SUMMARY

BIOLOGY

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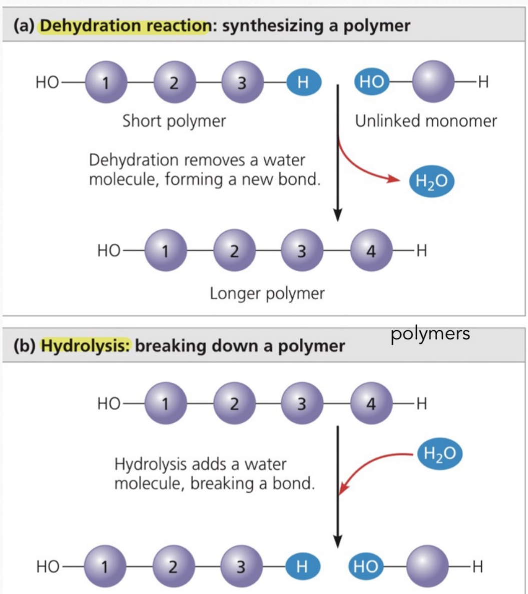
Chapter 5, Biological Macromolecules and Lipids

Concept 5.1: Macromolecules are polymers, built from monomers.

- A polymer is a long molecule consisting of many similar building blocks.
- These small building-block molecules are called monomers .
- Three of the four classes of life's organic molecules are polymers:
  - -Carbohydrates
  - -Proteins
  - -Nucleic acids

💥The Synthesis and Breakdown of Polymers



تزال مجموعة (OH) من
الmonomer الأول وذرة H من
الثاني لتكوين رابطة تساهمية
وحذف جزيء ماء.

تضاف مجموعة (OH) إلى
الmonomer الأول وذرة H إلى
الثاني لفك الرابطة التساهمية ويتطلب
ذلك إضافة جزيء ماء.

Concept 5.2: Carbohydrates serve as fuel and building material

- Carbohydrates include sugars and the polymers of sugars.
- The simplest carbohydrates are monosaccharides, or single sugars.
- Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks.

💥Sugars

⭐Monosaccharides (mono means one)

- Monosaccharides have molecular formulas that are usually multiples of CH_2O.
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- Monosaccharides are classified by:

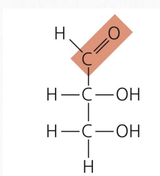
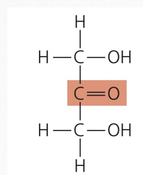
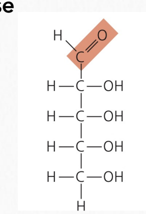
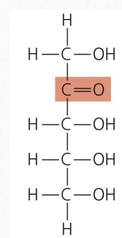
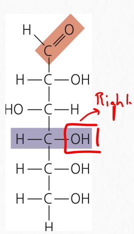
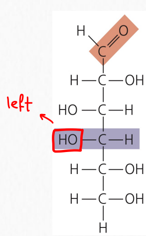
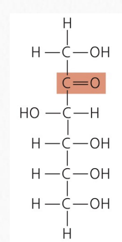
-The location of the carbonyl group (as aldose or ketose)

-The number of carbons in the carbon skeleton

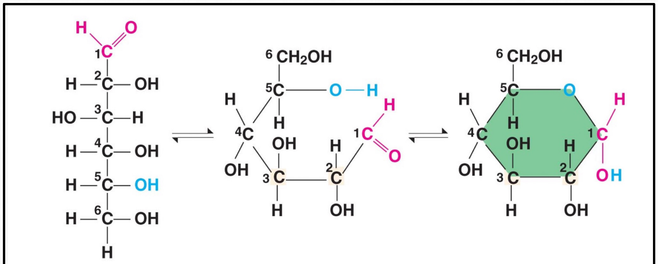
- Monosaccharides serve as a major fuel for cells and as raw material for building molecules.

Depending on the location of the carbonyl group

Depending on the size of the carbon skeleton

	Aldoses (Aldehyde Sugars) Carbonyl group at end of carbon skeleton	Ketoses (Ketone Sugars) Carbonyl group within carbon skeleton
Trioses: three-carbon sugars	**Glyceraldehyde**  * The simplest Aldose	**Dihydroxyacetone**  * The simplest Ketose
Pentoses: five-carbon sugars	**Ribose**  * A Component of RNA	**Ribulose** 
Hexoses: six-carbon sugars	**Glucose**  **Galactose** 	**Fructose** 

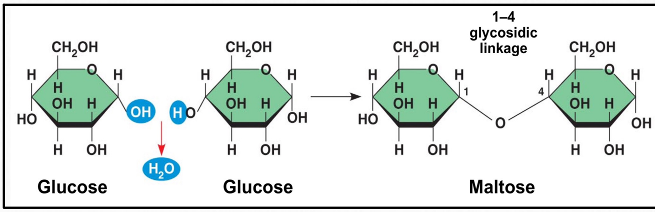
- Though often drawn as linear skeletons, in aqueous solutions many sugars form rings



(a) Linear and ring forms

⭐Disaccharides (di means two)

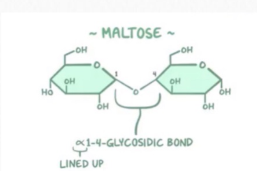
- A disaccharide is formed when a dehydration reaction joins two monosaccharides .
- This covalent bond is called a glycosidic linkage.



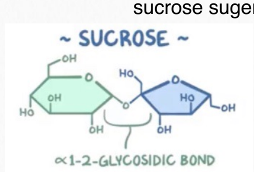
Dehydration reaction in the synthesis of maltose

- important disaccharides:

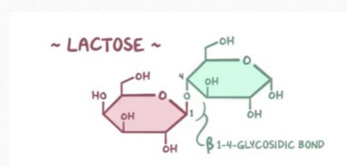
Maltose: malt sugar (سكر الشعير)
-used in brewing beer
-consists of **Glucose + Glucose**
-(1-4 glycosidic linkage)



Sucrose (table suger):
-Glucose +fructose
(1-2 glycosidic linkage)
ملاحظة: ينتقل الغذاء في النباتات من الأوراق للجذور على شكل sucrose suger



Lactose:milk suger
Glucose+ Galactose



⭐Polysaccharides.

- Polysaccharides, the polymers of sugars, have storage and structural roles.
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages(α of B glycosidic linkages)

💥Storage Polysaccharides

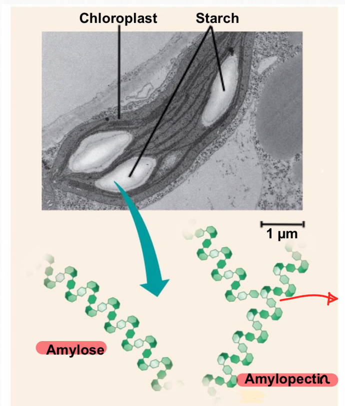
1-Starch, a storage polysaccharide of plants, consists entirely of alpha glucose monomers.

- Plants store excess starch as granules within chloroplasts and other plastids.

Forms of starch:

1-amylose (unbranched)

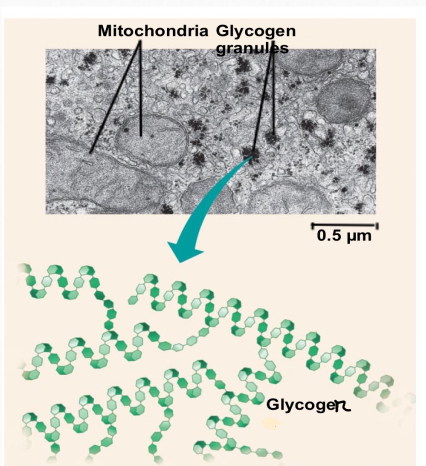
2-amylopectin : a branched polymer with 1-6 linkages at the branch points



2-Glycogen is a storage polysaccharide in animals.

- a polymer of alpha glucose monomers.
- Humans and other vertebrates store glycogen mainly in liver and muscle cells.
- it is like amylopectin but more extensively branched .
- the extensively branched structure of glycogen fits it's function:

(more free ends are available for hydrolysis)

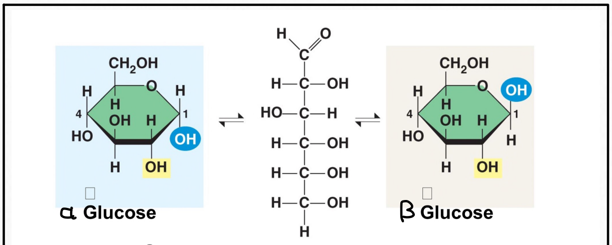


(b) Glycogen: an animal polysaccharide

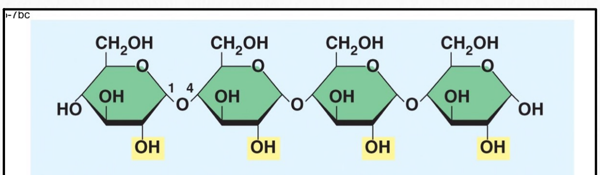
💥Structural Polysaccharides

1-cellulose

- The polysaccharide cellulose is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ.
- The difference is based on two ring forms for glucose: alpha (a) and beta (B)
- monomer of cellulose: beta glucose
- Beta linkages are tough and can't be broken easily,that's why they are found in structural polysaccharides



(a) α and β glucose ring structures

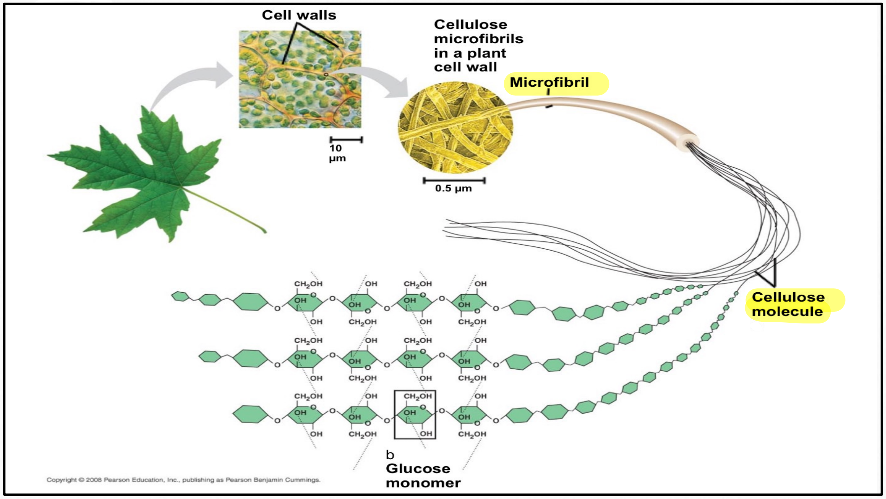

(b) Starch: 1–4 linkage of α glucose monomers

(c) Cellulose: 1–4 linkage of β glucose monomers

- starch molecules are largely helical while cellulose molecule is straight and never branch
- enzymes that digest starch by hydrolyzing it's a linkages are unable to hydrolyze the B linkages of cellulose due to the different shapes of these two molecules

• In straight structures, H atoms on one strand can bond with OH groups on other strands

• Parallel cellulose molecules held together this way are grouped into microfibrils, which form strong building materials for plants

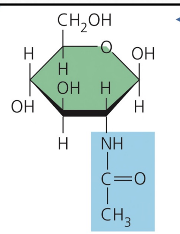


2-chitin

• Chitin is another structural polysaccharidewhich is found in the exoskeleton of arthropods(like insects and spiders)

• Chitin also provides structural support for the cell walls of many fungi.

• chitin is similar to cellulose,with B linkages,except that the glucose monomer of chitin has a nitrogen-containing attachment



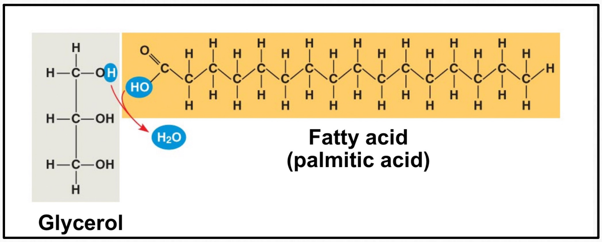
◀ The structure of the chitin monomer

Concept 5.3: Lipids are a diverse group of hydrophobic molecules

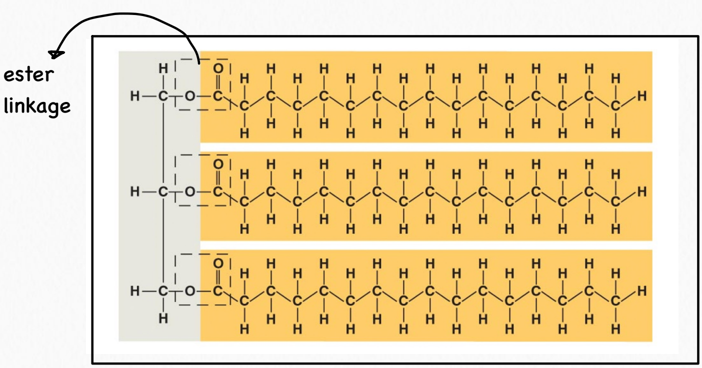
- Lipids are the one class of large biological molecules that do not form polymers.
- The unifying feature of lipids is having little or no affinity for water.
- Lipids are hydrophobic because they consist mostly of hydrocarbons, which form nonpolar covalent bonds
- The most biologically important lipids are fats, phospholipids, and steroids.

⭐Fats :

- Fats are constructed from two types of smaller molecules: glycerol and fatty acids
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon.
- A fatty acid consists of a carboxyl group attached to a long carbon skeleton.
- fat molecule = glycerol +3 fatty acids



(a) Dehydration reaction in the synthesis of a fat

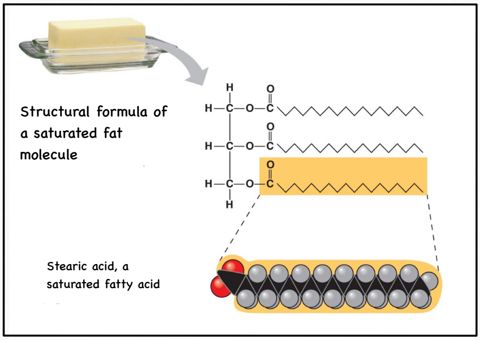


(b) fat molecule

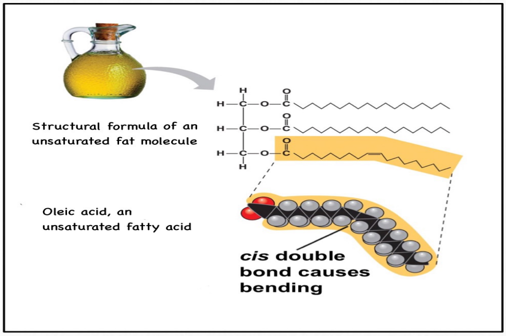
- In a fat, three fatty acids are joined to glycerol by an ester linkage, creating a triacylglycerol, or triglyceride.

» Fatty acids vary in length (number of carbons) and in the number and locations of double bonds.

- **Saturated fatty** acids have the maximum number of hydrogen atoms possible and no double bonds.
- **Unsaturated fatty** acids have one or more double bonds.



(a) Saturated fat



(b) Unsaturated fat

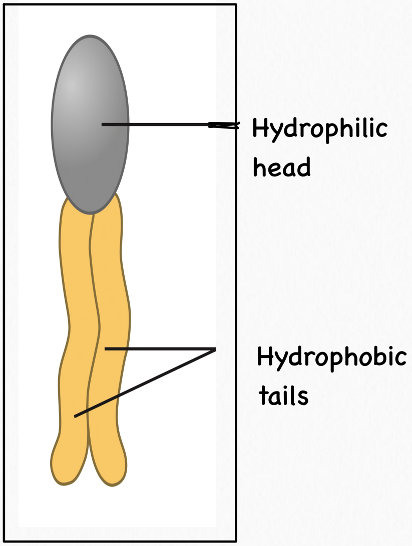
- Fats made from saturated fatty acids are called saturated fats, and are **solid** at room temperature.
- Most animal fats are saturated.
- Fats made from unsaturated fatty acids are called unsaturated fats or oils, and are **liquid** at room temperature.
- Plant fats and fish fats are usually unsaturated.

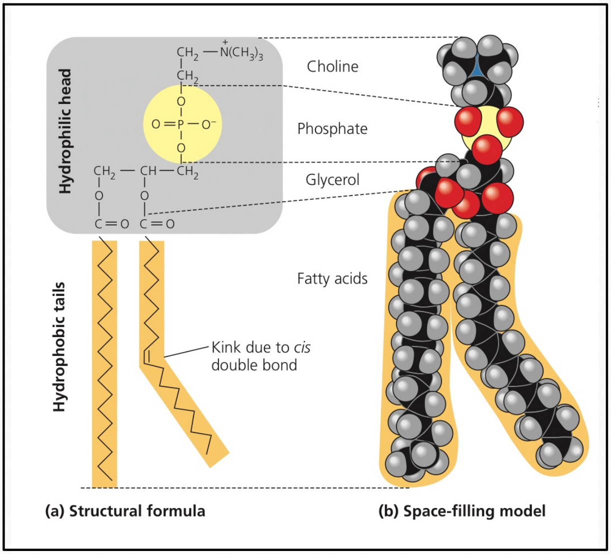
- A diet rich in saturated fats may contribute to cardiovascular disease through plaque deposits.
- **Hydrogenation** is the process of converting unsaturated fats to saturated fats by adding hydrogen.
- Hydrogenating vegetable oils also creates unsaturated fats with trans double bonds.
- These trans fats may contribute more than saturated fats to cardiovascular disease.

- The major function of fats is energy storage.
- Humans and other mammals store their fat in adipose cells.
- Adipose tissue also cushions vital organs and insulates the body.

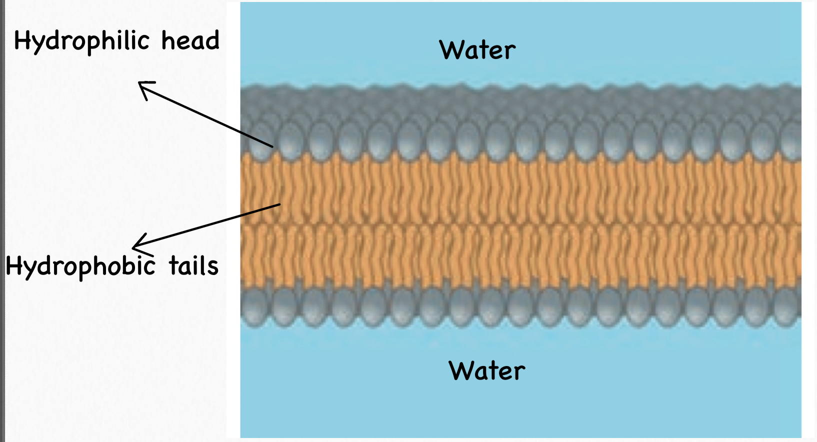
⭐Phospholipids

- In a phospholipid, two fatty acids and a phosphate group are attached to glycerol.
- The two fatty acid tails are hydrophobic, but the phosphate group and its attachments form a hydrophilic head.



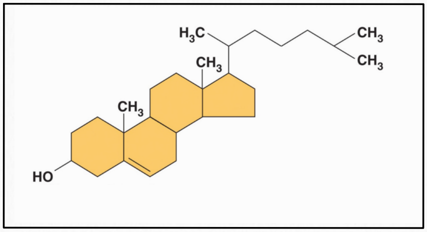


- When phospholipids are added to water, they self-assemble into a bilayer, with the hydrophobic tails pointing toward the interior
- The structure of phospholipids results in a bilayer arrangement found in cell membranes
- Phospholipids are the major component of all cell membranes



⭐Steroids

- Steroids are lipids characterized by a carbon skeleton consisting of four fused rings.
- Cholesterol, an important steroid, is a component in animal cell membranes.
- Although cholesterol is essential in animals, high levels in the blood may contribute to cardiovascular disease.



Cholesterol, a steroid.

Concept 5.4: Proteins have many structures, resulting in a wide range of functions

- Proteins account for more than 50% of the dry mass of most cells.
- Protein functions include structural support, storage, transport, cellular communications, movement, and defense against foreign substances.

Table 5.1 An Overview of Protein Functions

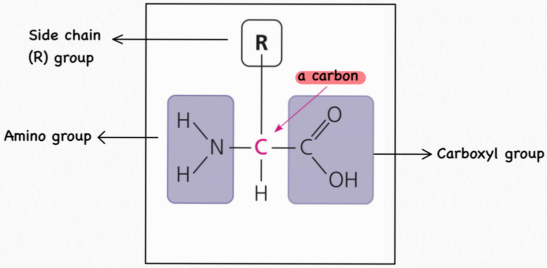
Type of Protein	Function	Examples
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes
Structural proteins	Support	Silk fibers; collagen and elastin in animal connective tissues; keratin in hair, horns, feathers, and other skin appendages
Storage proteins	Storage of amino acids	Ovalbumin in egg white; casein, the protein of milk; storage proteins in plant seeds
Transport proteins	Transport of other substances	Hemoglobin, transport proteins
Hormonal proteins	Coordination of an organism's activities	Insulin, a hormone secreted by the pancreas
Receptor proteins	Response of cell to chemical stimuli	Receptors in nerve cell membranes
Contractile and motor proteins	Movement	Actin and myosin in muscles, proteins in cilia and flagella
Defensive proteins	Protection against disease	Antibodies combat bacteria and viruses.

💥Polypeptides:

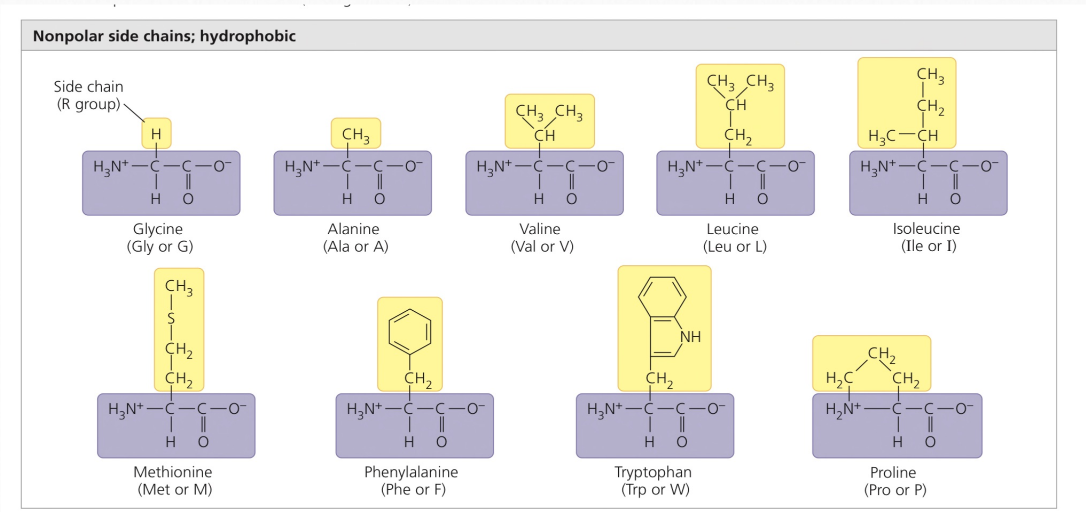
- **Polypeptides** are polymers built from the same set of 20 amino acids.
- A **protein** consists of one or more polypeptides.

💥Amino Acid Monomers :

- Amino acids are organic molecules with carboxyl and amino groups.
- Amino acids differ in their properties due to differing side chains, called R groups.



⭐the 20 amino acids of proteins:

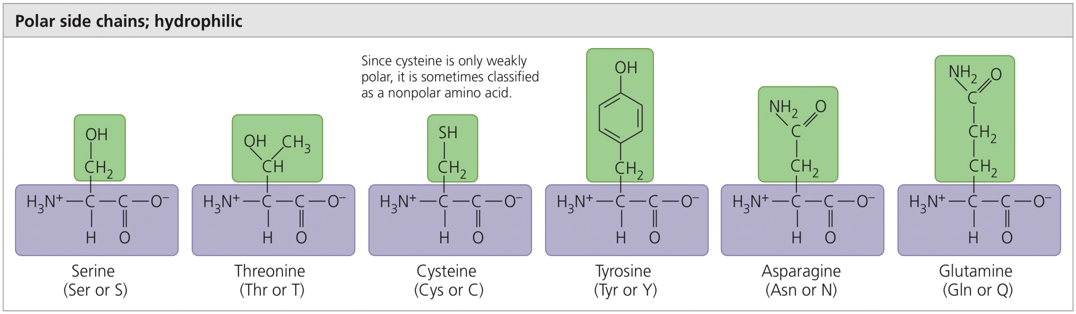


the amino acid is hydrophobic when

-when the side chain (R group) is hydrogen atom (glycine) or a hydrocarbon molecules (Alanine,valine ,leucine ,isoleucine,proline)

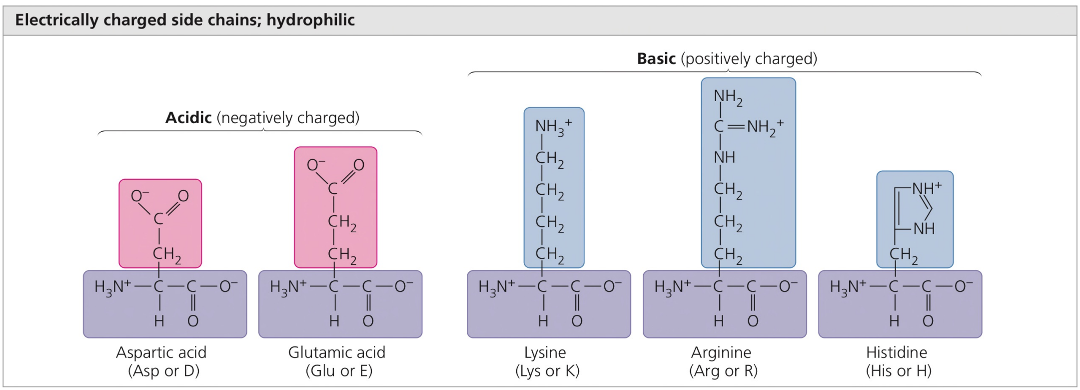
-in methionine we have S atom but it's electronegativity value is close to that of carbon so it is nonpolar amino acid.

-tryptophan and phenylalanine have benzene rings.



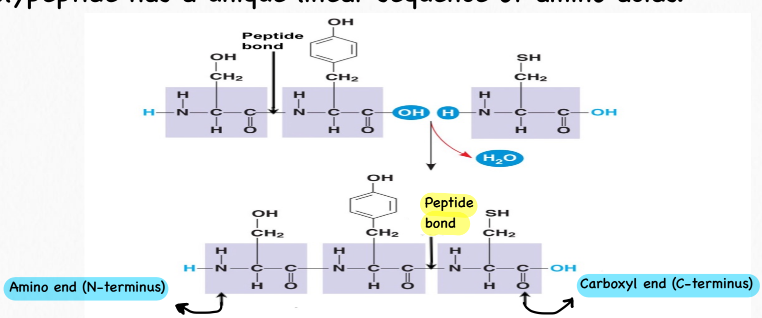
- the side chain has OH group (serine ,threonine , tyrosine) or NH2 group (aspargine ,glutamate)

- cysteine is only weakly polar, it is sometimes classified as a nonpolar amino acid.



💥Amino Acid Polymers:

- Amino acids are linked by **peptide bonds.**
- A **polypeptide** is a polymer of amino acids.
- Polypeptides range in length from a few to more than a thousand monomers.
- Each polypeptide has a unique linear sequence of amino acids.



💥Protein Structure and Function:

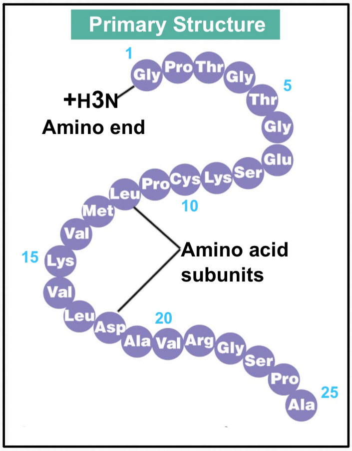
- A functional protein consists of one or more polypeptides twisted, folded, and coiled into a unique shape.
- The sequence of amino acids determines a protein's three-dimensional structure.

💥Four Levels of Protein Structure:

- The primary structure of a protein is its unique sequence of amino acids.
- Secondary structure, found in most proteins, consists of coils and folds in the polypeptide chain.
- Tertiary structure is determined by interactions among various side chains (R groups)
- Quaternary structure results when a protein consists of multiple polypeptide chains.

primary structure

- Primary structure is the sequence of amino acids in a protein.
- it is like the order of letters in a long word.
- Primary structure is determined by inherited genetic information.



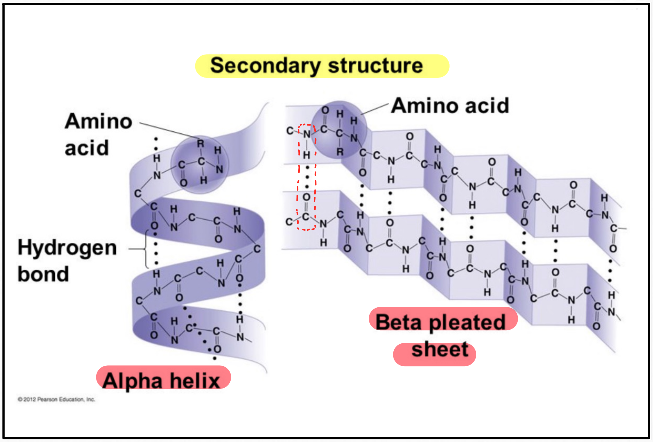
secondary structure

- The coils and folds of secondary structure result from hydrogen bonds between repeating constituents of the polypeptide backbone(not the amino acid side chains)
- When we mention the hydrogen bonds within the backbone of the protein structure, we mean the bond between the hydrogen atom in the amine group of one amino acid and the oxygen atom in the hydroxyl group of another amino acid in the same protein.

Main types of protein secondary structure:

A. Alpha helix: delicate coil held together by hydrogen bonding between every fourth amino acid .

B. Beta-pleated sheet : two or more segments of yhe polypeptide chain lying side by side and connected by hydrogen bonds between parts of the two parallel segments of polypeptide backbone.

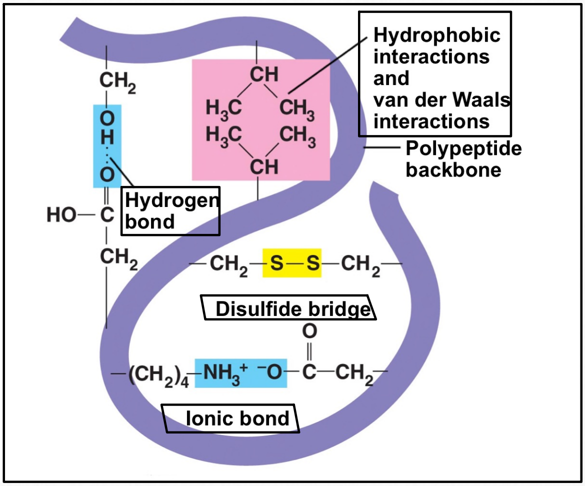


Tertiary structure

- tertiary structure is the overall shape of polypeptide resulting from interactions between the side chains (R groups) of the various amino acids.

-to differentiate between secondary and tertiary structures:
Tertiary structure is determined by interactions between R groups, rather than interactions between backbone constituents which determines the secondary structure.

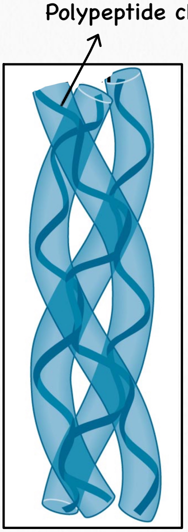
»types of interactions between R groups:
1-hydrophobic interactions (between non-polar side chains)
2-van der waals interactions (between non-polar side chains)
3-hydrogen bondes (between polar side chains)
4-ionic interactions (between positively and negatively charged side chains)
5-disulfide bridges (type of covalent bonds reinforce the protein's structure)
[Disulfide bridges form where two cysteine monomers, which have (-SH) groups on their side chains are brought close together by the folding of the protein. The sulfur of one cysteine bonds to the sulfur of the second, and the disulfide bridge (—S—S—) links parts of the protein together]



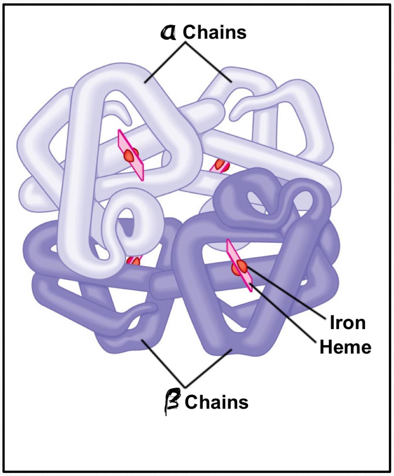
Quaternary structure

- Quaternary structure results when two or more polypeptide chains form one macromolecule.
- Collagen is a fibrous protein consisting of three polypeptides coiled like a rope.
- Hemoglobin is a globular protein consisting of four polypeptides: two alpha and two beta chains.

Polypeptide chain



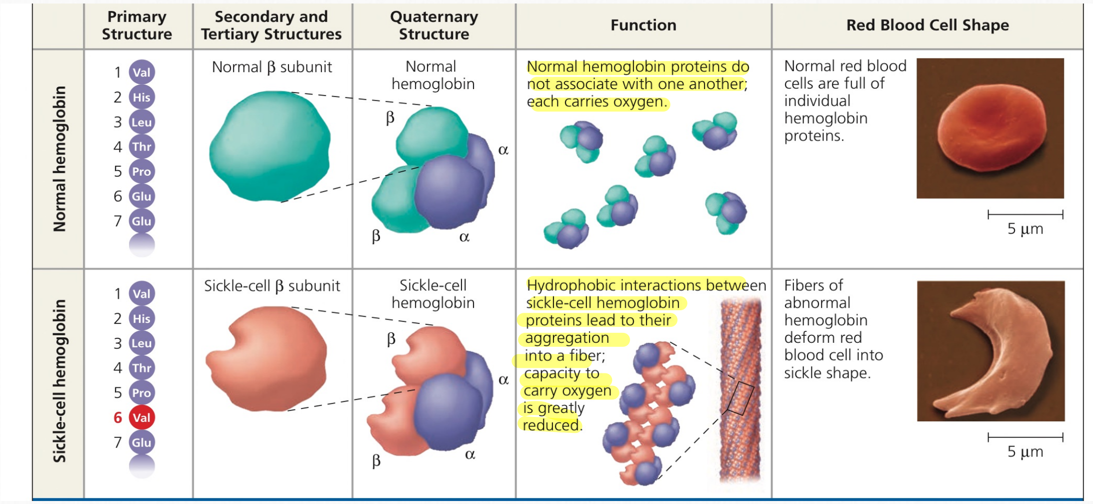
Collagen



Hemoglubin

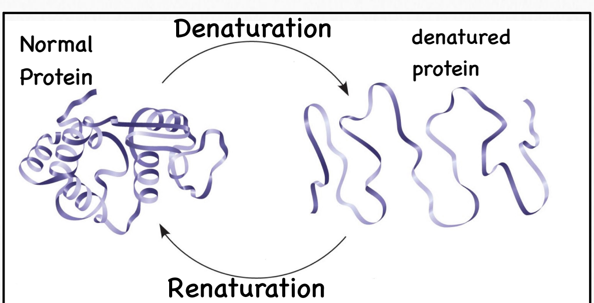
🩸Sickle-Cell Disease: A Change in Primary Structure:

- A slight change in primary structure can affect a protein's structure and ability to function.
- sickle-cell disease:an inherited blood disorder,is caused by the substitution of one amino acid (valine) for the normal one (glutamic acid) at the position of the sixth amino acid in the primary structure of protein.



💥What Determines Protein Structure?

- In addition to primary structure, physical and chemical conditions can affect structure.
- Alterations in pH, salt concentration, temperature, or other environmental factors can cause a protein to unravel.
- This loss of a protein's native structure is called **denaturation**.
- A denatured protein is biologically inactive.



💥Protein Folding in the Cell

- the protein-folding process is not that simple. Most proteins probably go through several intermediate structures on their way to a stable shape.
- Many diseases—such as cystic fibrosis, Alzheimer's, Parkinson's, and mad cow disease—are associated with an accumulation of misfolded proteins.
- The methods used to determine the 3-D structure of a protein:
  - X-ray crystallography (which depends on the diffraction of an X-ray beam by the atoms of a crystallized molecule)
  - nuclear magnetic resonance (NMR) spectroscopy.
  - Bioinformatics.

Concept 5.5 / Nucleic acids store and transmit hereditary information

- The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a gene.
- Genes are made of DNA, a nucleic acid.

» There are two types of nucleic acids:

1-Deoxyribonucleic acid (DNA)

2-Ribonucleic acid (RNA)

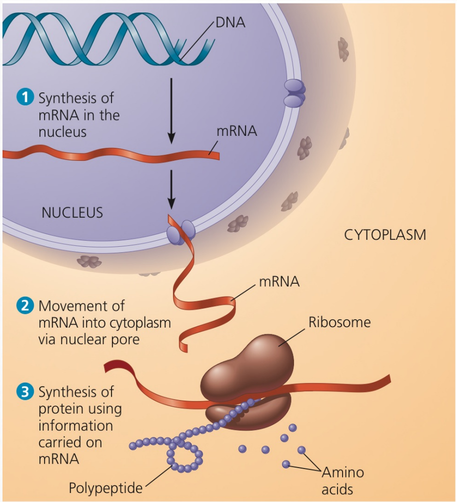
- each chromosome contains one long DNA molecule,usually carrying several hundred or more genes
- **Gene expression** is the process by which information from a gene is used to create a functional genetic product. Most of these products are proteins, but some genes are expressed to synthesize functional RNA.

Gene expression: DNA»RNA »protein

1-Synthesis of mRNA in the nucleus. **(Transcription)**

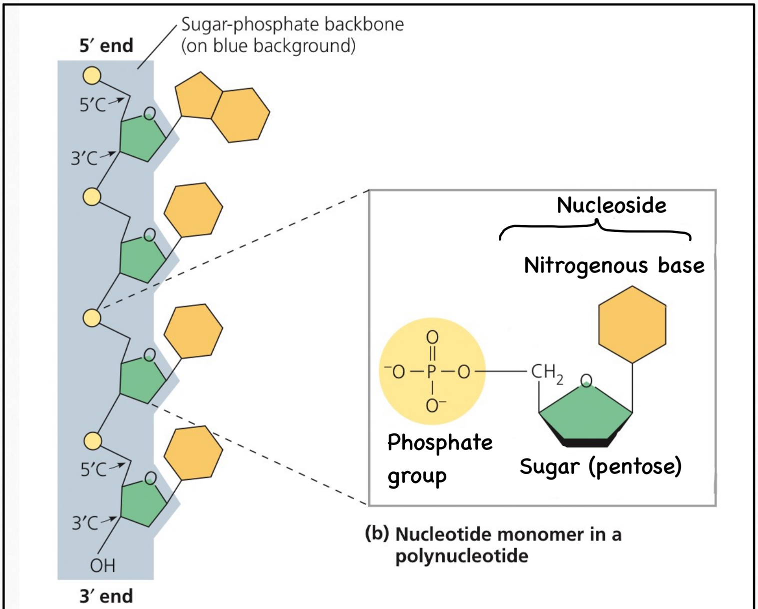
2-Movement of mRNA into cytoplasm via nuclear pore.

3-Synthesis of protein using information carried on mRNA **(translation)**



💥The Structure of Nucleic Acids:

- Nucleic acids are polymers called polynucleotides.
- Each polynucleotide is made of monomers called nucleotides.
- Each nucleotide consists of a nitrogenous base, a pentose sugar, and a phosphate group.
- The portion of a nucleotide without the phosphate group is called a nucleoside.



(a) Polynucleotide, or nucleic acid

(b) Nucleotide monomer in a polynucleotide

💥Nucleotide Monomers:

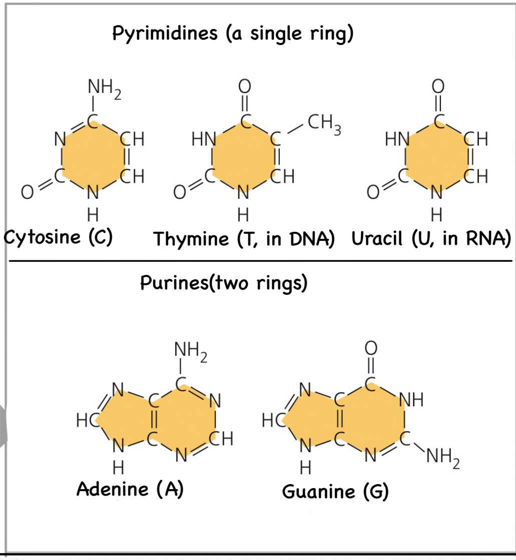
- Nucleoside = nitrogenous base + sugar.
- There are two families of nitrogenous bases:

1-**Pyrimidines** (cytosine, thymine, and uracil) have a single six-membered ring.

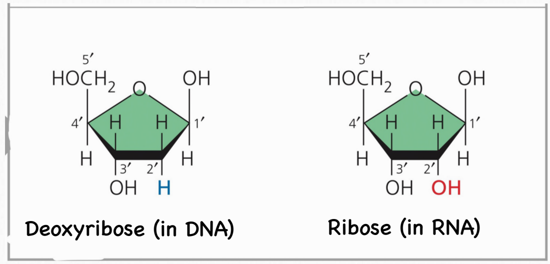
2-**Purines** (adenine and guanine) have a six-membered ring fused to a five-membered ring

- In DNA, the sugar is deoxyribose; in RNA, the sugar is ribose.
- Nucleotide = nucleoside + phosphate group.

Nitrogenous bases



Sugars



-we notice that carbon number two in deoxyribose sugar has H aton instead of hydroxyl group .

💥Nucleotide Polymers

- Nucleotide polymers are linked together to build a polynucleotide.
- Adjacent nucleotides are joined by covalent bonds that form between the -OH group on the 3
- These links create a backbone of sugar- phosphate units with nitrogenous bases as appendages.

-The structure of DNA & RNA molecules:

- The sequence of bases along a DNA or mRNA polymer is unique for each gene.
- A DNA molecule has two polynucleotides spiraling around an imaginary axis, forming a double helix.
- In the DNA double helix, the two backbones run in opposite 5⟶ 3

One DNA molecule includes many genes

- The nitrogenous bases in DNA pair up and form hydrogen bonds: adenine (A) always with thymine (T), and guanine (G) always with cytosine (C)
- RNA molecules exist as single strands.
- Complementary base pairing can occur between regions of two RNA molecules or even between two stretches of nucleotides in the same RNA molecule.
- in fact, this base pairing within an RNA molecule allowes it to take on the particular three dimensional shape necessary for it's function (for example transfer RNA tRNA)
- in RNA adenine pairs with uracil; thymine is not present in RNA .

🟣 in a DNA double helix, a region along one DNA strand has this sequence of nitrogenous bases: 5′-TAGGCCT-3′,write down the completely sequence:

the answer: 3′-AGGCCTA-5′