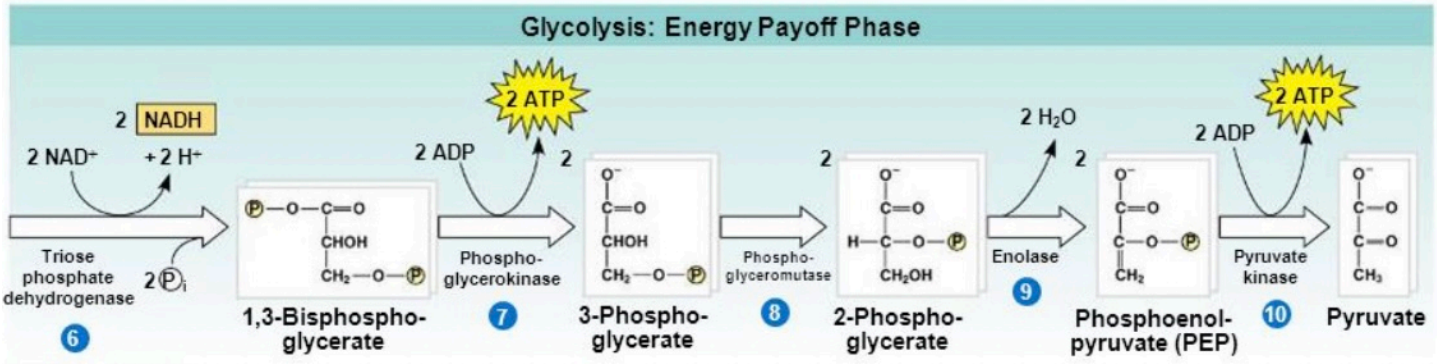


10.2: Glycolysis



- In glycolysis, glucose is split into two three-carbon sugars called pyruvate.
- two phases:
  1. energy investment phase: spends 2 ATP
  2. energy payoff phase: gains 4 ATP + 2NADH
- ATP is produced through substrate level phosphorylation which is the direct transfer of phosphate group from an organic substrate to ADP by enzymes.
- It occurs whether O_2 is present or not.
- If O2 is present, the chemical energy stored in pyruvate and NADH can be extracted by pyruvate oxidation, the citric acid cycle and oxidative phosphorylation.
- No carbon is released as CO_2 during glycolysis.

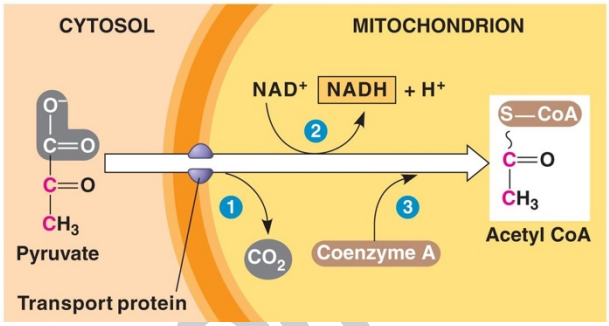


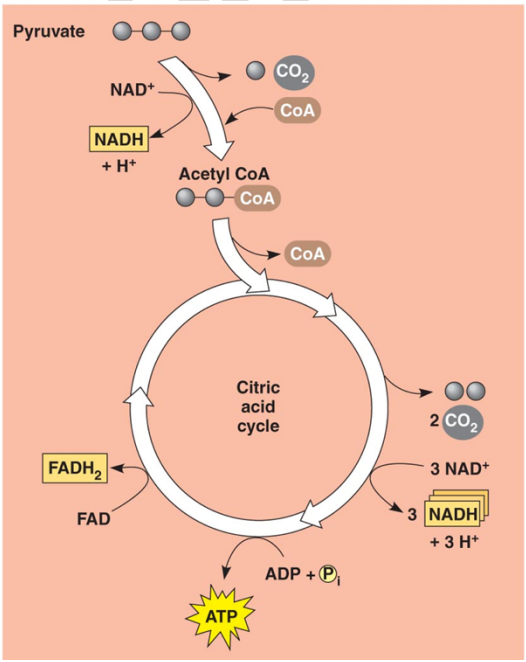


- Kinase: add phosphate to the substrate. Isomerase: change the shape.
  Dehydrogenase: transfer electrons to NAD^+ creating NADH.

10.3: Pyruvate Dehydrogenase and Citric Acid Cycle

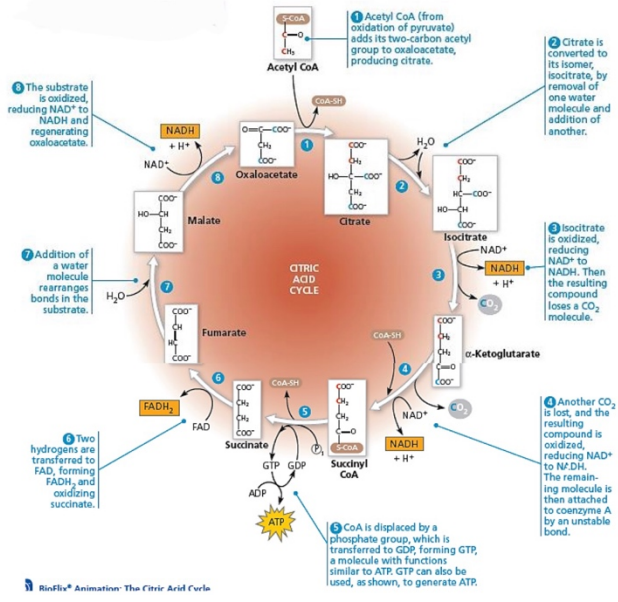
- **In the presence of O_2**, Pyruvate enters the mitochondrion to complete glucose oxidation in Eukaryotes.
- In prokaryotes this happens in the cytosol.
- Pyruvate enters the mitochondrion via active transport to be oxidized into acetyl coenzyme A (acetyl CoA) through a multi-enzyme complex called: pyruvate dehydrogenase complex.
- Three reactions:
  1) Pyruvate's carboxyl group-COO is released as a molecule of CO_2.
  2) The remaining 2 carbons are oxidized giving off NADH molecule.
  3) Acetyl CoA is formed (contains sulfur).





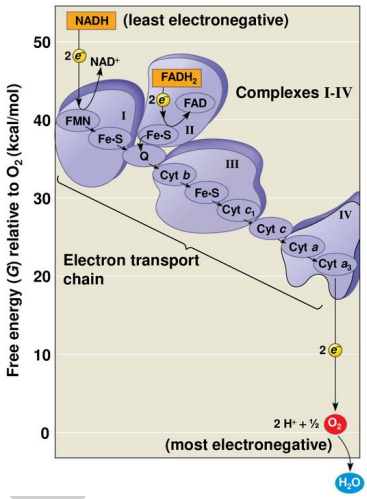
Citric Acid/ Kreps Cycle

- Each acetyl CoA that enters the cycles produces: **1 ATP, 3 NADH, 1 $FADH_2$ and 2CO_2**
- remember that each glucose makes 2 Acetyl CoA
- the citric acid cycle consists of 8 steps with different enzymes.
- all the citric acid cycle enzymes are in the mitochondrial matrix except for the enzyme that catalyzes step 6, which resides in the inner mitochondrial membrane.
- **The cycle starts with Oxaloacetate and ends with it.**
- FAD: flavin adenine dinucleotide derived from riboflavin (vitamin B).

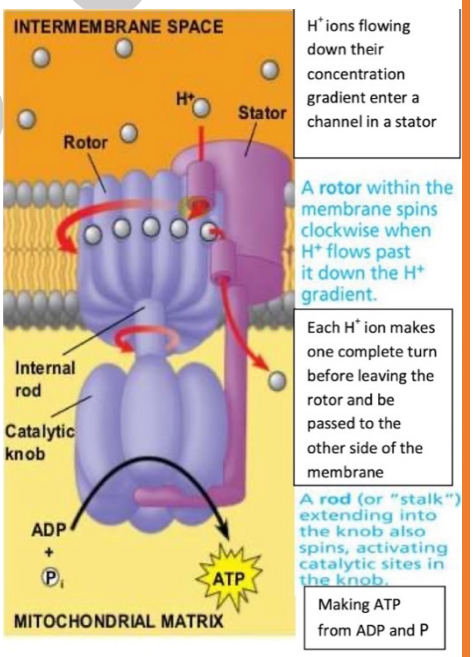


- In many cells the reaction produces a guanosine triphosphate GTP by substrate level phosphorylation.

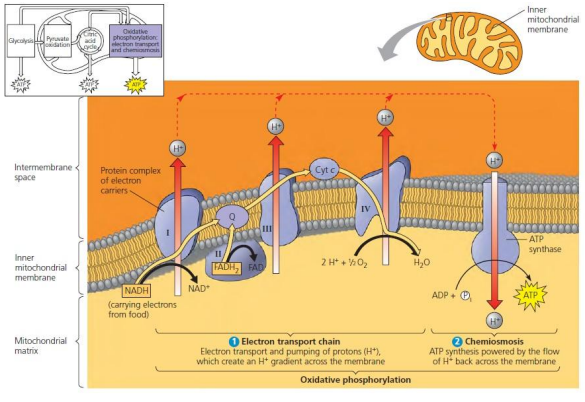
10.4: Electron Transport Chain



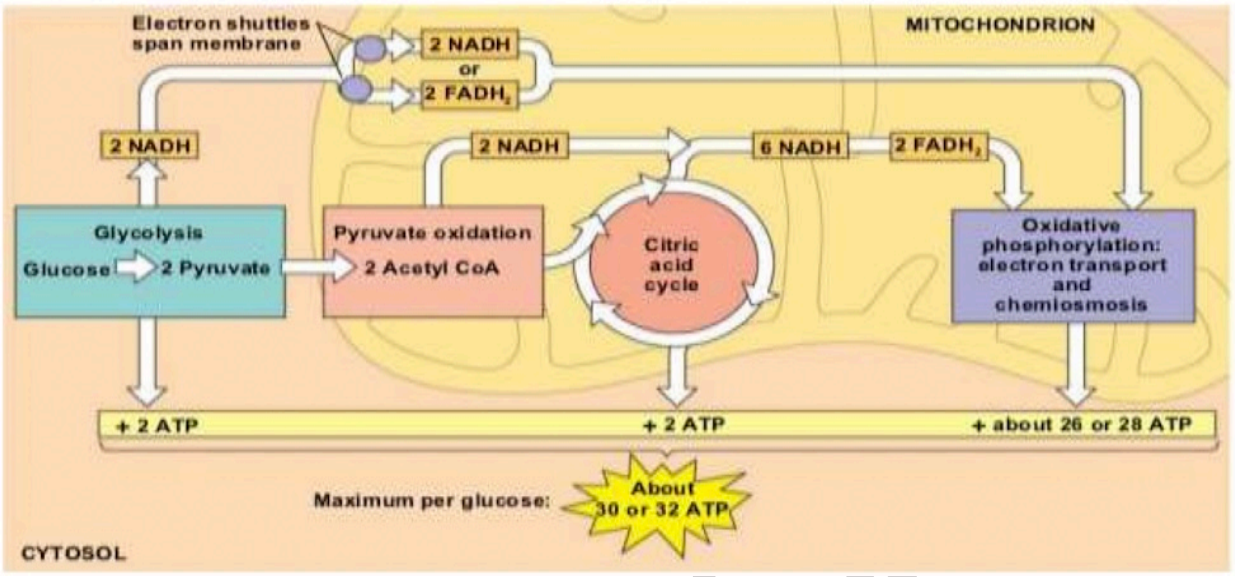
- At this stage, we want to convert the potential energy that is stored in NADH and $FADH_2$ into ATP.
- Most components of the chain are proteins which exist in multi-protein complexes numbered I through IV.
- Prosthetic groups: non-protein components essential for the catalytic functions of certain enzymes.
- Complex (I) is a flavoprotein that has a prosthetic group called flavin mononucleotide (FMN).
- Q (ubiquinone) electron carrier: is a small hydrophobic molecule, the only none-protein member.
- It is mobile within the membrane rather than residing in a particular complex, also Called coenzyme Q.
- Other electron carriers are proteins called cytochromes that contains a heme group (has iron).
- When Oxygen is reduced, it forms water
- $FADH_2$ adds its electrons from within complex II, at a lower energy level than NADH does.
- NADH has more energy than $FADH_2$.
- Chemiosmosis (energy-coupling) is the process in which energy stored in the form of a hydrogen ion gradient across a membrane is used to drive cellular work such as the synthesis of ATP.



- The exergonic flow of electrons from NADH and FADH2 is used to pump H^+ creating an electrochemical gradient that drives the production of ATP through the enzyme ATP synthase. This process is called **oxidative phosphorylation**.
- Proton-motive force is the H+ gradient across the inner mitochondrial membrane.
- ATP synthase is a multi-subunit complex with four main parts (stator, rotor, rod, knob)
- chloroplasts use chemiosmosis to generate ATP during photosynthesis.



- Prokaryotes generate H+ gradient across their plasma membrane and use it for their flagella and to pump nutrients across the membranes.
- Summary for cellular respiration:

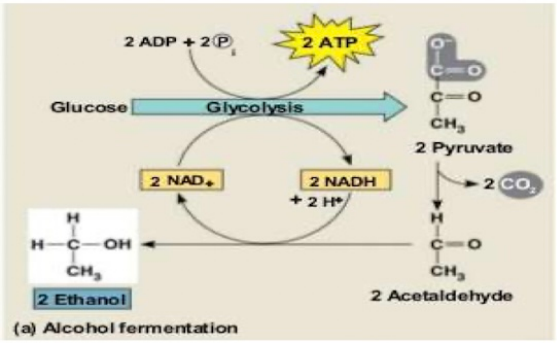


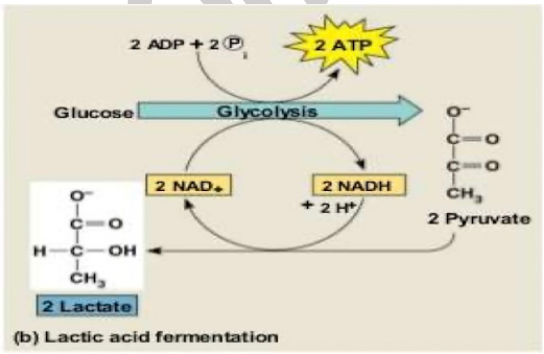
- Total ATP production is either 30 or 32, **why is this the case**?
  1. Phosphorylation and the redox reactions are not directly coupled to each other, so the ratio of the number of NADH molecules to the number of ATP molecules is not a whole number.
     1 NADH = 10 H^+ pumped 4 H^+ = 1 ATP 1 NADH= 2.5 ATP
     1 $FADH_2$= 1.5 ATP
  2. The type of shuttle used to transport electrons from the cytosol into the mitochondrion.
  3. The use of the proton-motive force to drive other kinds of work like the uptake of pyruvate from cytosol.
- If all the proton-motive force were used to drive ATP synthesis, one glucose could generate a maximum of 28 ATP produced by oxidative phosphorylation + 4 ATP from substrate-level phosphorylation.
- for glucose oxidation = -686 kcal/mol, for ATP hydrolysis ΔG = -7.3 kcal/mol for 32 ATP ΔG = -233.6 kcal/mol. 34% of the potential energy stored in glucose is used to make ATP while the rest is lost as Heat.
- Brown fat is made up of cells packed full of mitochondria, the inner mitochondrial membrane contains a channel protein called the **uncoupling protein** that allows protons to flow back down their concentration gradient without generating ATP.

- Activation of these proteins in hibernating mammals results in generating heat.

10.5: Fermentation and Anaerobic Respiration

- anaerobic respiration takes place in prokaryotes that live in environments without oxygen, they have an electron transport chain, but they do not use oxygen as a final electron acceptor.
- Some use sulfur producing H_2S as a by-product instead of water.
- Fermentation is an extension of glycolysis that allows continuous generation of ATP by the substrate-level phosphorylation.
- For this happen, NADH must be recycled to NAD^+ to accept electrons during the oxidation step of glycolysis. this is done by transferring electrons from NADH to pyruvate.





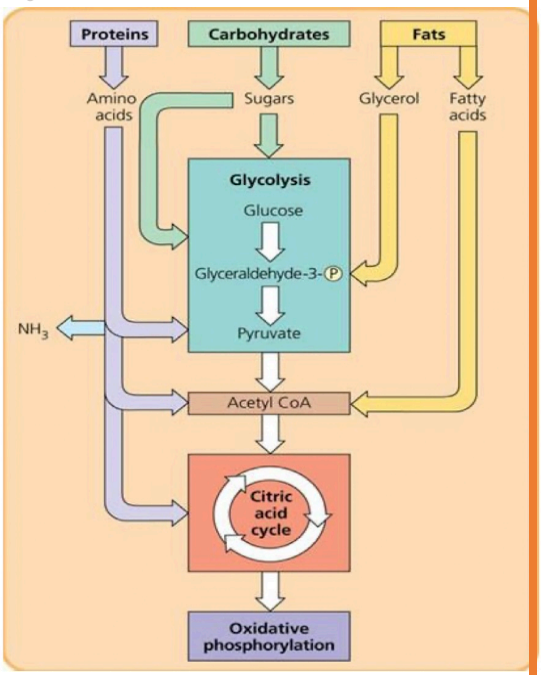
- **Two types of fermentation:**
  1. Alcohol fermentation: the final product is Ethanol.
     Uses: bacteria, yeast, and humans for baking.
  2. Lactic acid fermentation: the final product is Lactate.
     Uses: cheese and yoghurt, muscles during exercise.
- Fermentation, anaerobic respiration, and aerobic respiration are three alternative cellular pathways for producing ATP by harvesting the chemical energy of food.
- All use glycolysis to oxidize glucose to pyruvate, with a net production of 2 ATP by substrate-level phosphorylation.
- In all three pathways NAD^+ is the oxidizing agent that accepts electrons during glycolysis.
- The difference is in the mechanism of oxidizing NADH back to NAD^+ and in the amount of ATP produced:
  Fermentation: the final electron acceptor is pyruvate with 2 ATP molecules.
  Cellular respiration: NADH is transferred to the electron transport chain with 32 ATP molecules.

- Obligate anaerobes: carry out only fermentation or anaerobic respiration, they cannot survive in the presence of oxygen.
- Facultative anaerobes: make ATP using fermentation or respiration, like some bacteria and yeast.
- An important example is our muscle cells: under aerobic conditions, pyruvate can be converted to acetyl CoA, and oxidation continues in the citric acid cycle, however, under anaerobic conditions, lactic acid fermentation occurs, and to make the same amount of ATP it must be repeated several times.
- Brain cells can use aerobic respiration only.

10.6: Glycolysis and the citric acid cycle connections to other pathways.

In anabolism:

- intermediates of glycolysis and citric acid cycle can be used in anabolic pathways to synthesize the molecules that the cell requires.
- Humans can make about half of the 20 amino acids by modifying compounds from the citric acid cycle, the rest are "essential amino acids" that must be obtained in the diet.
- Glucose can be made from pyruvate, and fatty acids can be synthesized from acetyl CoA.

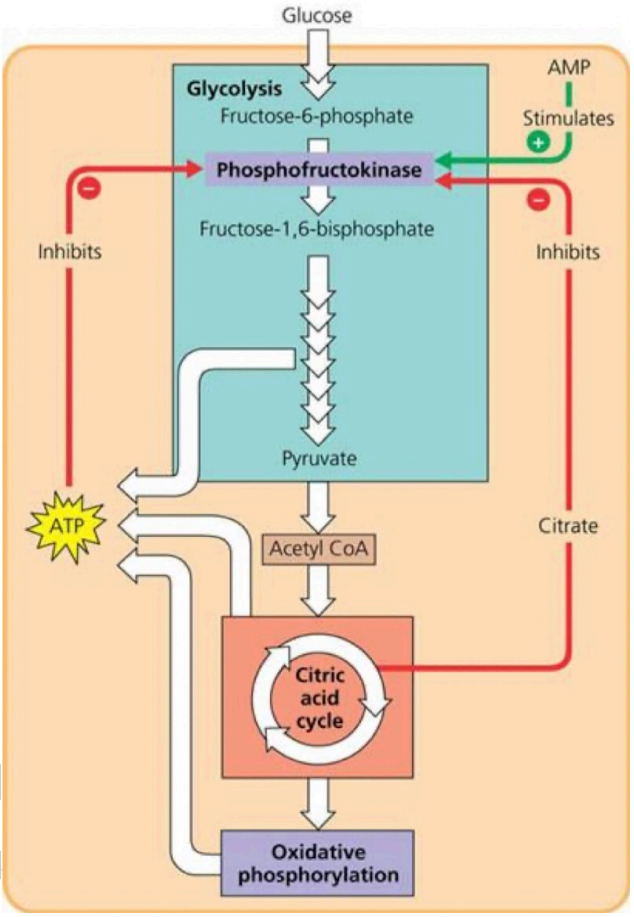


In catabolism:

- Starch, glycogen, and disaccharides are hydrolyzed to glucose.
- Proteins are digested into amino acids and when there is excess in them, they are converted by enzymes to intermediates of glycolysis and the citric acid cycle.
- their amino groups must be removed, a process called Deamination.
- Fats are digested to glycerol and fatty acids, the glycerol is converted to G3P, beta oxidation breaks the fatty acids down to two-carbon fragments, which enter the citric acid cycle as acetyl CoA.
- NADH and FADH2 are also generated during beta oxidation; they can enter the electron transport chain, leading to further ATP production.
- Fats are excellent fuels because of the many C-H bonds.
- A gram of fat oxidized by respiration produces more than twice as much ATP as a gram of carbohydrate.

Regulation of Cellular Respiration:

- Feedback inhibition happens when the end product of the metabolic pathway inhibits the enzyme that catalyzes an early step of the pathway.
- when ATP concentration drops, respiration speeds up. When there is excess ATP, respiration slows down.
- **Phosphofructokinase is considered the pacemaker of respiration**, by controlling the rate of this step, the cell can speed up or slow down the entire catabolic process.



Metabolism	عمليات الأيض	shuttles	ينقل	hibernating	السبات الشتوي
Fermentation	التخمر	redox reactions	التأكسد والاختزال	harvesting	يحصد
Aerobic	هوائي	derived	مشتق	Obligate	اجباري
relocation	تغيير موقع	convert	يحول	Facultative	اختياري

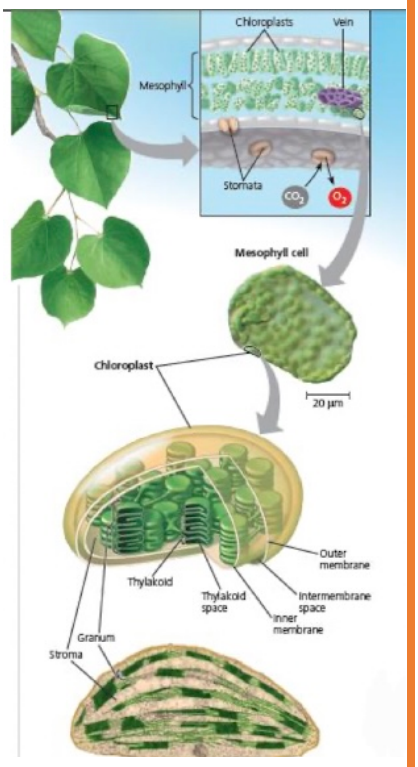
Chapter 11

11.1:

- Photosynthesis: the process of conversion of light energy from the sun to chemical energy stored in sugar and other organic compounds.
- This is done through chloroplasts.
- Two types of organisms based on the way they feed:

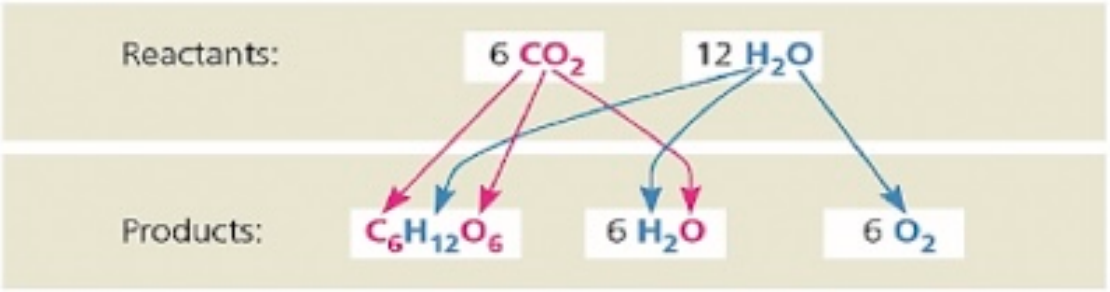
Autotrophs	Heterotrophs
producers	consumers
produce their food from CO2	unable to make their own food
Source of organic compounds for all organisms	depend -either directly or indirectly- on photoautotrophs for food and oxygen
Plants, algae, and certain prokaryotes are autotrophs	Some heterotrophs consume the remains of other organisms (decomposers)
require water, minerals, and CO2	

Chloroplasts:



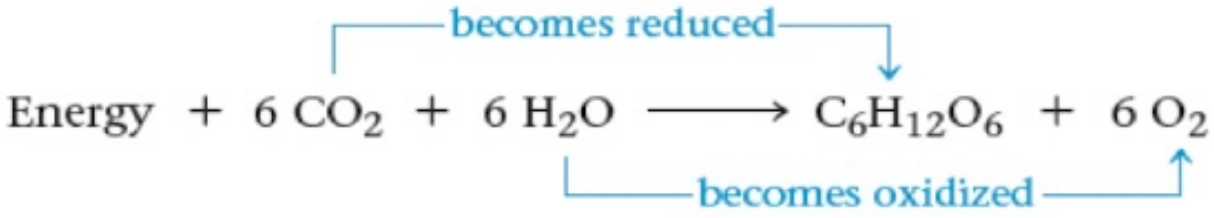
- the leaves are the major sites of photosynthesis.
- Chloroplasts are found mainly in the cells of the mesophyll (interior of the leaf).
- They are green because of the chlorophyll.
- CO_2 enters the leaf, and O_2 exits, through pores called stomata.
- A chloroplast has two membranes surrounding a dense fluid called the stroma.
- Suspended within the stroma is a third membrane system, made up of sacs called thylakoids.
- when thylakoid sacs are stacked in columns it's called grana.
- chlorophyll is the green pigment that gives leaves their color and absorbs light energy from the sun.
- it resides in the thylakoid membranes of the chloroplast.
- Chloroplasts also contain stroma, a dense interior fluid

- Tracking Atoms Through Photosynthesis:
  $6\ CO_2 + 12\ H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$
  $6\ CO_2 + 6\ H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$
- photosynthesis is the reverse of cellular respiration; both occur in plant cells.
- The chloroplast splits water into hydrogen and oxygen, incorporating the electrons of hydrogen into sugar molecules and releasing oxygen as a by-product.
- O_2 given off by plants is derived from H_2O and not from CO_2.

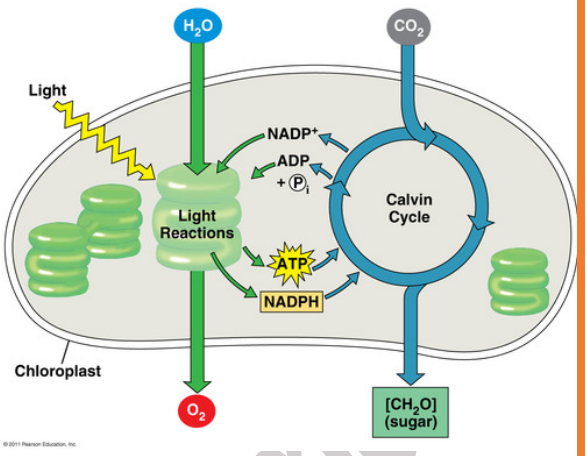


$$\text{Sulfur bacteria: } CO_2 + 2\,H_2S \rightarrow [CH_2O] + H_2O + 2\,S$$
$$\text{Plants: } CO_2 + 2\,H_2O \rightarrow [CH_2O] + H_2O + O_2$$
$$\text{General: } CO_2 + 2\,H_2X \rightarrow [CH_2O] + H_2O + 2\,X$$

- photosynthesis also involves redox reactions.
- It reverses the direction of electron flow in cellular respiration; one H_2O is split, and its electrons are transferred along with hydrogen ions (H^+) from the water to carbon dioxide, reducing it to sugar.
- Photosynthesis is an endergonic process; the energy boost is provided by light

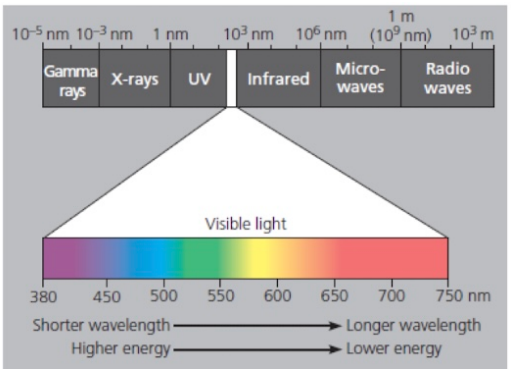


- Photosynthesis is divided into two processes:
  1. light reactions: thylakoid
     water is split into electrons, H^+, and O^2.
     light energy reduces NADP+ into NADPH
     generates ATP through chemiosmosis (photophosphorylation)
  - the products are: ATP (energy)
    NADPH (reducing power)

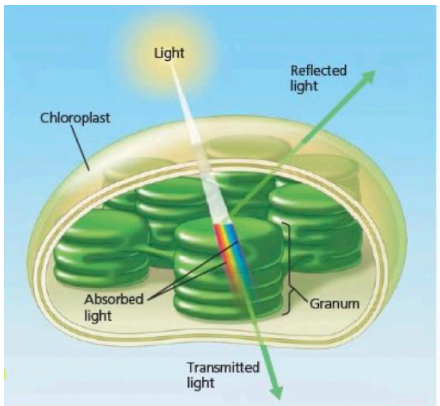


  2. Calvin cycle: stroma
     a) uses CO_2 found in the air to produce G3P sugar.
     b) Uses ATP and NADPH from the light reactions.
     c) Known as dark reactions or light independent.
     d) Occurs in daylight.
     e) Has 3 phases: carbon fixation, reduction, regeneration of CO_2 acceptor.

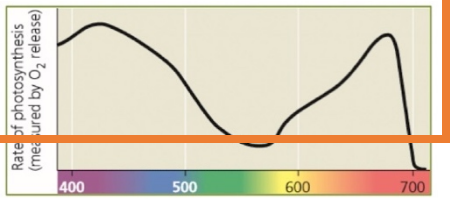
11.2: light reactions



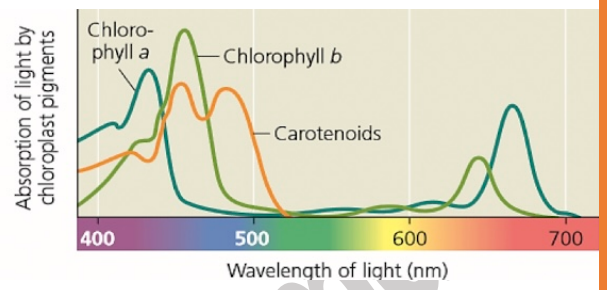
- Nature of light: electromagnetic energy, it travels in rhythmic waves.
- Wavelength: the distance between the crests of waves.
- Wavelength determines the type of electromagnetic energy.
- Visible light is the radiation that drives photosynthesis.
- Light is made of particles called photons each of them has a fixed quantity of energy.



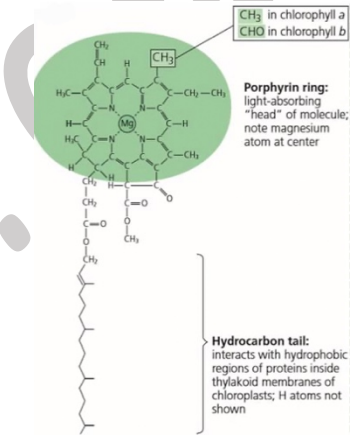
- Pigments: Substances that absorb visible light, different pigments absorb light of different wavelengths.
- Wavelengths that are not absorbed are reflected or transmitted.
- Leaves appear green because chlorophyll reflects and transmits green light.
- chlorophyll absorbs violet-blue and red light while transmitting and reflecting green light.



- action spectrum: profiles the relative effectiveness of different wavelengths of radiation in driving the process.
- The action spectrum for photosynthesis is much broader than that of chlorophyll. Why?
- because accessory pigments with different absorption spectra also present in chloroplasts.
- three types of pigments in chloroplasts:

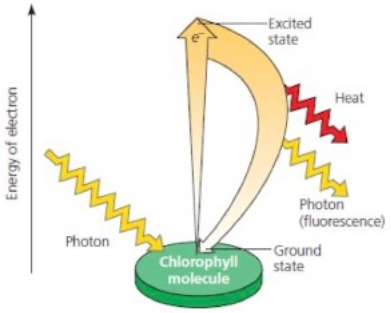


  Chlorophyll A: the main pigment.
  Chlorophyll B: an accessory pigment.
  Carotenoids: a separate group of accessory pigments. Absorbs violet, blue, and green. (Appears orange)

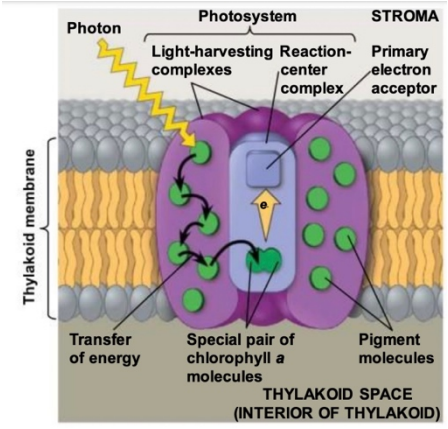


- Carotenoid function is photo-protection by absorbing excessive energy that can damage chlorophyll A and has a protective function in the human eyes as well.

- When a pigment absorbs light, it goes from a ground state to an excited state, which is unstable.
- When excited electrons fall back to the ground state, photons are given off, as light and heat.



- Photosystem: consists of a protein reaction-center complex surrounded by light-harvesting complexes that transfer the energy of photons to the center.
- Photosystems are in the thylakoid membrane.
- The light-harvesting complexes are pigments bound to proteins.
- A primary electron acceptor in the reaction center accepts excited electrons and is reduced as a result.
- Solar-powered transfer of an electron from chlorophyll A molecule to the primary electron acceptor is the first step of the light reactions.

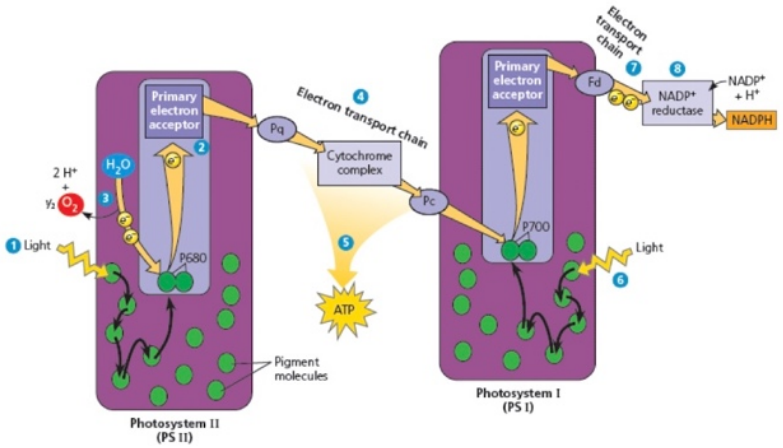


- Two types of photosystems:

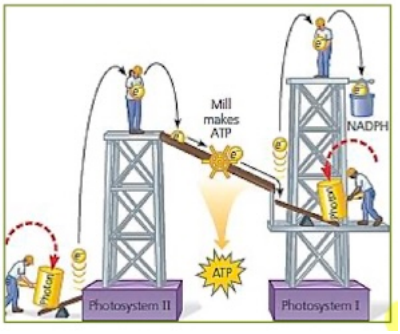
Photosystem I	Photosystem II

Functions second	Functions first
Discovered first	Discovered second
absorbing light of wavelength 700mm	absorbing light of wavelength 680mm
Reaction center: P700	Reaction center: P680

- P680 and P700 are nearly identical, but their association with different proteins results in different light-absorbing properties.
- Linear electron flow involves the flow of electrons through the photosystems and other molecules embedded in the thylakoid membrane to produce ATP and NADPH using light energy.



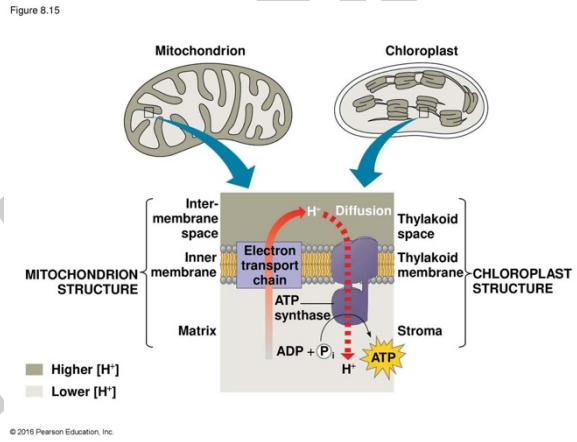
1. A photon hits a pigment, and its energy is passed among pigment molecules until it excites P680.
2. An excited electron from P680 is transferred to the primary electron acceptor (we now call it P680+)
3. H_2O is split by enzymes, and the electrons are transferred from the hydrogen atoms to P680+, thus reducing it to P680; O2 is released as a by-product.
4. Each electron "falls" down an electron transport chain from the primary electron acceptor of PS II to PS I.
5. Energy released by the fall drives the creation of a proton gradient across the thylakoid membrane; diffusion of H+ (protons) across the membrane drives ATP synthesis.
6. In PS I (like PS II), transferred light energy excites P700, causing it to lose an electron to an electron acceptor (we now call it P700+), P700+ accepts an electron passed down from PS II via the electron transport chain.
7. Excited electrons "fall" down an electron transport chain from the primary electron acceptor of PS I to the protein ferredoxin (Fd).
8. The electrons are transferred to NADP+, reducing it to NADPH, and become available for the reactions of the Calvin cycle.
9. This process also removes an H^+ from the stroma



- **Chemiosmosis** in:

Chloroplasts	Mitochondria
Light energy from sun	Chemical energy from food
H+ is pumped to the thylakoid space and diffuse back into the stroma	H+ is pumped to the intermembrane space and diffuse back into the matrix
Have electron transport chain and ATP synthase	Have electron transport chain and ATP synthase

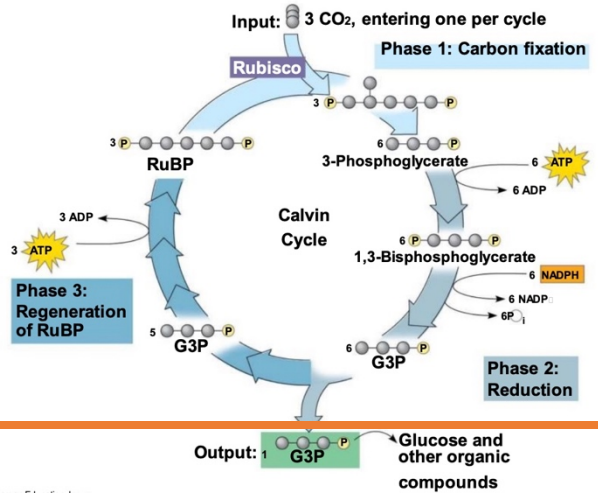
- The light reactions of photosynthesis generate ATP and increase the potential energy of electrons by moving them from H_2O to NADPH.
- ATP and NADPH are produced on the side of the thylakoid membrane facing the stroma, where the Calvin cycle takes place.
- The Calvin cycle uses ATP and NADPH to power the synthesis of sugar from CO2.



11.3: Calvin cycle

- like the citric acid cycle, regenerates its starting material after molecules enter and leave the cycle but it is Anabolic.
- It builds sugar from CO2 by using ATP and the reducing power of electrons carried by NADPH (products of light reactions)
- Carbon enters the cycle as CO2 and leaves glyceraldehyde 3-phospate (G3P), the cycle must take place three times, fixing three molecules of CO2

- 3 phases:
  Phase 1: Carbon fixation: the incorporation of the CO2 molecules into ribulose bisphosphate (RuBP) using the enzyme rubisco.



Phase 2: Reduction: involves the reduction and phosphorylation of 3-phosphoglycerate to G3P, 6 ATP and 6 NADPH are required to produce 6 molecules of G3P, but only one exits the cycle for use by the cell.

Phase 3, Regeneration, involves the rearrangement of the five remaining molecules of G3P to regenerate the initial CO2 receptor, RuBP Three additional ATP are required to power this step

LIGHT REACTIONS	CALVIN CYCLE REACTIONS
• Are carried out by molecules in the thylakoid membranes • Convert light energy to the chemical energy of ATP and NADPH • Split H_2O and release O_2	• Take place in the stroma • Use ATP and NADPH to convert CO_2 to the sugar G3P • Return ADP, inorganic phosphate, and NADP to the light reactions

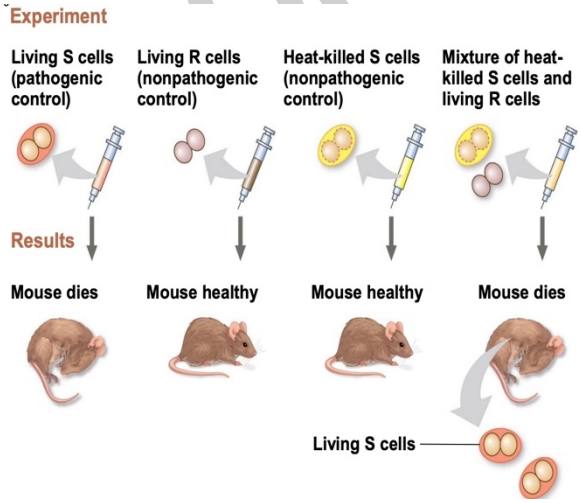
Chapter 16

16.1: DNA

- James Watson and Francis Crick introduced an elegant double-helical model for the structure of DNA.
- Hereditary information is encoded in DNA and reproduced in all cells of the body.
- DNA is a polymer of nucleotides, each consisting of a nitrogenous base, a sugar, and a phosphate group.
- The nitrogenous bases can be adenine (A), thymine (T), guanine (G), cytosine (C)
- **Three** experiments to prove that DNA is the genetic information:

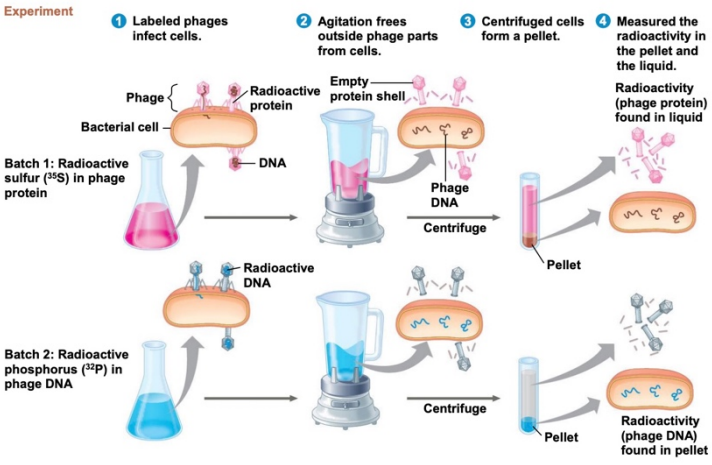
1) Frederick Griffith:

- two strains of a bacterium, one pathogenic and one harmless.
- When he mixed heat-killed remains of the pathogenic strain with living cells of the harmless strain, some living cells became pathogenic.
- **transformation**: a change in genotype and phenotype due to assimilation of foreign DNA.



2) Hershey-Chase experiment:

- viruses called bacteriophages (or phages) infect bacteria and are widely used in molecular genetics research.
- A virus is DNA (sometimes RNA) enclosed by a protective coat, often simply protein.
- They designed an experiment showing that only one of the two components of a phage called T2 (DNA or protein) enters a bacterial cell during infection.
- They concluded that the injected DNA of the phage provides the genetic information

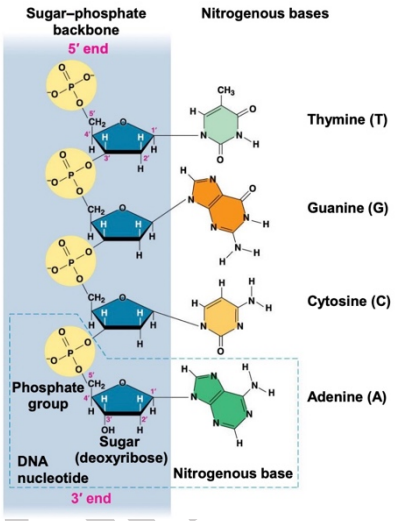


3) Chargaff's experiment:

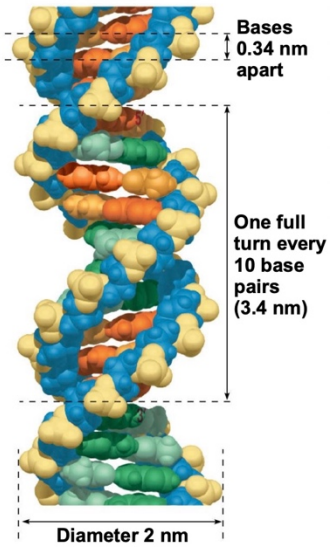
- analyzed the base composition of DNA from several different organisms. He concluded the following rules (**Chargaff's rules**):

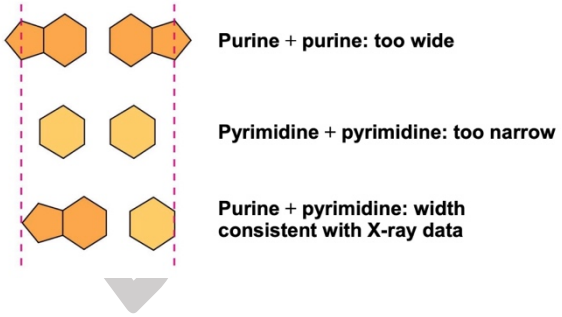
a) The base composition of DNA varies between species.

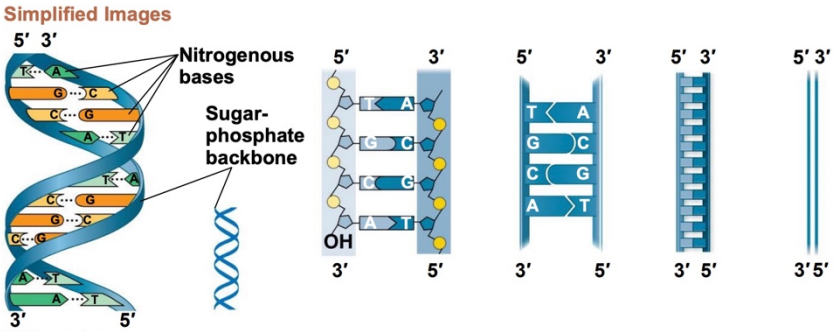
b) In any species the number of A and T bases is equal, and the number of G and C bases is equal.



- After DNA was accepted as the genetic material, the challenge was to determine how its structure accounts for its role in heredity.
- Franklin used a technique called X-ray crystallography to study molecular structure of the DNA.
- X-ray crystallographic images of DNA enabled Watson to deduce that DNA was helical.
- the DNA molecule is made up of two strands, forming a double helix, two outer sugar-phosphate **backbones**, with the nitrogenous bases paired in the molecule's interior.
- Watson built a model in which the backbones were **antiparallel** (their subunits run in opposite directions).
- pairing a purine (A or G) with a pyrimidine (C or T) resulted in a uniform width

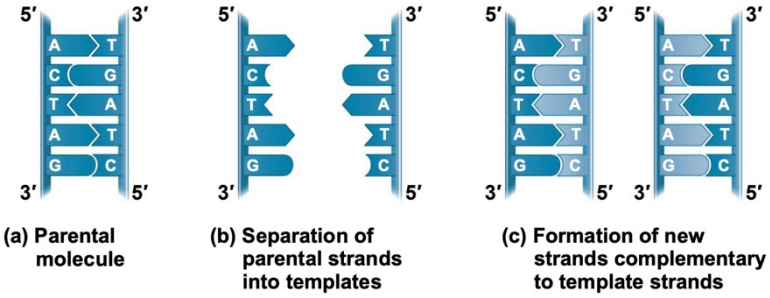




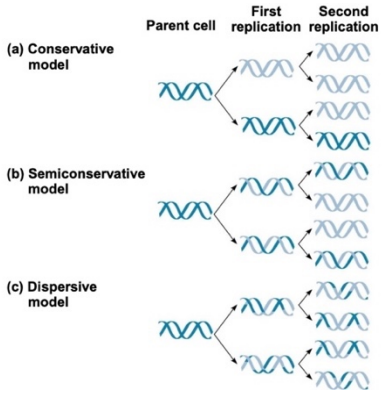


16.2: DNA replication

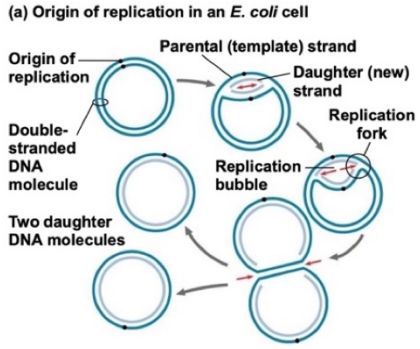
- The relationship between structure and function is manifest in the double helix.
- Since the two strands of DNA are complementary, each strand acts as a template for building a new strand in replication.



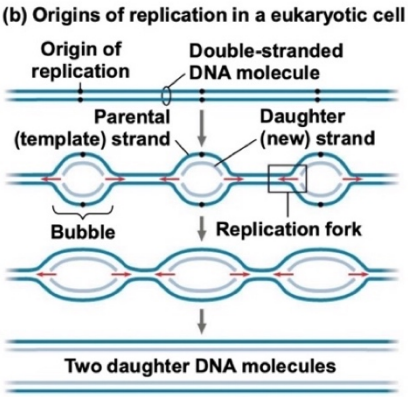
- In DNA replication, the parent molecule unwinds, and two new daughter strands are built based on base-pairing rules
- Watson and Crick's **semiconservative model** of replication predicts that when a double helix replicates, each daughter molecule will have one old strand (derived or "conserved" from the parent molecule) and one new strand.



- other models were the conservative model (the two parent strands rejoin) and the dispersive model (each strand is a mix of old and new).
- The copying of DNA is remarkable in its speed and accuracy
- More than a dozen enzymes and other proteins participate in DNA replication.

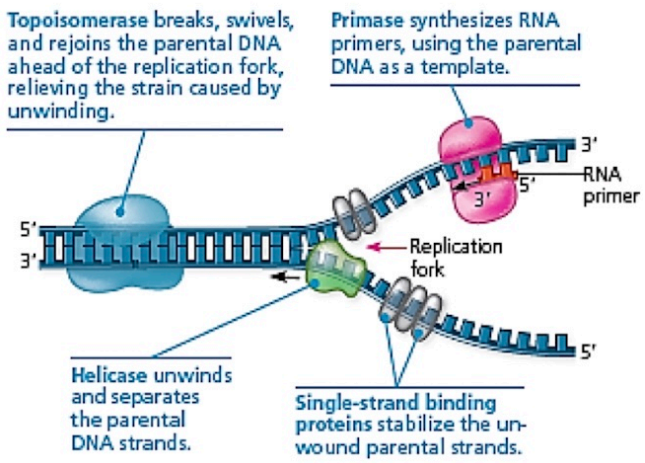


- **origins of replication**: short stretches of DNA that has a specific sequence of nucleotides which the replication of DNA starts from it.
  A. The bacterial chromosome is circular and has a single origin.
  Proteins that initiate DNA replication recognize this sequence and attach to the DNA, separating the two strands and opening a **replication bubble**.
  Replication of DNA then proceeds in both directions until the entire molecule is copied.

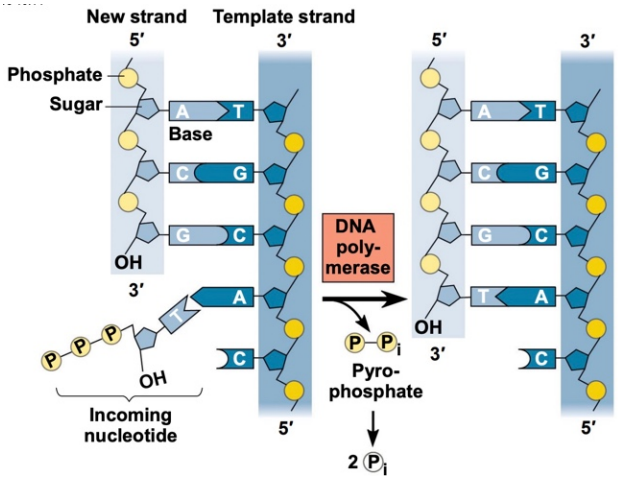


B. Eukaryotic chromosome is linear and may have hundreds to a thousand replication origins.
Proteins that initiate DNA replication open multiple replication bubbles which eventually fuse, thus speeding up the copying of the very long DNA molecules.

- At each end of a replication bubble is a **replication fork**: a Y-shaped region where the parental strands of DNA are being unwound.



- **Enzymes involved in DNA replication**:
  1. Helicase: untwists the double helix at the replication forks, separating the two parental strands.
  2. Single-strand binding proteins (SSBP): bind to the unpaired DNA strands, keeping them from re-pairing stabilizing the unwound strands.
  3. Topoisomerase**:** helps relieve wounding strain by breaking, swiveling, and rejoining DNA strands ahead of replication fork.
  4. Primase: synthesizes **RNA primers**, using the parental DNA as a template.
     - Enzymes can add DNA nucleotides only at the 3’ end, therefore we need a primer.
     - **Primer:** The initial short stretch of RNA (5–10 nucleotides) that is produced during DNA synthesis.
     - The completed primer is base paired to the template strand.
     - <u>The new DNA strand will start from the 3’ end of the RNA primer.</u>

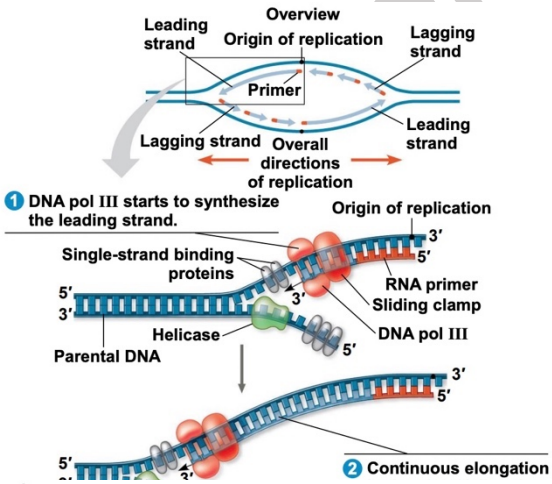


  5. DNA polymerase: add nucleotides to the 3’ end of a preexisting chain (elongating the DNA).
     - The rate of elongation is 500 nucleotides/s in bacteria and 50/s in humans.
     - Each nucleotide that is added to a growing DNA strand is a nucleoside triphosphate (dATP, dTTP, dGTP, dCTP).

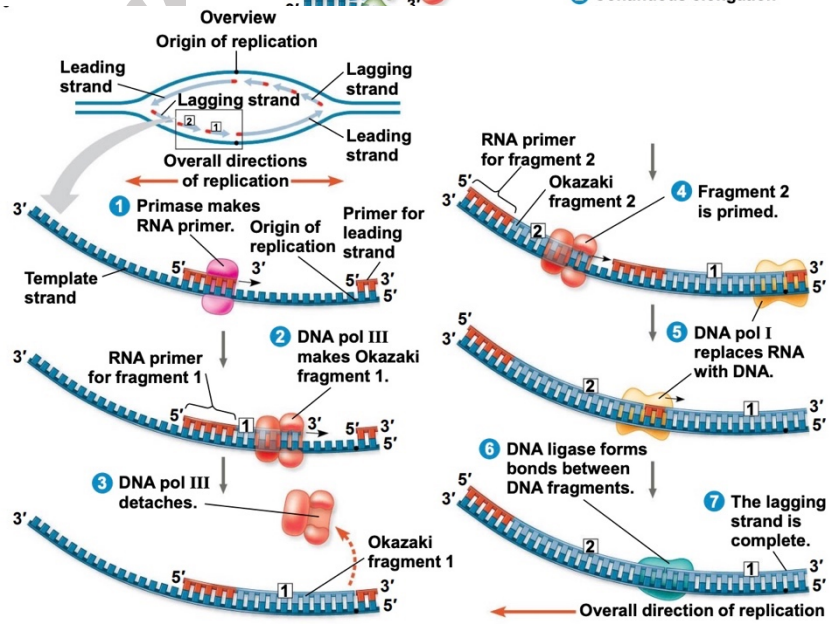
- As each monomer is joined to the growing end of a DNA strand, two phosphate groups are lost as a molecule of pyrophosphate.
- Hydrolysis of the pyrophosphate is a coupled exergonic reaction that helps drive the polymerization reaction.
- DNA pol III: adds nucleotides. DNA pol I: replaces primers with DNA

6. DNA ligase: joins the final DNA nucleotide to the first one added after the replacement of the primer by a dehydration reaction.

Antiparallel elongation:

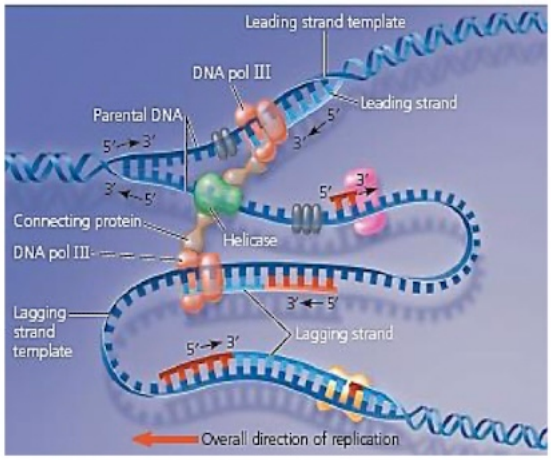


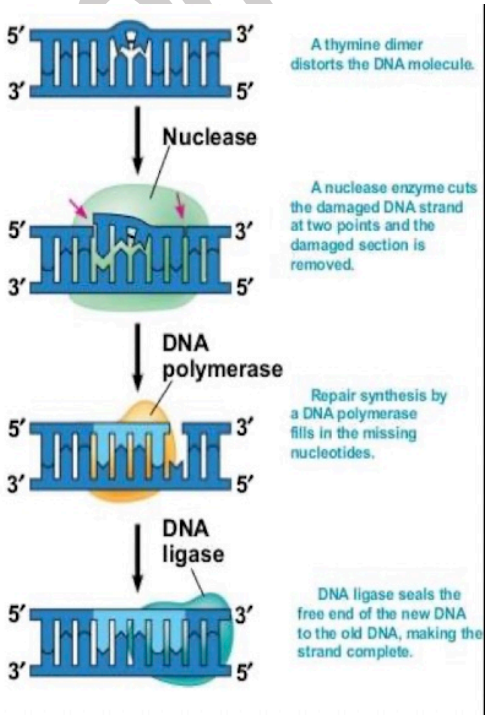
- A new DNA strand can elongate only in the 5′ to 3′ direction.
- The leading strand: has a free 3′ end that nucleotides can be added to it in a continuous manner and needs only one primer.
- The lagging strand: doesn't have a 3′ free end; so multiple primers are added along the strand and DNA synthesis happens between them.
- It is synthesized discontinuously, as a series of segments; these segments are called Okazaki fragments, and each one requires a primer.
- Synthesis of the leading strand and synthesis of the lagging strand occur the same rate.
- The direction of the leading strand is the same as the direction of the replication bubble, while the lagging strand moves in the opposite direction.

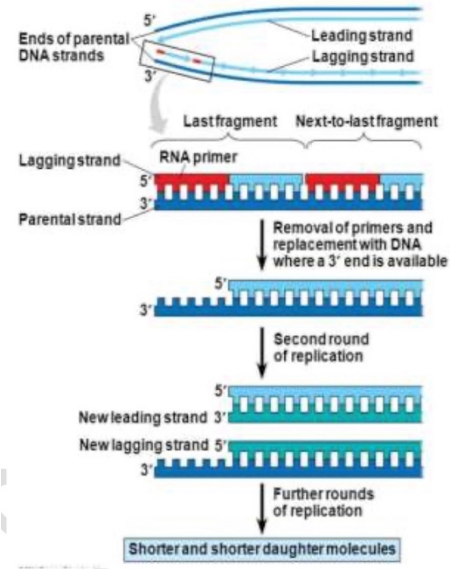


The DNA replication complex:

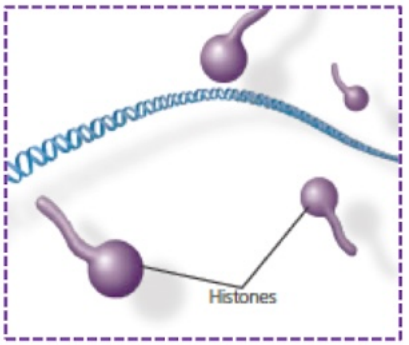
- the various proteins that participate in DNA replication form a single large complex, a "DNA replication machine".
- the DNA move through the fixed complex during the replication process and not the other way around.
- Recent studies support a model in which DNA polymerase molecules "reel in" parental DNA and extrude newly made daughter DNA molecules, it is called the trombone model.
- DNA polymerases **proofread** each nucleotide against its template as soon as it is covalently bonded to the growing strand.
- Upon finding an incorrectly paired nucleotide, the polymerases remove the nucleotide and then resumes synthesis.
- Mismatched nucleotides that evade proofreading by a DNA polymerase are repaired in another mechanism called **mismatch repair** where other enzymes remove and replace the mismatched nucleotides.
- colon cancer happens When there is a problem in the mismatch repair enzymes.
- Sometimes the DNA can be damaged when it is subjected to potentially harmful chemical and physical agents, such as X-rays.
- These damages must be repaired through **nucleotide excision repair**.
- Limitations of DNA polymerase create problems for the linear DNA of eukaryotic chromosomes.
- The usual replication machinery provides no way to complete the 5′ ends, so repeated rounds of replication produce shorter DNA molecules with uneven ends.





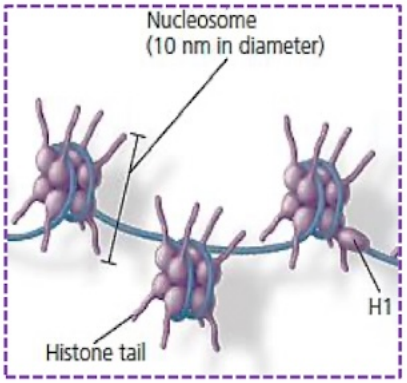


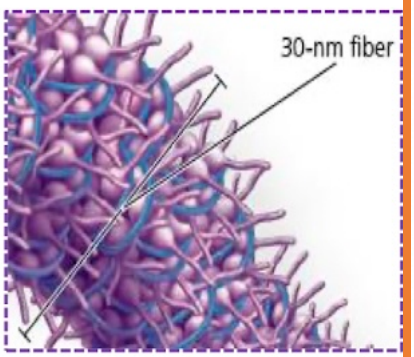
- This is not a problem for prokaryotes, most of which have circular chromosomes
- Eukaryotic chromosomal DNA molecules have special nucleotide sequences at their ends called **telomeres**.
- Telomeres do not prevent the shortening of DNA molecules, but they do postpone the destruction of genes near the ends of DNA molecules.
- It has been proposed that the shortening of telomeres is connected to aging.
- The shortening of telomeres might protect cells from cancerous growth by limiting the number of cell divisions.
- Germ cells must preserve their length, the enzyme telomerase catalyzes the lengthening of telomeres in these cells.
- There is evidence of telomerase activity in cancer cells, which may allow cancer cells to persist.
- Telomere sequence is: TTAGGG.

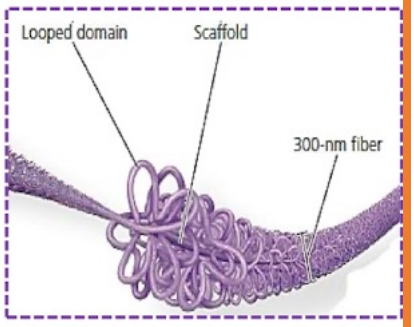


16.3: Chromosomes

- The bacterial chromosome is a double-stranded, circular DNA molecule associated with a small amount of protein, it is described as "supercoiled" and found in a region of the cell called the nucleoid.
- Eukaryotic chromosomes have linear DNA molecules associated with a large amount of protein, In the eukaryotic cell, DNA is precisely combined with proteins in a complex called **chromatin**.
- Chromosomes fit into the nucleus through an elaborate, multilevel system of packing.
- Proteins called histones are responsible for the first level of packing in chromatin
- Unfolded chromatin resembles beads on a string, with each "bead" being a **nucleosome**, the basic unit of DNA packaging.
- Nucleosomes, are involved in the regulation of gene expression.
- Loosely packed chromatin is called euchromatin while highly condensed is called heterochromatin.



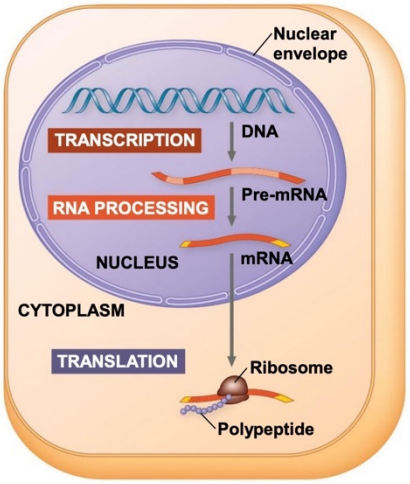




Chapter 17

17.1: Genes

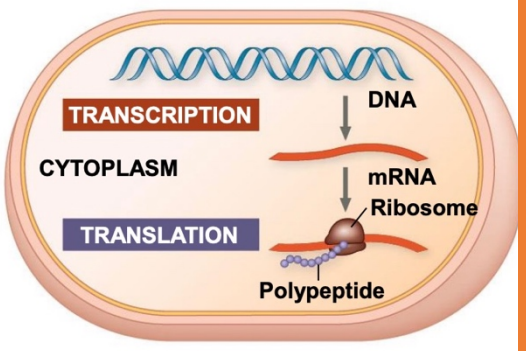
- The DNA inherited by an organism leads to specific traits by dictating the synthesis of proteins.
- Proteins are the links between genotype and phenotype.
- The information content of genes is in the specific sequences of nucleotides.
- Gene expression: the process by which DNA directs protein synthesis, includes two stages: transcription and translation.
- Three theories:
  1. one gene – one enzyme.
  2. one gene – one protein.
  3. one gene- one polypeptide.



(b) Eukaryotic cell

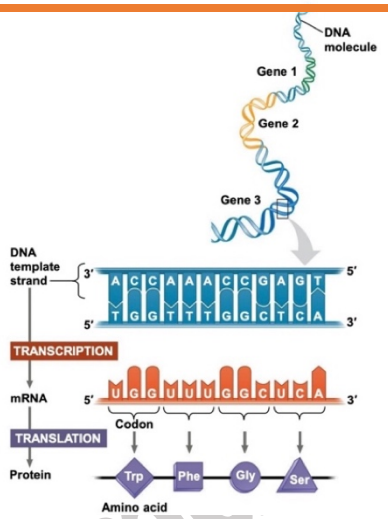
Basic principles:

- Transcription is the synthesis of messenger RNA (mRNA) using information in DNA.
- Translation is the synthesis of a polypeptide, using information in the mRNA.
- Ribosomes are the sites of translation.
- In prokaryotes, translation of mRNA can begin before transcription has finished.
- In a eukaryotic cell, the nuclear envelope separates transcription from translation.
- In Eukaryotic cells, Transcription results in **pre-mRNA**, and further processing yields the mature mRNA.

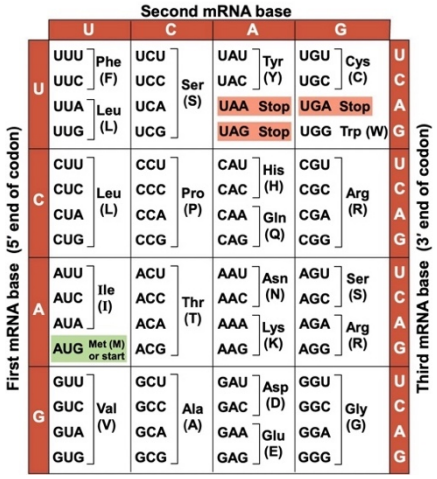


(a) Bacterial cell

- A primary transcript is the initial RNA transcript from any gene prior to processing
- The central dogma is the concept that cells are governed by a cellular chain of command: DNA → RNA → protein.



- There are 20 amino acids, but there are only four nucleotide bases in DNA.
- The flow of information from gene to protein is based on a triplet code: a series of three nucleotide words.
- The words of a gene are transcribed into complementary three-nucleotide words of mRNA called codons.
- These codons are then translated into a chain of amino acids, forming a polypeptide.
- the template strand: the strand that provides a template for ordering the sequence of complementary nucleotides in an RNA transcript.
- The template strand is always the same strand for a given gene
- During translation, the mRNA codons, are read in the 5′ → 3′ direction.
- The nontemplate strand is called the **coding strand** because the nucleotides of this strand are identical to the codons, except that T is present in the DNA in place of U in the RNA.

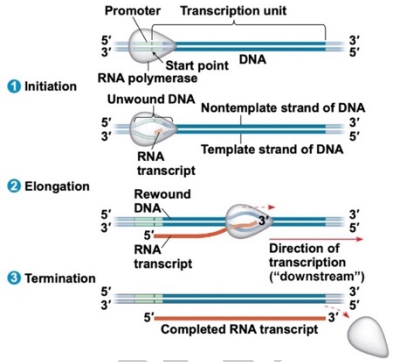


- Each codon specifies the amino acid to be placed at the corresponding position along a polypeptide.
- Of the 64 triplets, 61 code for amino acids; 3 triplets are "stop" signals to end translation
- The genetic code is redundant (more than one codon may specify a particular amino acid) but not ambiguous; no codon specifies more than one amino acid.
- The redundancy in the code is not random; codons that are synonyms for a particular amino acid differ only in the third nucleotide base of the triplet.
- The codon **AUG** codes for the amino acid methionine (Met, or M) and it functions as a **start codon**.

17.2: Transcription

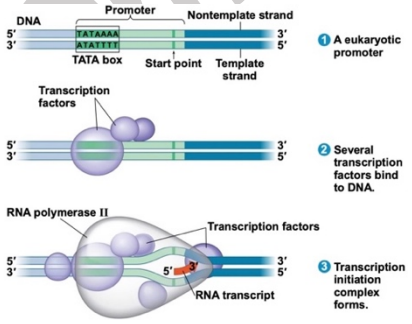
- the first stage of gene expression
- RNA synthesis is catalyzed by **RNA polymerase**, which pries the DNA strands apart and joins together the RNA nucleotides.
- The RNA is complementary to the DNA template strand.

- RNA polymerase does not need any primer and it follows the same base-pairing rules as DNA, except that uracil substitutes for thymine.
- Promoter: The DNA sequence where RNA polymerase attaches.
- Terminator: the sequence signaling the end of transcription in bacteria.
- Bacteria have a single type of RNA polymerase while eukaryotes have three types.
- the one used for pre-mRNA synthesis is called RNA polymerase II.

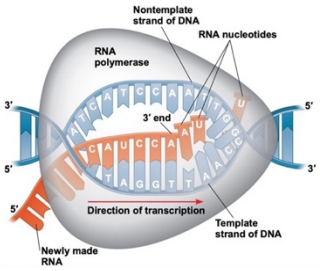


The three stages of transcription:

1. Initiation:
   - Promoters signal the transcription start point and usually extend several dozen nucleotide pairs upstream of the start point.
   - Transcription factors mediate the binding of RNA polymerase and the initiation of transcription.
   - transcription initiation complex: The completed assembly of transcription factors and RNA polymerase II bound to a promoter.
   - A promoter called a TATA box is important in eukaryotes



2. Elongation:
   - As RNA polymerase moves along the DNA, it untwists the double helix, 10 to 20 bases at a time.
   - Nucleotides are **added to the 3' end** of the growing RNA molecule.
   - A single gene can be transcribed simultaneously by several RNA polymerases following each other.



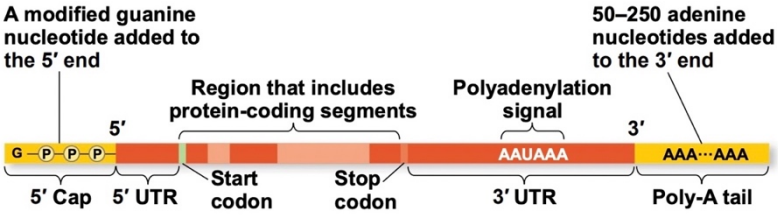
3. Termination:
   - The mechanisms of termination are different in bacteria and eukaryotes.
   - In bacteria, the polymerase stops transcription at the end of the terminator and the mRNA can be translated without further modification.
   - In eukaryotes, RNA polymerase II transcribes the polyadenylation signal sequence; the RNA transcript is released 10–35 nucleotides past this polyadenylation sequence.

17.3: Post-Transcriptional Modifications in Eukaryotes

- Enzymes in the eukaryotic nucleus modify pre-mRNA (RNA processing) before the genetic messages are dispatched to the cytoplasm.

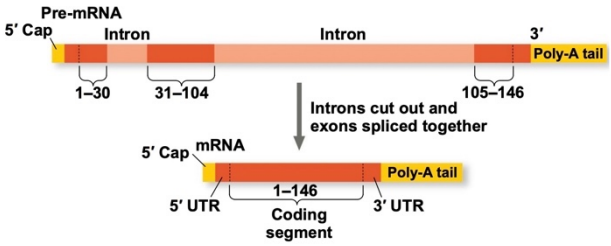
1. Alteration of mRNA Ends

- Each end of a pre-mRNA molecule is modified in a particular way.
- The 5′ end receives a modified nucleotide 5′ cap.
- The 3′ end gets a poly-A tail.
- These modifications share several functions:
  a) They seem to facilitate the export of mRNA to the cytoplasm.
  b) They protect mRNA from hydrolytic enzymes.
  c) They help ribosomes attach to the 5′ end of the mRNA once the mRNA reaches the cytoplasm.

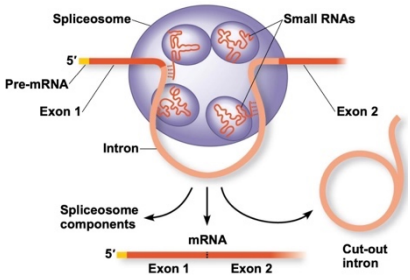


2. Split Genes and RNA Splicing

- Most eukaryotic genes and their RNA transcripts have long noncoding stretches of nucleotides that lie between coding regions.



- These noncoding regions are called introns.
- The other regions are called exons because they are eventually expressed, usually translated into amino acid sequences.
- RNA splicing removes introns and joins exons, creating an mRNA molecule with a continuous coding sequence.



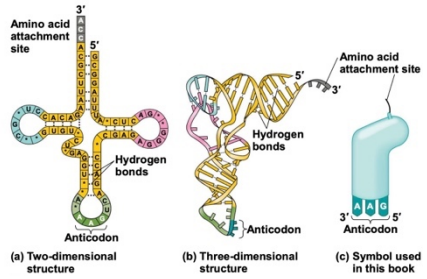
- RNA splicing is carried out by spliceosomes.
- Spliceosomes consist of a variety of proteins and several small RNAs that recognize the splice sites and catalyze the splicing reaction.
- Ribozymes are catalytic RNA molecules that function as enzymes and can splice RNA.

- The discovery of ribozymes rendered obsolete the belief that all biological catalysts were proteins

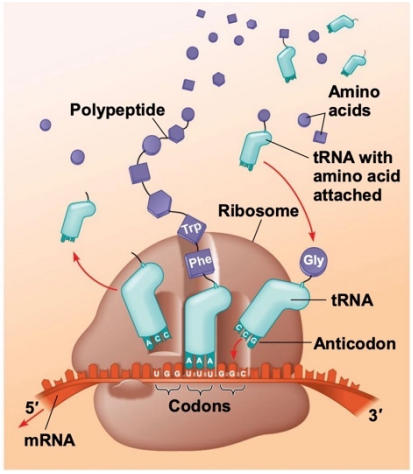
  Three properties of RNA enable it to function as an enzyme:

1. It can form a three-dimensional structure because of its ability to base-pair with itself.
2. Some bases in RNA contain functional groups that may participate in catalysis.
3. RNA may hydrogen-bond with other nucleic acid molecules.

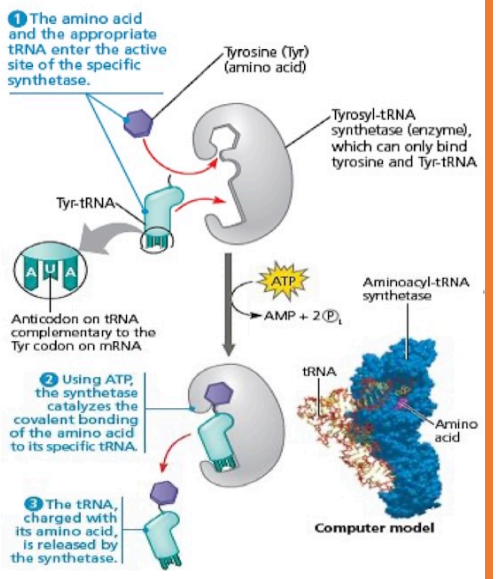
17.4: Translation



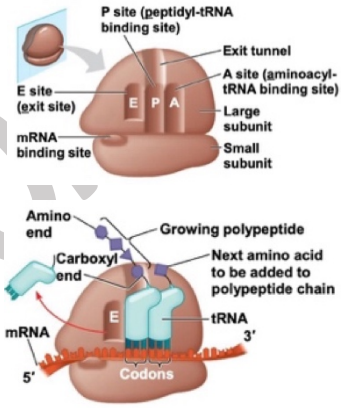
- Genetic information flows from mRNA to protein through the process of translation.
- A cell translates an mRNA message into protein with the help of transfer RNA (tRNA).
- tRNAs transfer amino acids to the growing polypeptide in a ribosome.
- **Each tRNA molecule enables translation of a given mRNA codon into a certain amino acid.**



- Each carries a specific amino acid on one end.
- Each has an anticodon on the other end that base-pairs with the complementary codon on mRNA.
- A tRNA molecule consists of a single RNA strand that is only about 80 nucleotides long.
- Because of hydrogen bonds, tRNA twists and folds into a three-dimensional molecule.
- tRNA is roughly L-shaped with the 5' and 3' ends both located near one end of the structure.
- The protruding 3' end acts as an attachment site for an amino acid.
- Accurate translation requires two steps:
  1. a correct match between a tRNA and an amino acid, done by the enzyme aminoacyl-tRNA synthetase.
  2. a correct match between the tRNA anticodon and an mRNA codon.

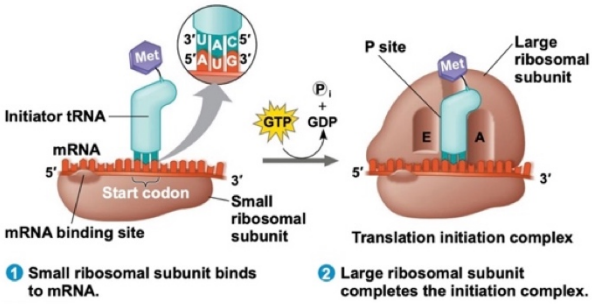


- Wobble: Flexible pairing at the third base of a codon and allows some tRNAs to bind to more than one codon.
- Ribosomes facilitate specific coupling of tRNA anticodons with mRNA codons in protein synthesis.
- The two ribosomal subunits (large and small) are made of proteins and ribosomal RNA (rRNA).
- Bacterial and eukaryotic ribosomes are somewhat similar but have significant differences.
- A ribosome has three binding sites for tRNA:
  1. The P site holds the tRNA that carries the growing polypeptide chain.
  2. The A site holds the tRNA that carries the next amino acid to be added to the chain.
  3. The E site is the exit site, where discharged tRNAs leave the ribosome.



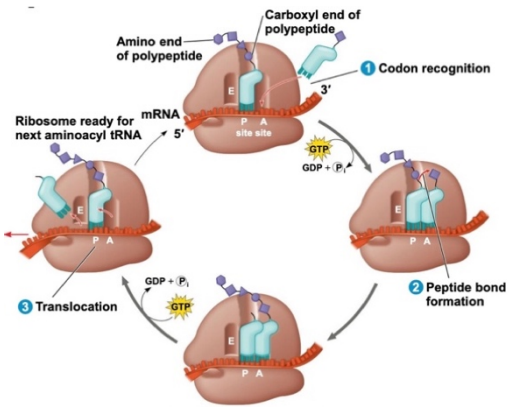
- Three stages of translation:

1. Initiation
   - The **start codon (AUG)** signals the start of translation
   - small ribosomal subunit binds with mRNA and a special initiator tRNA.
   - the small subunit moves along the mRNA until it reaches the start codon.
   - Proteins called initiation factors bring in the large subunit that completes the **translation initiation complex**.
   - Hydrolysis of GTP provides the energy for this assembly.



2. Elongation
   - amino acids are added one by one to the C-terminus of the growing peptide
   - Each addition involves proteins called elongation factors.
   - Elongation occurs in three steps:

a) codon recognition: The anticodon of an incoming aminoacyl tRNA base-pairs with the complementary mRNA codon in the A site, Hydrolysis of GTP is required.



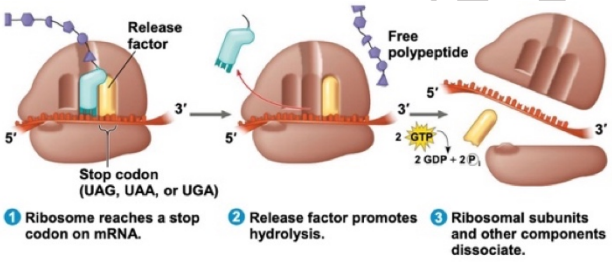
b) peptide bond formation: removes the polypeptide from the tRNA in the P site and attaches it to the amino acid on the tRNA in the A site.

c) Translocation: The ribosome translocates the tRNA in the A site to the P site and releases the empty tRNA to the E site and the cytoplasm. Hydrolysis of GTP is required.

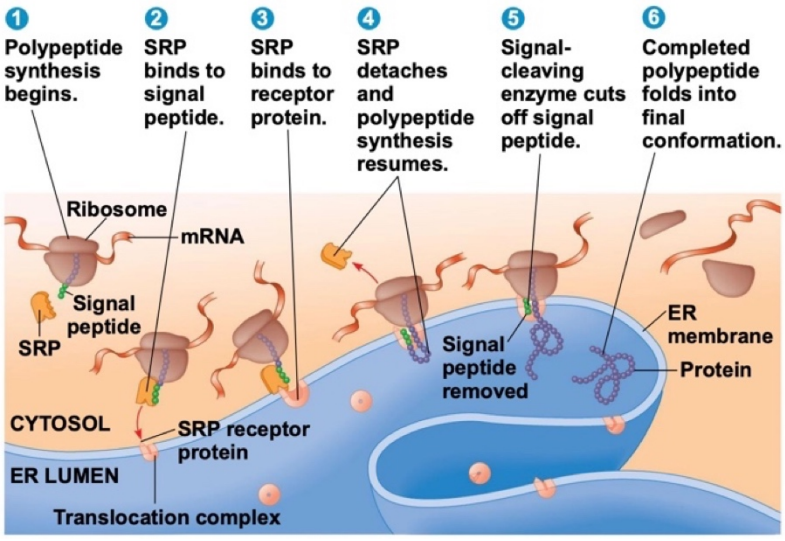
- Translation proceeds along the mRNA in a 5′ → 3′ direction

3. Termination

- Elongation continues until a stop codon in the mRNA reaches the A site of the ribosome.
- The A site accepts a protein called a release factor that causes the addition of a water molecule instead of an amino acid.
- This reaction releases the polypeptide, and the translation assembly comes apart consuming to GTP.



- Polypeptide chains are modified after translation or targeted to specific sites in the cell
- During its synthesis, a polypeptide chain begins to coil and fold spontaneously into a specific three-dimensional shape with secondary and tertiary structure.
- A gene determines primary structure, and primary structure in turn determines shape.
- Post-translational modifications may be required before the protein can begin doing its job in the cell.
- Polypeptide synthesis always begins in the cytosol.



- Synthesis finishes in the cytosol unless the polypeptide signals the ribosome to attach to the ER.
- Polypeptides destined for the ER or for secretion are marked by a signal peptide
- A signal-recognition particle (SRP) binds to the signal peptide and escorts the ribosome to a receptor protein built into the ER membrane.

- Multiple ribosomes can translate a single mRNA simultaneously, forming a polyribosome (or polysome)
- Polyribosomes enable a cell to make many copies of a polypeptide very quickly
- A bacterial cell ensures a streamlined process by coupling transcription and translation.