Course: Cell Physiology-PHYS-115

CHEMISTRY REVIEW

Chemical Components in The Cell-

Organic Components

Carbohydrates & Proteins

Learning Objectives:

- ❖ List the common functional groups of organic molecules.
- ❖ Describe the dehydration synthesis and hydrolysis reactions.
- ❖ Review the carbon cycle.
- ❖ Describe the different types of carbohydrates.
- ❖ Describe the levels of protein structures.
- ❖ Explain the lock and key hypothesis and describe some examples of this hypothesis occurring in human body.

Organic Compounds:

- Molecules unique to living systems***, carbohydrates, lipids (fats), proteins,*** and ***nucleic acids***, all contain carbon and hence are organic compounds.

- Organic compounds are generally distinguished by the fact that they contain carbon, and inorganic compounds are defined as compounds that lack carbon (few exception e.g. CO & CO_2 they have carbon but are inorganic).

- For the most part, organic molecules are very large molecules, but their interactions with other molecules typically involve only small, reactive parts of their structure called ***functional groups (acid groups, amines, and others).***

- Many biological molecules (e.g. carbohydrates and proteins) are polymers. **Polymers** are chainlike molecules made of many similar or repeating units (**monomers**), which are joined together by ***dehydration synthesis***.

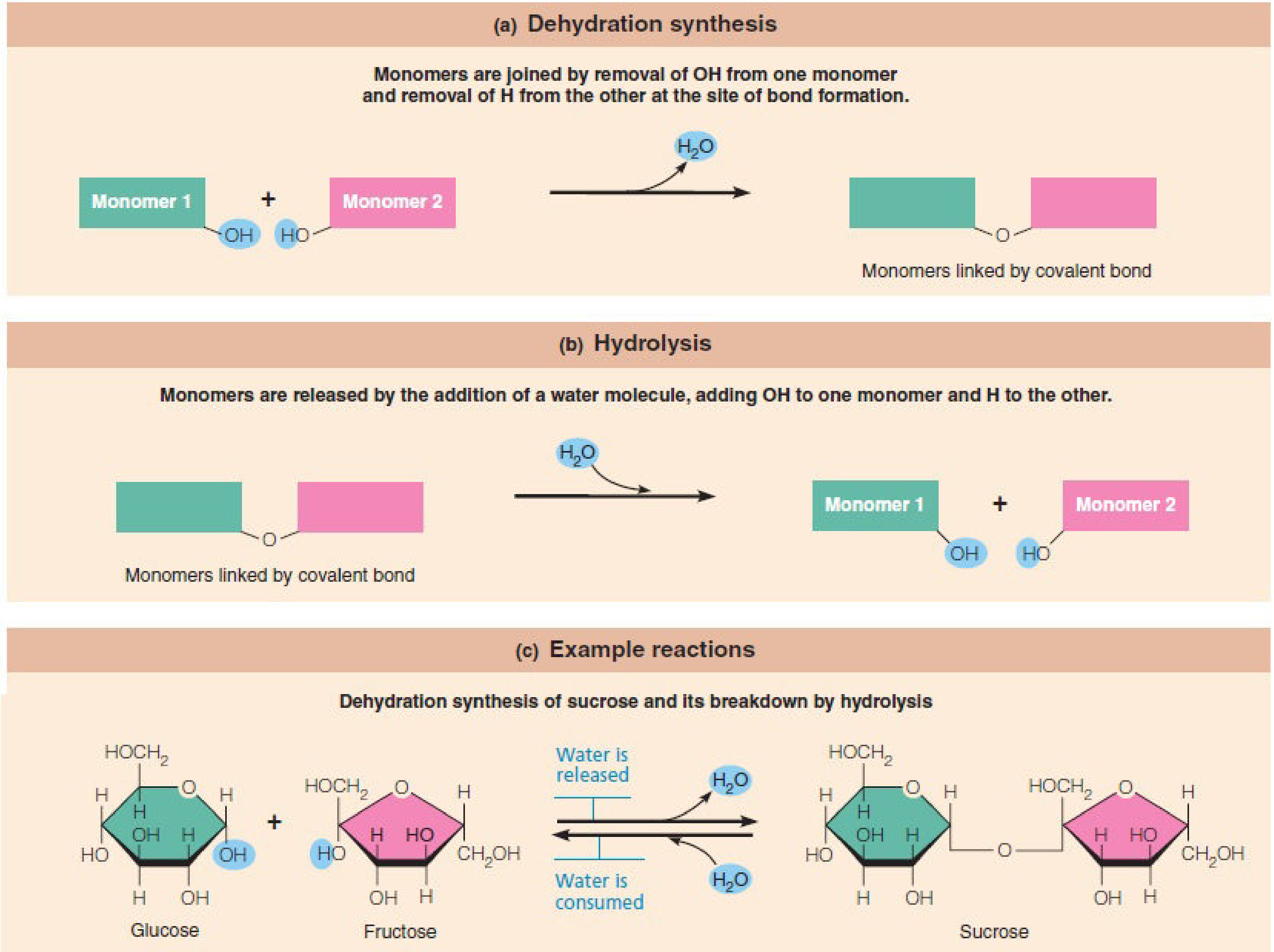
Functional Groups:

ORGANIC COMPOUNDS IN THE BODY

Functional groups:

Family	Group	Name	Importance
Alcohol	R—OH	Hydroxyl	Polar, water-soluble, forms hydrogen bonds. Can be formed by reducing aldehyde/ketone.
Aldehyde	R C = O H	Carbonyl	Polar, found in aldo-sugars. Formed by oxidation of alcohols.
Ketone	R C = O R'	Carbonyl	Polar, found in keto sugars
Acids	R C = O OH	Carboxyl	Weak acid. Can dissociate to form an anion and a proton. Formed by oxidation of aldehyde, or by two steps of oxidation of alcohol.
Amines	R - NH_2	Amino	Weak base. Can accept a proton to form a cation.
Amides	R C = O NH_2	Amido	Polar but does not ionize.
Thiols	R - SH	Thiol	Does not form hydrogen bonds. Less soluble than alcohols.
Esters	R C = O O R'	Ester	Formed by reacting acid with alcohol. Fatty acids form esters by reacting with glycerol to form triglycerides.
Double bond	CH = CH	Alkene	Important structural component of many biomolecules, e.g. lipids.

Organic Compounds:



Organic Compounds *- Carbohydrates:*

- Carbohydrates, a group of molecules that includes sugars and starches, represent ***1–2%*** of cell mass. Carbohydrates contain ***carbon, hydrogen, and oxygen, and generally the hydrogen and oxygen atoms occur in the same 2:1 ratio*** as in water. This ratio is reflected in the word ***carbohydrate ("hydrated carbon").***

- The unit of carbohydrate chemistry is the ***monosaccharide,*** or ***simple sugar.***

- Glucose has a special place in the ecosystem, because plants (prototroph) make it from water & CO_2 by trapping solar energy and converting it to chemical energy. Glucose is found in vegetables for this reason. It is also found in grapes and honey.

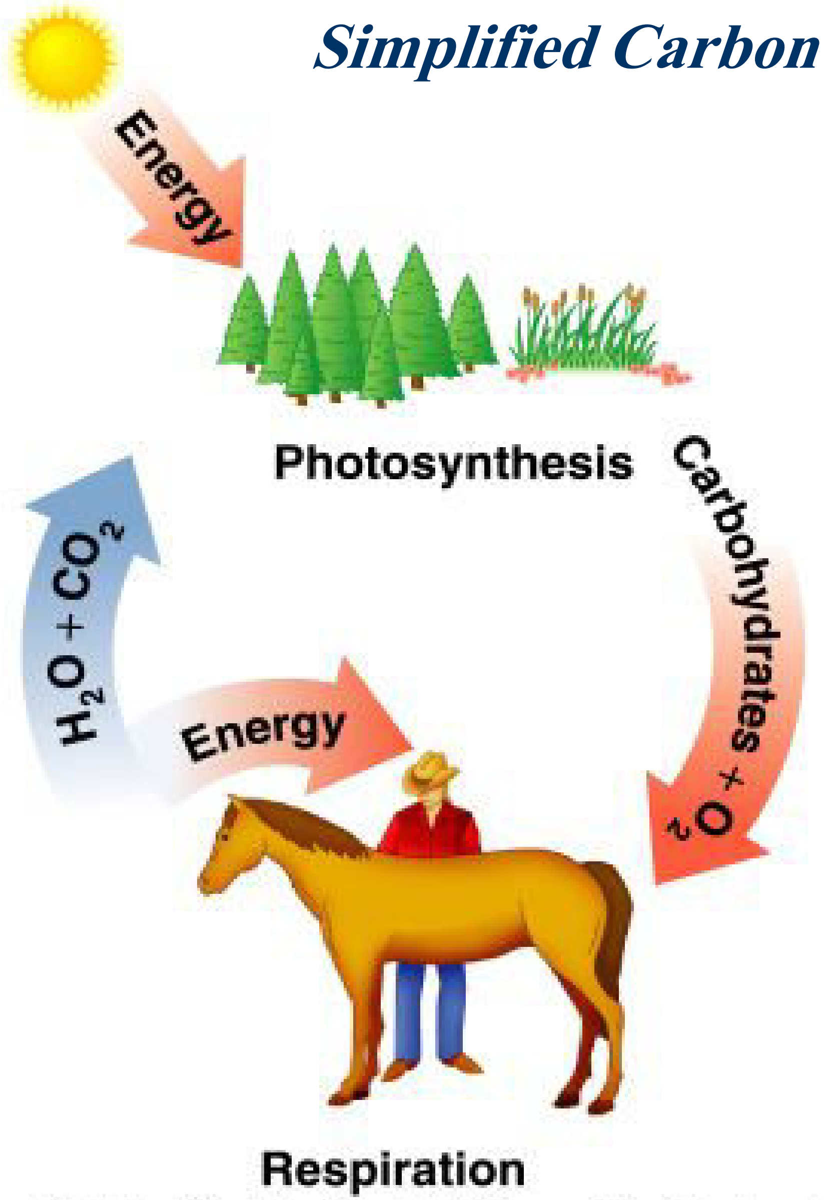
$$6CO_2 + 6H_2O + \text{Energy} \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$$

- Glucose is the main energy source of animals (chemotrophs) and circulates in our blood.

- Sweet food more often contains fructose or sucrose ***(disaccharide).***

Organic Compounds - *Carbohydrates:*

Simplified Carbon Cycle

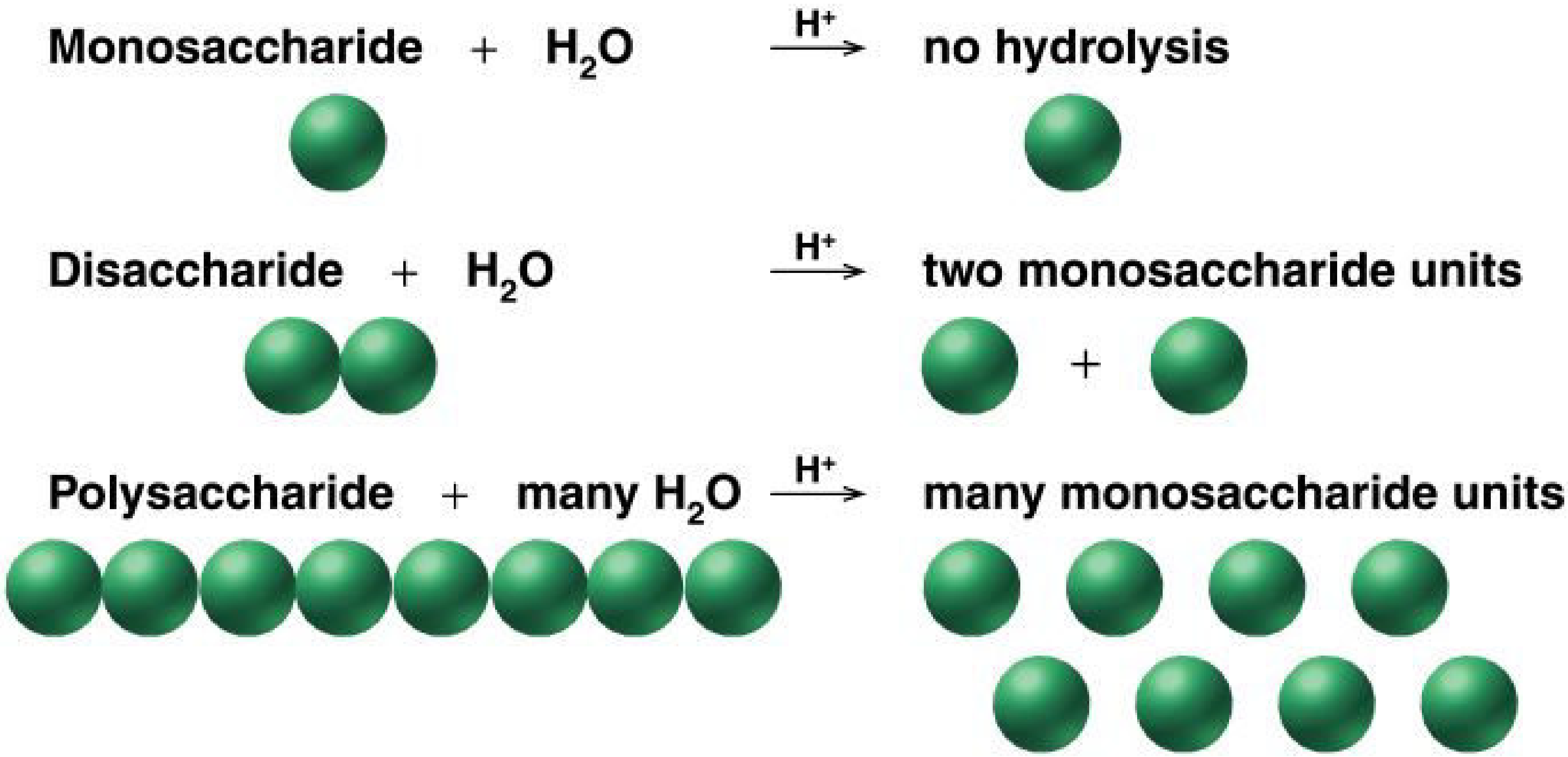


Organic Compounds *- Carbohydrates:*

Types of Carbohydrates:

- **Monosaccharides** are the simplest carbohydrates
  - Also called "simple sugars".
  - Cannot be split into smaller carbohydrate units.
  - Examples: glucose, fructose, galactose, ribose.
- **Disaccharides** are two monosaccharides bonded together
  - Can be split into two monosaccharides using an acid or enzyme catalyst.
  - Examples: sucrose (table sugar), lactose (milk sugar).
- **Polysaccharides** are polymers of monosaccharides:
  - Used for storage of carbohydrates.
  - Can be split into many monosaccharides with acid or enzymes.
  - Examples: starch, cellulose, glycogen.

Organic Compounds - *Carbohydrates:*



Organic Compounds - *Carbohydrates:*

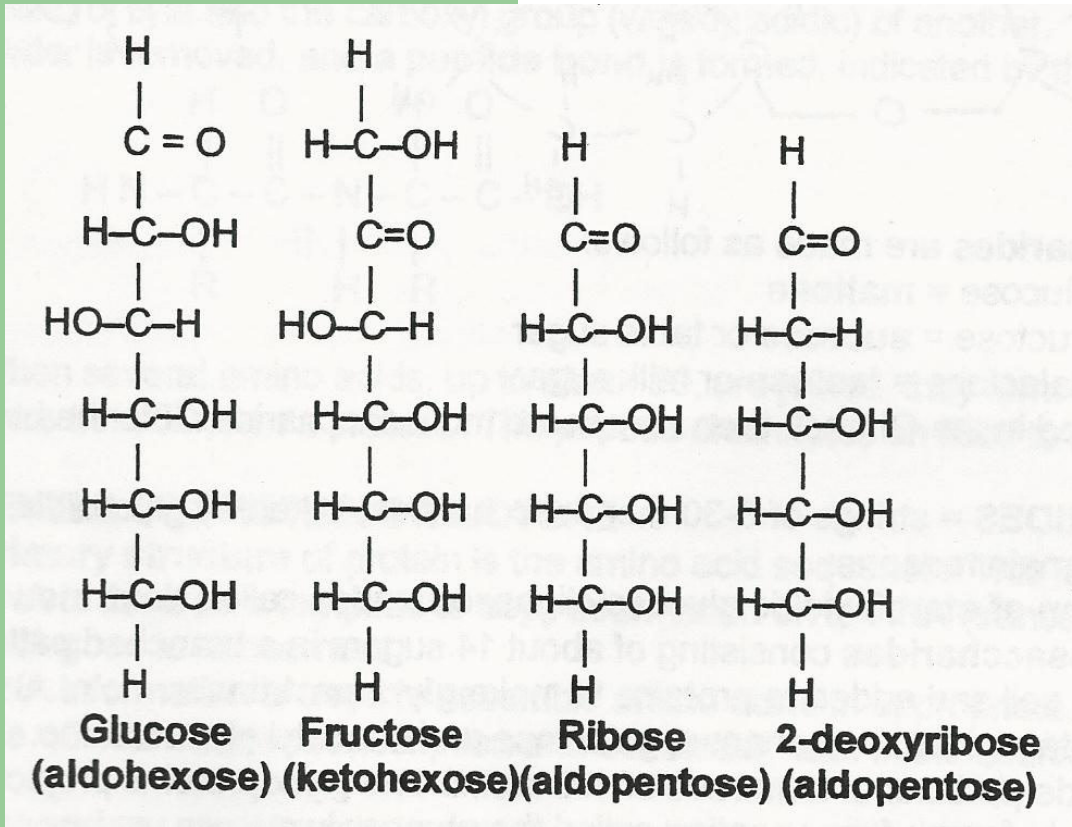
- ***Monosaccharides*** often contain 6 carbon atoms, but may contain 3-9 carbon atoms.

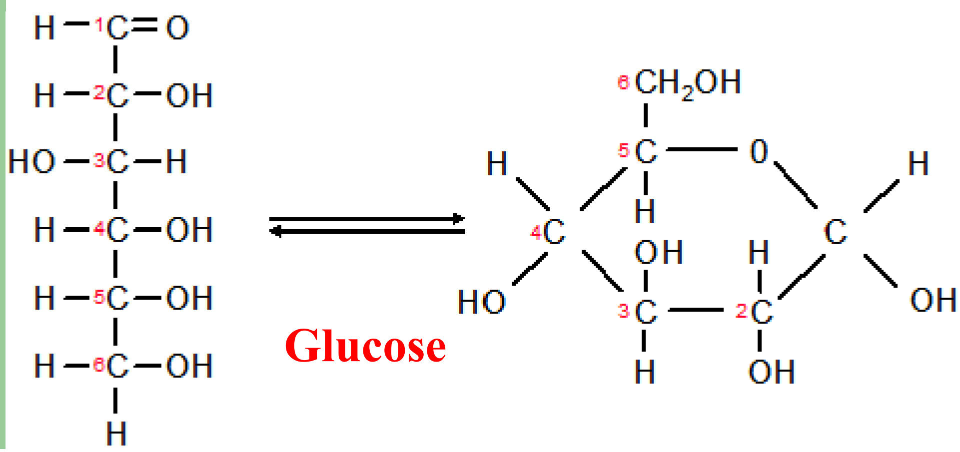
- Monosaccharides are named generically according to the number of carbon atoms they contain. Most important in the body are the ***pentose (five-carbon) and hexose (six-carbon) sugars***. For example, ***the pentose deoxyribose is part of DNA, and glucose, a hexose, is blood sugar.***

- Three other hexoses, ***galactose , mannose and fructose***, *are* ***isomers*** of glucose. That is, they have the same molecular formula (**$C_6H_{12}O_6$**), but their atoms are arranged differently, giving them different chemical properties.

- Another 6-carbon sugar that is used structurally in the cell, is ***N-acetyl glucosamine***. ***Ribose and Deoxyribose*** are not isomers and they are used in nucleic acids.

Organic Compounds - *Carbohydrates:*

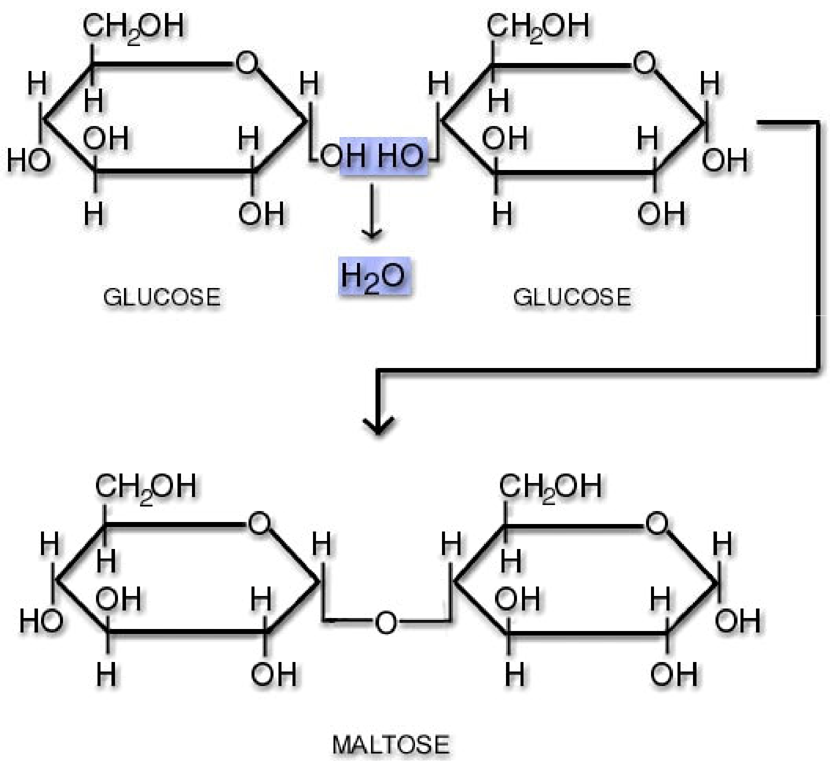




Monosaccharides spend some of their time alternating between the linear structure and the ring structure

Organic Compounds - *Carbohydrates:*

- ***Disaccharides*** are pairs of monosacchrides linked by dehydration synthesis or condensation, to form glycosidic bonds, as shown below for glucose to maltose:



-réaction de condensation du maltose

- Common disaccharides are made as follows:
  - **Glucose+Glucose=Maltose**
  - **Glucose+Fructose= Sucrose or table sugar**
  - **Glucose+Galactose= Lactose or milk sugar.**
- They are hydrolyzed in the GI tract, then we absorb monosacchrides into the blood.

Organic Compounds *- Carbohydrates:*

- ***Oligosaccharides*** are strings of 3-30 monosacchrides, linked by glycosidic bonds. These occur for two main reasons:

  - Partial digestion of starch yields glucose oligosaccharides called *dextrins*.

  - Complex oligosacchrides consisting of 14 sugars in a branched pattern, are synthesized in the cell and added to proteins to make *glycoproteins.*

- Glycoproteins contain *glucose, mannose, galactose* and *N-acetyl glucosamine*
.

- The oligosacchrides portions of hundreds of cell membrane glycoprtoeins project on the outside of the cell, to form a fuzzy coating called the ***glycocalyx*** . These play an essential role in cell communication.

- Polysacchrides are formed from glucose in plants as starch, and in our liver and muscle as glycogen, but muscle glycogen is only broken down to glucose for use in the muscle themselves.

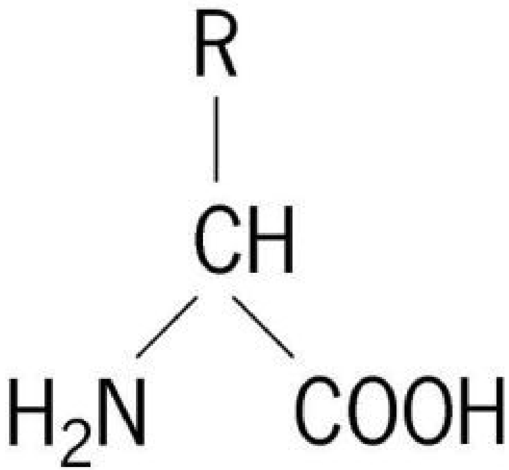
Organic Compounds - *Proteins:*

- Protein composes ***10–30%*** of cell mass and is the basic structural material of the body. However, not all proteins are construction materials. Many play vital roles in cell function.

- Proteins, which include ***enzymes*** (biological catalysts), ***hemoglobin*** of the blood, and ***contractile proteins*** of muscle, have the most varied functions of any molecules in the body.

- All proteins contain ***carbon, oxygen, hydrogen, and nitrogen***, and many contain ***sulfur*** as well.

Amino acids are the building blocks of proteins, each amino acid contains an amino group and a carboxyl group, both attached to the "α carbon" which also bears a side chain or R group.



Organic Compounds - *Proteins:*

- The amino group is a weak base which ionizes by taking up an extra proton.

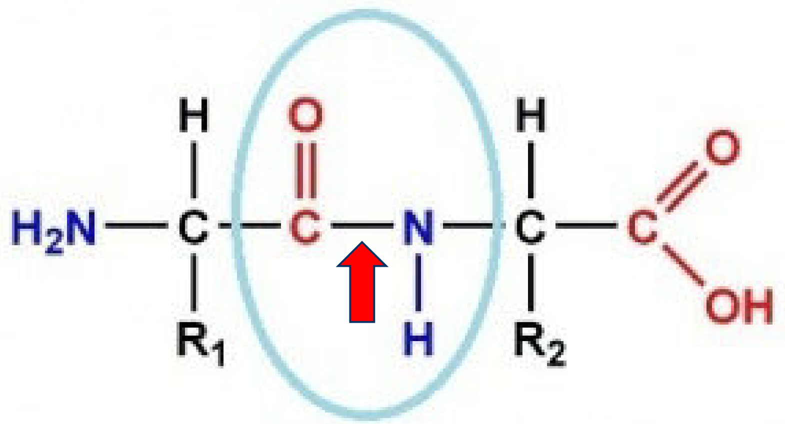
- The carboxyl group is a weak acid which ionizes by losing a proton.

- There are ***20 different types of amino acids*** involved in protein building. Some R groups are as follows:

Amino acid	R- Group
Glycine	H
Alanine	CH_3
Serine	CH_2OH
Phenylalanine	Benzene ring-CH_2
Glutamate	$(CH_2)_2$-COOH
Lysine	$(CH_2)_4$-NH2

Organic Compounds *- Proteins:*

- **Peptide bond formation**: Amino acids are joined by a *neutralization reaction* between the amino group (weakly basic) of one and the carboxyl group (weakly acidic) of another. Water is removed, and a peptide bond is formed, indicated by the arrow below:



- When several amino acids, up to about 50, are joined, they form a (poly) peptide. ***More than 50 form a protein***. ***The peptide chain folds on itself to make a 3-D shape.***

Organic Compounds – *Proteins* – *Level of Protein Structure:*

- Proteins can be described in terms of four structural levels.

- ***Primary structure of protein:*** The linear sequence of amino acids composing the polypeptide chain is called the ***primary structure of a protein****. This structure,* which resembles a ***strand of amino acid "beads,"*** is the backbone of the protein molecule.

- This is determined by genes:

  - DNA is used as a template to copy information on to RNA (***transcription***).

  - RNA goes to ribosomes. RNA information is used to assemble amino acids in appropriate sequence (***translation***). We will learn about transcription & translation later in the course.

Organic Compounds – *Proteins* – *Level of Protein Structure:*

- ***Secondary structure of protein*** is formed from ***hydrogen bonding*** between different amino acids. *Hydrogen bonding occurs between C=O of one peptide chain, and N-H of another. It happens when R groups are small and uninvolved.* It results in the formation of:

  (a) ***α helix within 1 peptide chain***, used in **collagen & keratin** (***resemble coils of a telephone cord***).

  (b) ***β pleated sheets between different peptide chains***. the primary polypeptide chains ***do not coil***, but are linked side by side by ***hydrogen bonds*** to form a ***pleated***, ***ribbonlike structure that resembles an accordion's bellows***. ***Structural proteins, with insoluble structures, are made this way***. Notice that in this type of secondary structure, the hydrogen bonds may link together *different polypeptide chains as well as different parts of the same chain that has* ***folded back on itself.***

  (c) ***A single polypeptide chain may exhibit both types*** *of secondary structure at various places along its length.*

Organic Compounds – *Proteins* – *Level of Protein Structure:*

- ***Tertiary structure of protein*** is achieved when ***α-helical or β-pleated regions*** of the polypeptide chain fold upon one another to produce a soluble compact ***ball-like***, or ***globular, molecule***. *This is formed when the R groups within one protein molecule interact with each other in any of three different ways:*

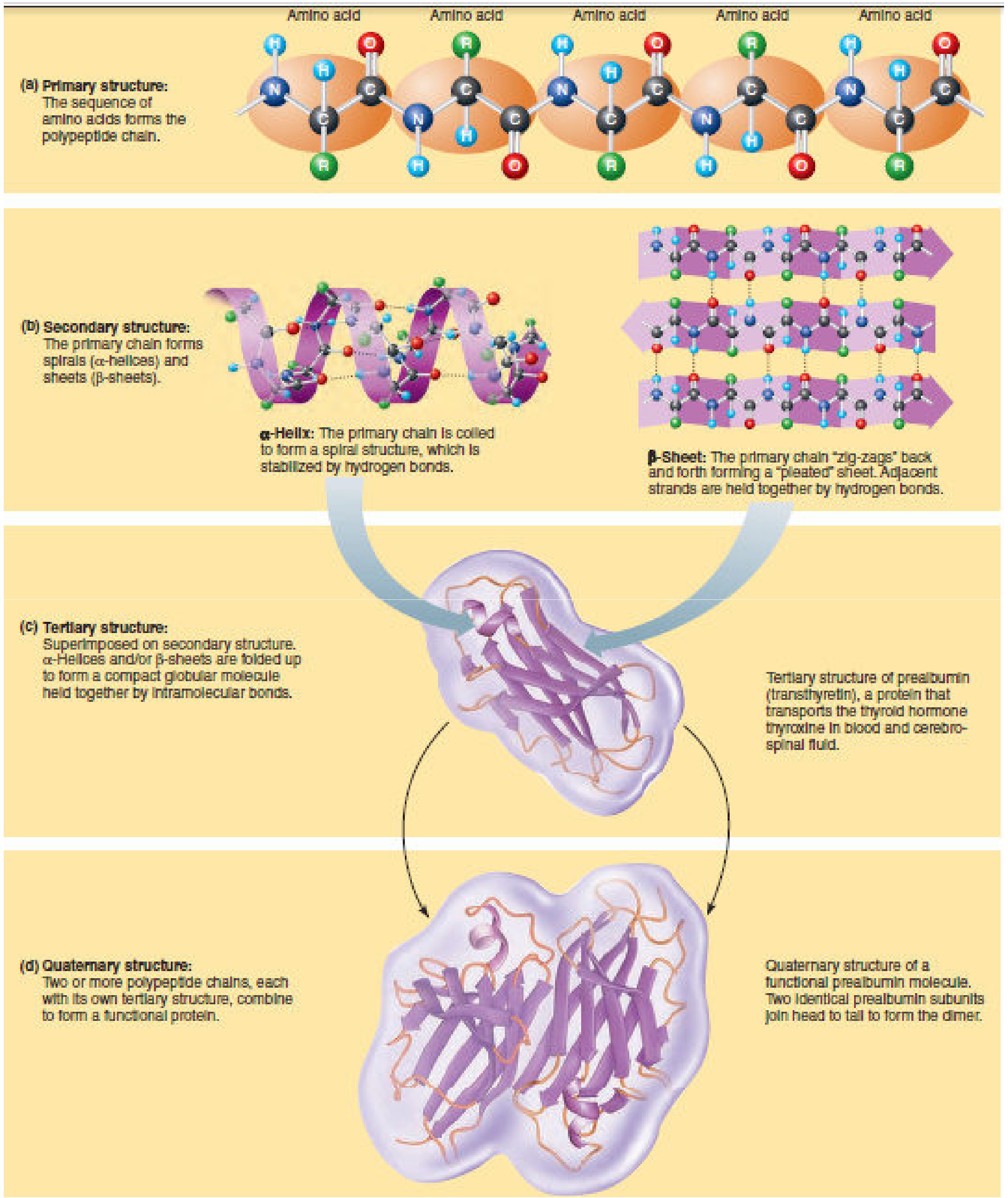
  - *Ionizable R groups* interact with each other to form ***ionic bonds.***

  - *Hydrophobic R groups* form ***hydrophobic bonds***.

  - ***Disulfide bridges (covalent)*** form between ***thiol groups*** of ***cysteine R groups***.

- ***Quaternary structure of protein*** is the same as tertiary, but takes place between two or more molecules. Other molecules involved may be more peptide chains, or they may be non-protein molecules or ions. Quaternary structure is much more common than tertiary. e.g. ***Insulin*** is made up of ***two peptide chains*** joined by disulfide bridges. ***Hemoglobin*** consists of ***4 heme (non-protein) groups and 4 globin (protein) molecules.***

Levels of Protein Structure



Organic Compounds – *Proteins:*

- ***Functional Proteins:*** Soluble, globular proteins are folded by tertiary and quaternary structure. The tertiary and quaternary structures give the proteins intricate 3-dimensional shapes. These shapes are used to enable the proteins to interact with other molecules.

- ***Lock & Key hypothesis:*** The part of the molecule with a specific configuration which allows another molecule to lock into a key in a lock is called the active site.

- ***Examples of possible Lock-and –Key functions***:

  - **Enzymes:** The active site allows substrate(s) to lock into the enzyme. The substrate trigger a change in the configuration of the enzyme, which in turn causes the substrate to be chemically converted into product(s).

  - **Receptors:** On the surface of cells are receptor protein, specific hormones. The hormone fits into an active site on the cell membrane protein receptor. Active sites on hormone receptors often involve glycoprotein. The hormone triggers a change in configuration of the receptor, which in turn causes the cell to make certain responses which are appropriate for that hormone.

Examples of possible Lock-and –Key functions contd.

- **Second messengers** are used by cells in response to certain hormones:

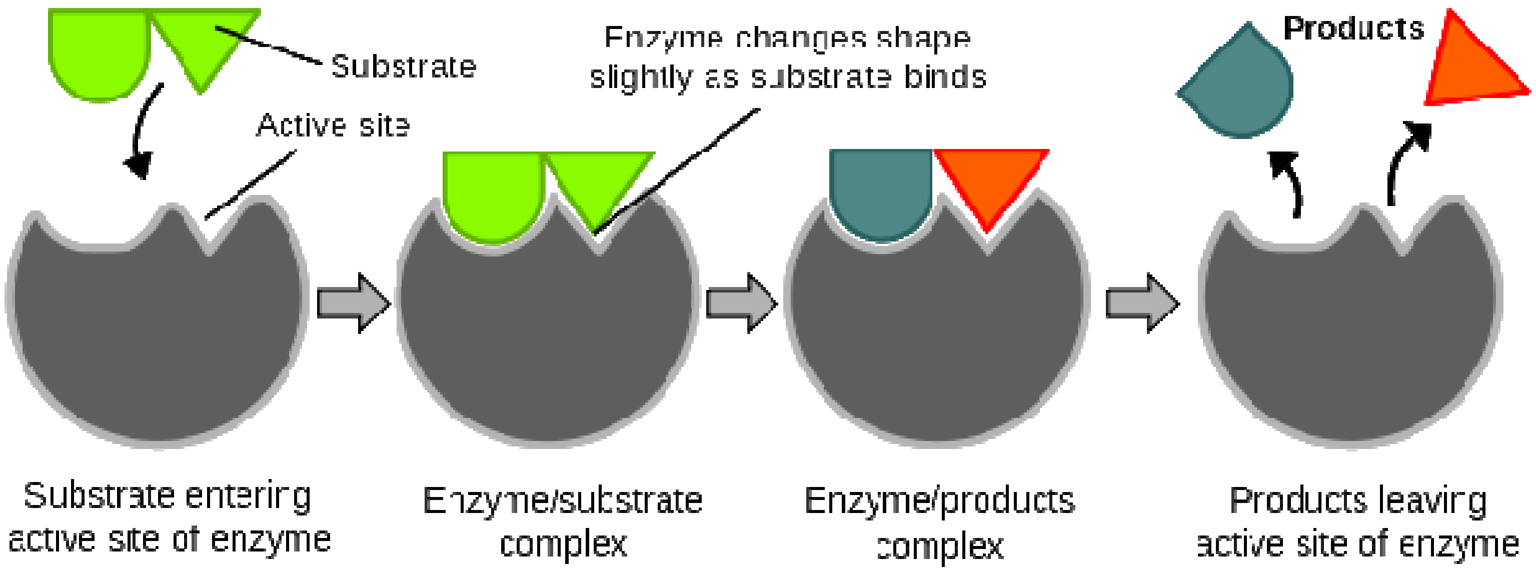
  - ✓ The hormone receptor may trigger the formation of cyclic AMP within the cell which mediates cellular responses to the hormone, often by influencing the DNA.

  - ✓ ***Calcium ions*** are sometimes used as second messengers within cells.

- **Antibodies:** Foreign molecules/organism in the body, trigger an immune response. The foreign molecules or organism is called an ***antigen.*** ***B-lymphocytes*** respond to the presence of the antigen, by making ***antibodies***. ***Antibodies are highly specific for each antigen***, perhaps due to. The quaternary structure of an antibody involves *2 heavy chains* and *2 lighter chains*, linked together by *disulfide bridges* to make a characteristic Y-shaped structure. The active site, at the tips of the prongs of the Y, react with the antigen to make a large conglomerate of material, which may precipitate out. It is then eaten by ***macrophages.***

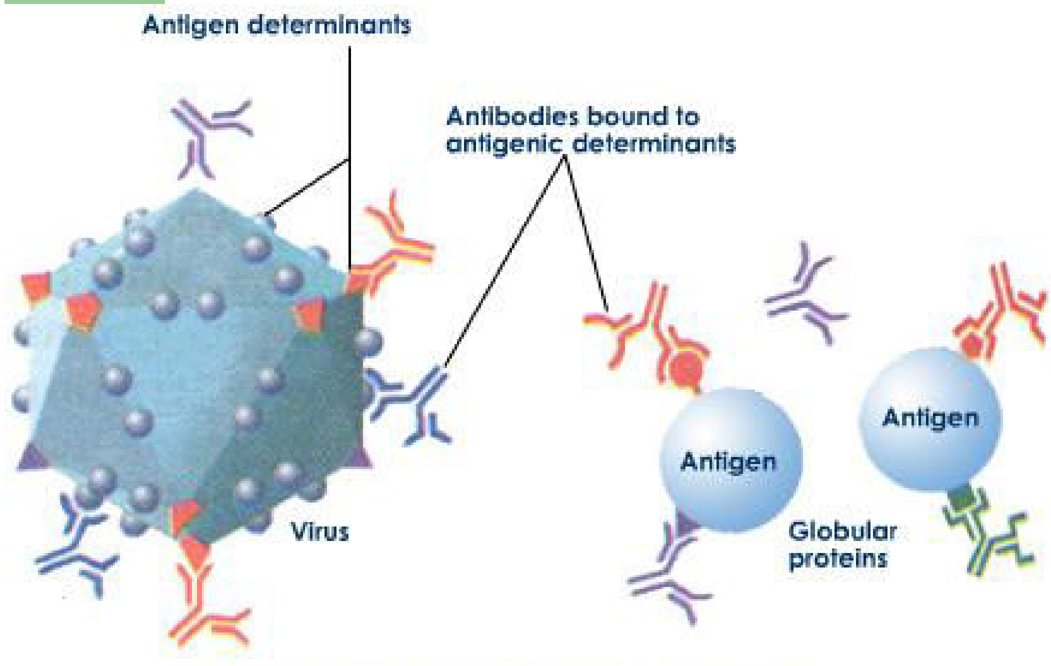
Examples of possible Lock-and –Key functions :

Enzyme action is an example of Lock & Key Hypothesis



Examples of possible Lock-and –Key functions :

Ag-Ab complex is an example of Lock & Key Hypothesis



Formation of antigen-antibody complex