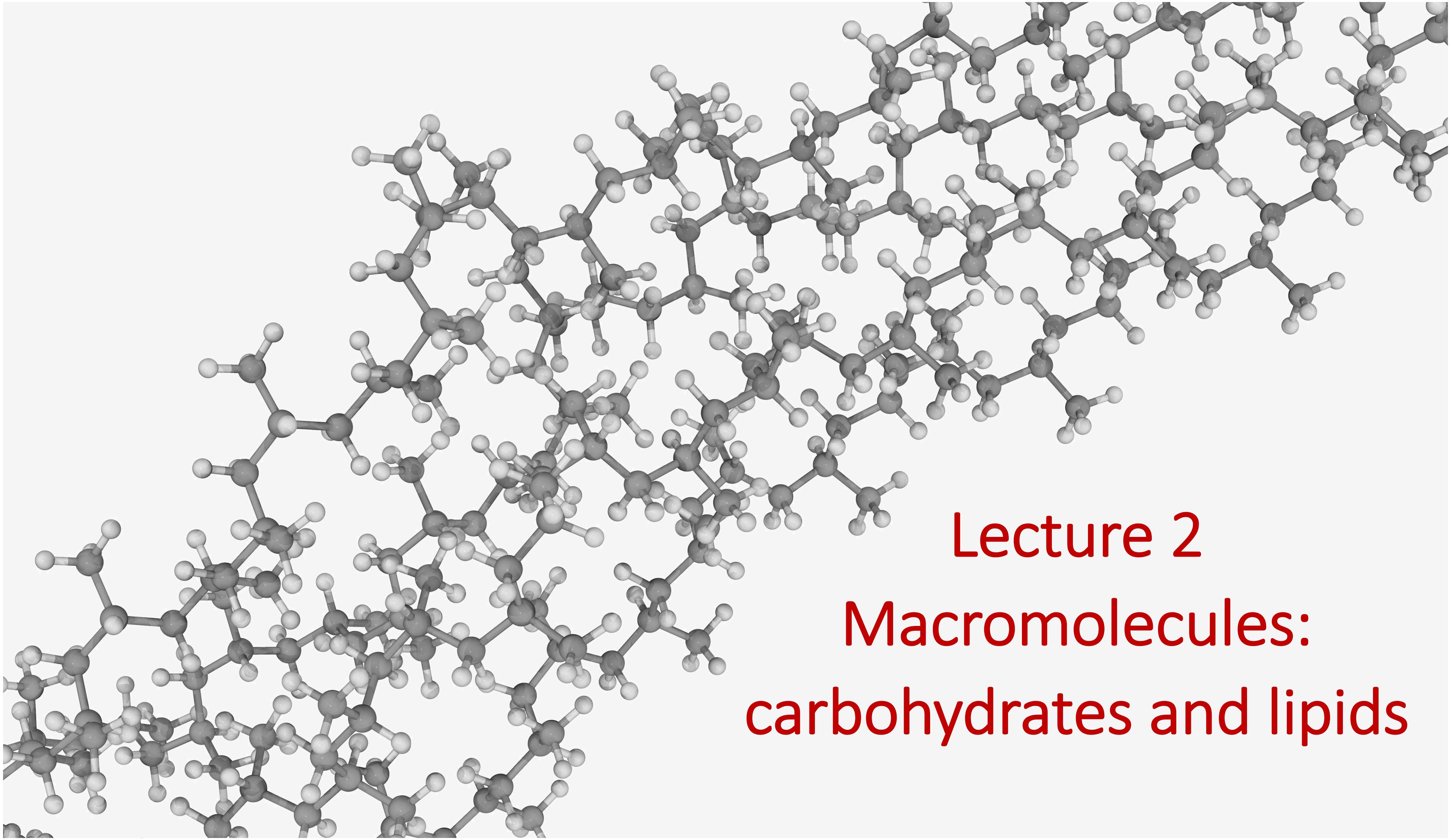
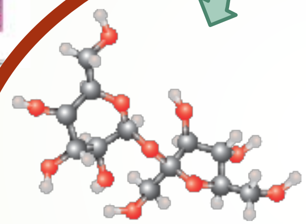
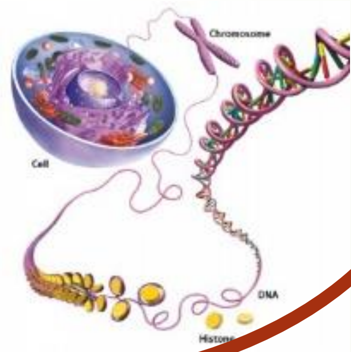
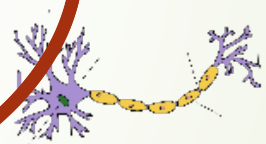


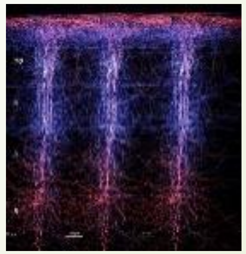
Lecture 2
Macromolecules: carbohydrates and lipids

Biological chemistry, is the study of chemical processes within and relating to living organisms. Protagonists in this field are 4 family of MACROMOLECULES

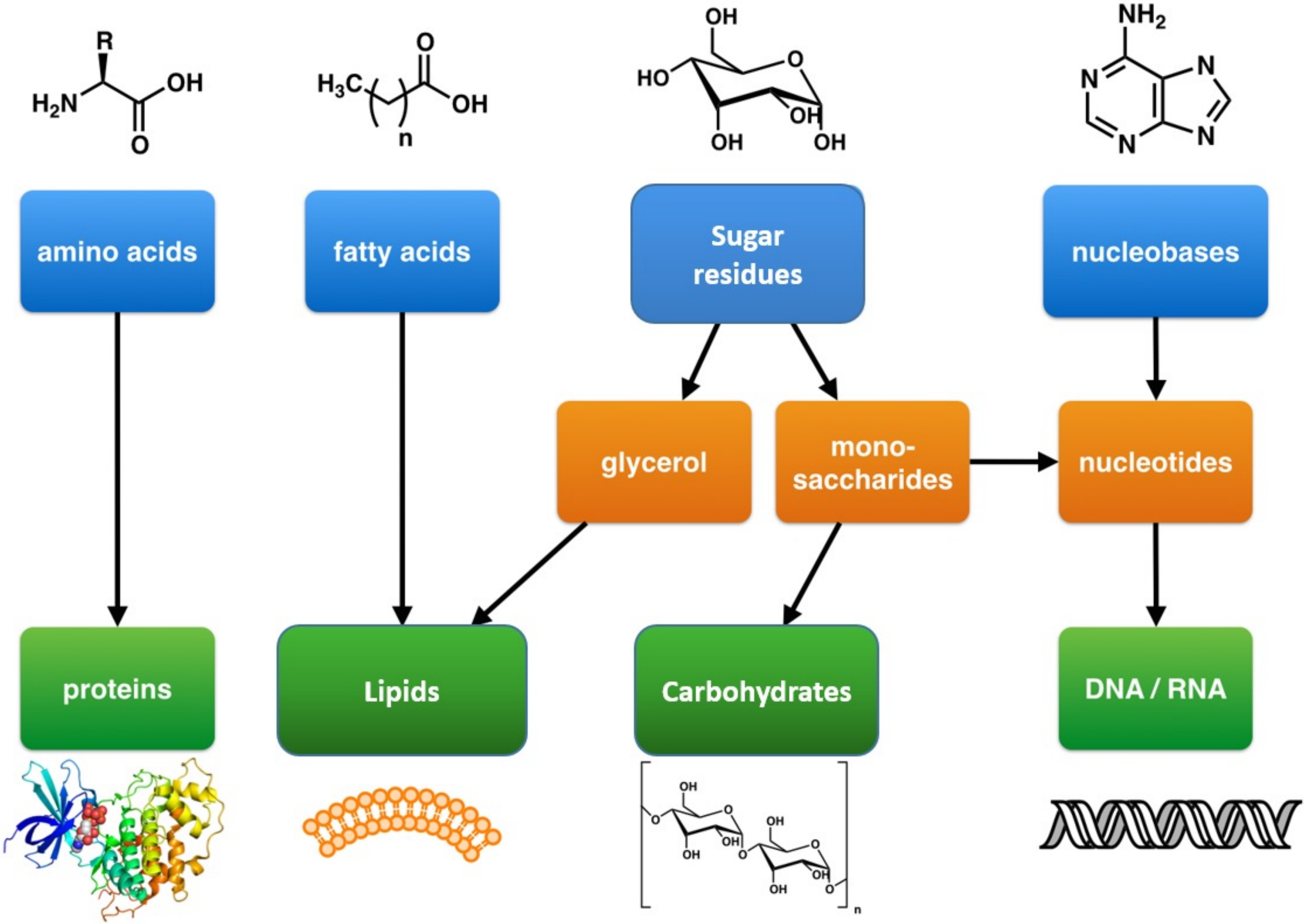






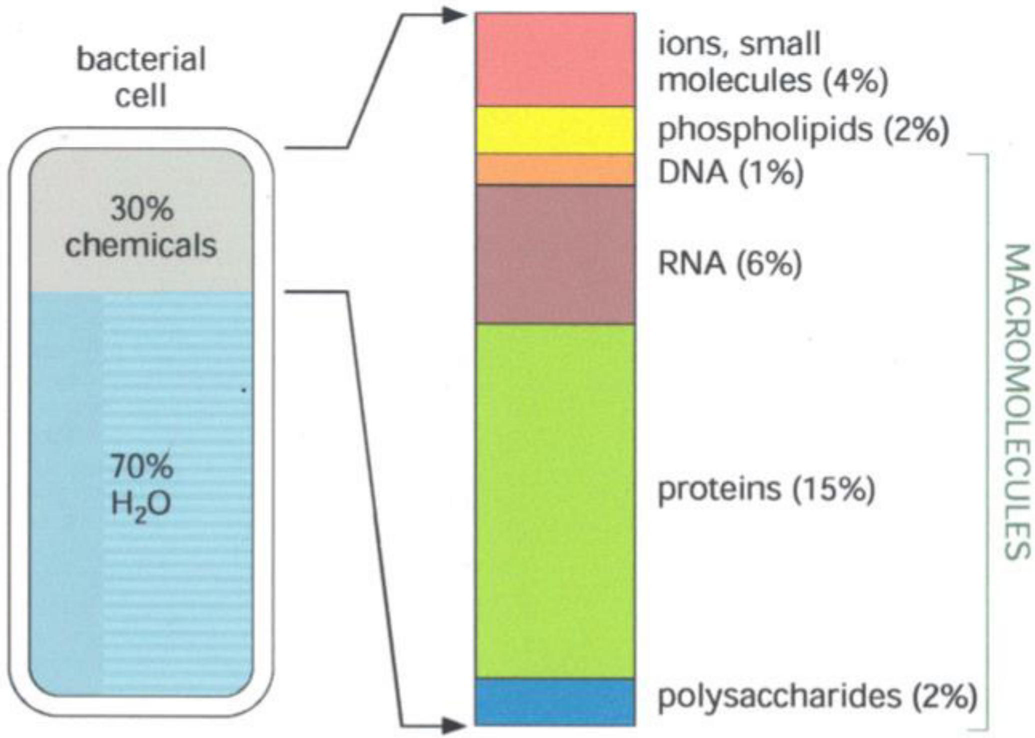


Macromolecules are constituted by individual molecular units, that, like molecular bricks, polymerize to form gigantic compounds



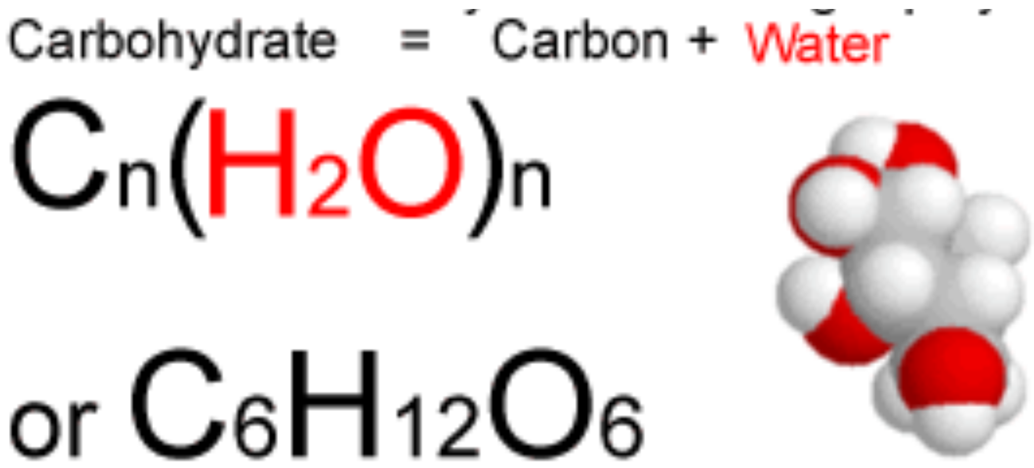
amino acids
fatty acids
Sugar residues
nucleobases
glycerol
mono-saccharides
nucleotides
proteins
Lipids
Carbohydrates
DNA / RNA

Macromolecules in the cell

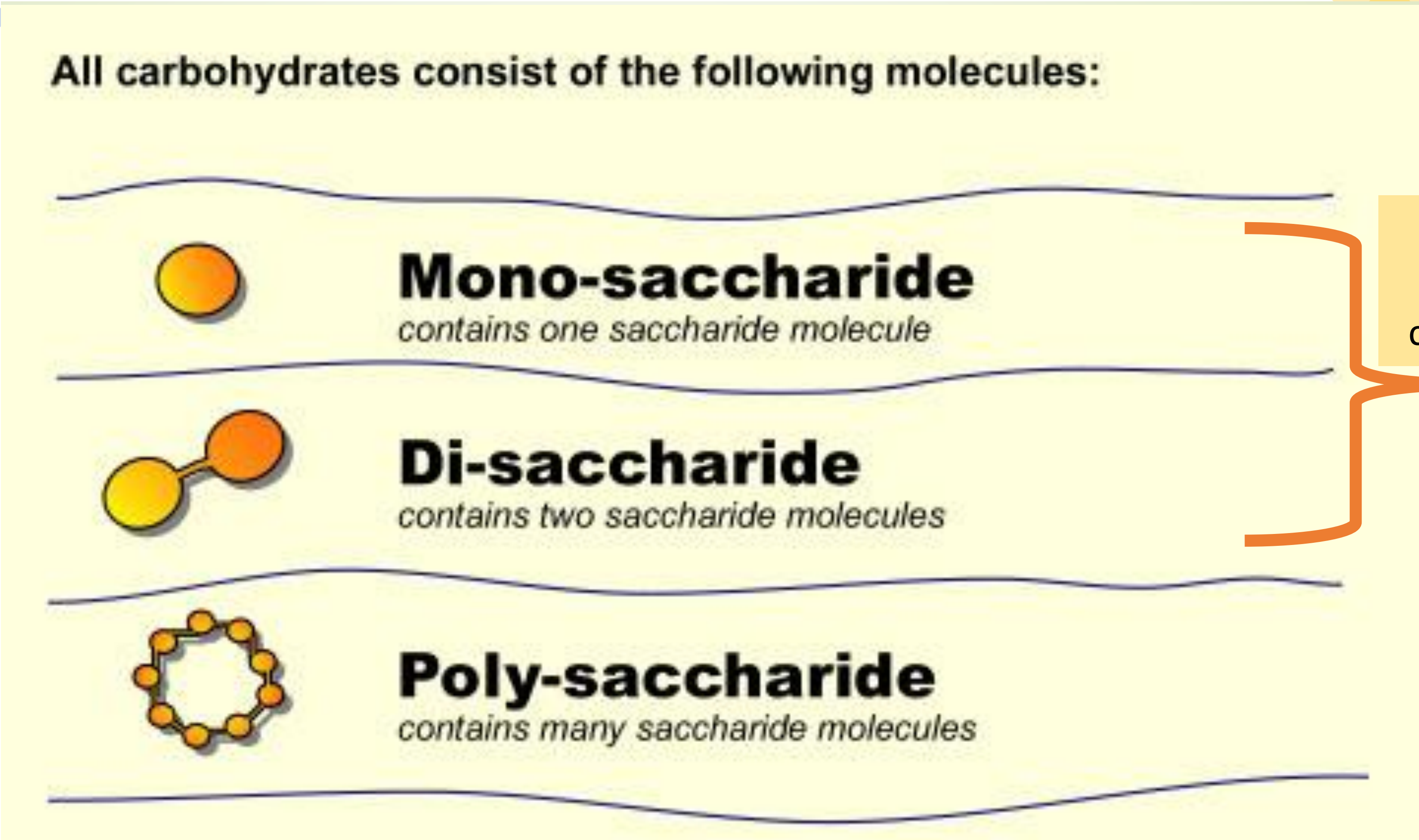


Carbohydrates

- A carbohydrate is a biomolecule consisting of carbon (C), hydrogen (H) and oxygen (O) atoms, usually with a hydrogen–oxygen atom ratio of 2:1 and thus with the empirical formula



Carbohydrates are called also Saccharides



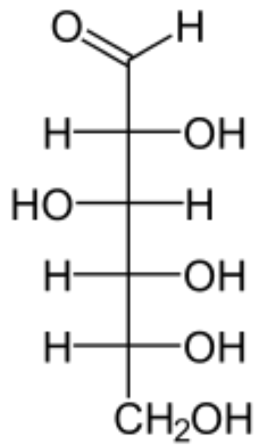
These are commonly called **sugars**

Oligo-saccharide

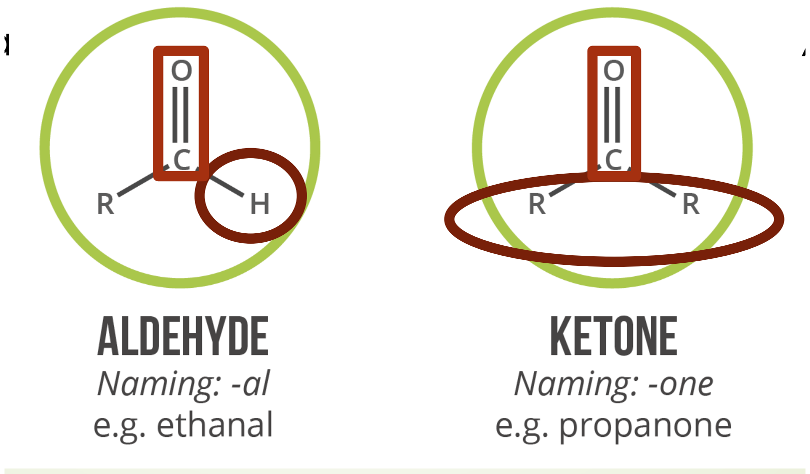
Contains few saccharide molecules

Mono-saccharides

- are the simplest form of sugar and the most basic units (monomers) of carbohydrates
- Physical properties: They are usually colorless, water-soluble, and crystalline solids.
- Examples: Glucose, fructose, galactose
- Chemistry: they are poly-alcohols (more than two –OH) with either one aldehyde (*aldose* sugars) or one ketone (*ketose* sugar) group



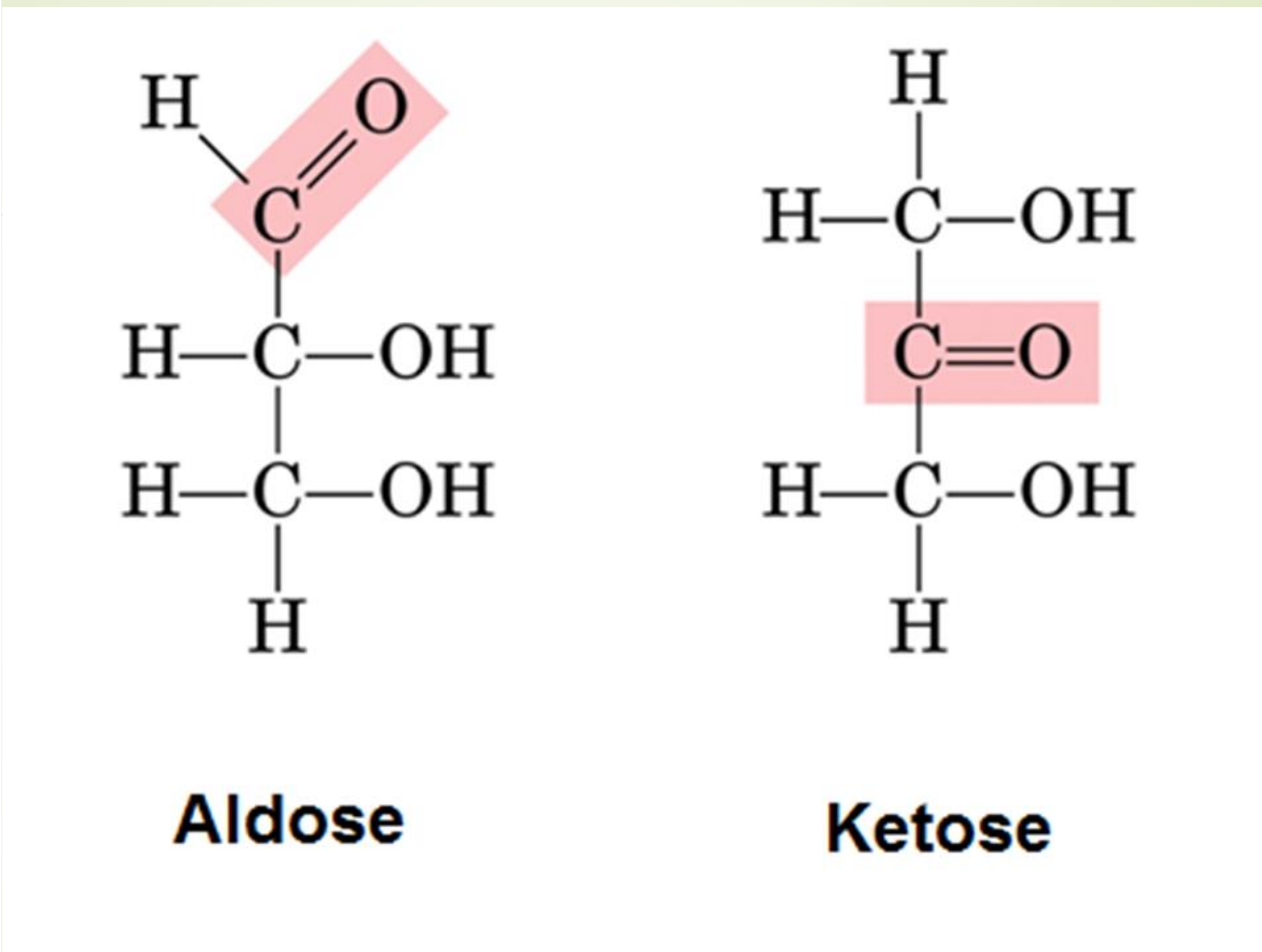
D-Glucose



Monosaccharides are classified based on two chemical features:

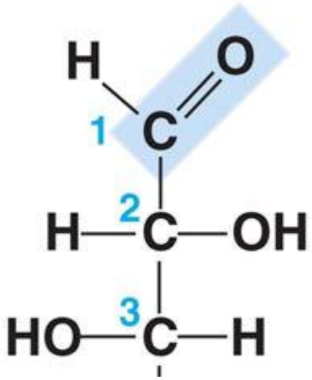
1. The presence of aldehyde or ketone
2. The number of C in the molecule skeleton

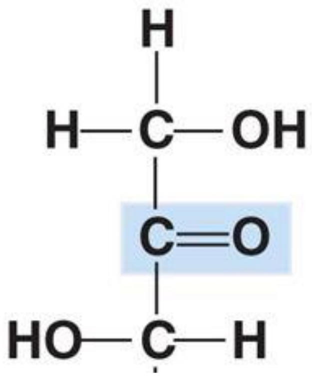
1



2

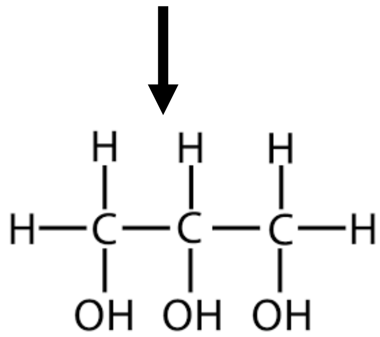
triose



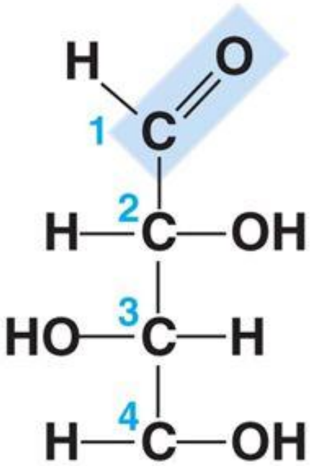


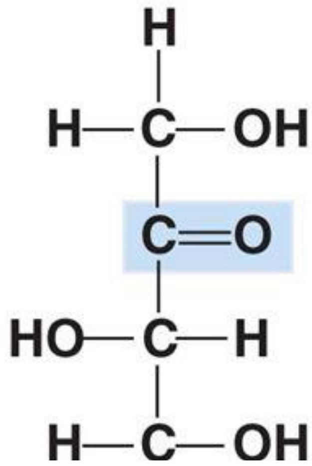
Glyceraldehyde

Glycerol, part of lipid molecules

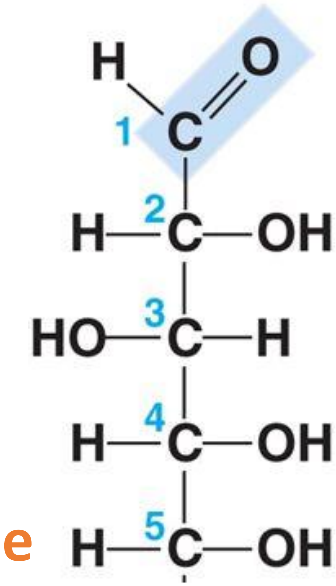


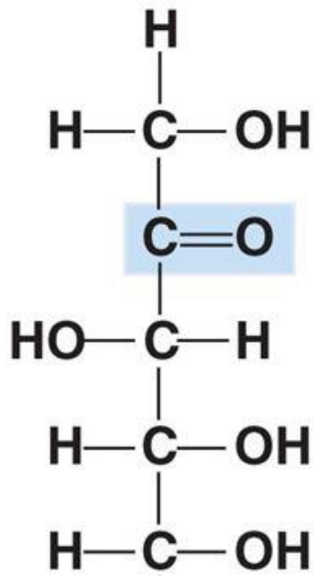
tetrose





pentose



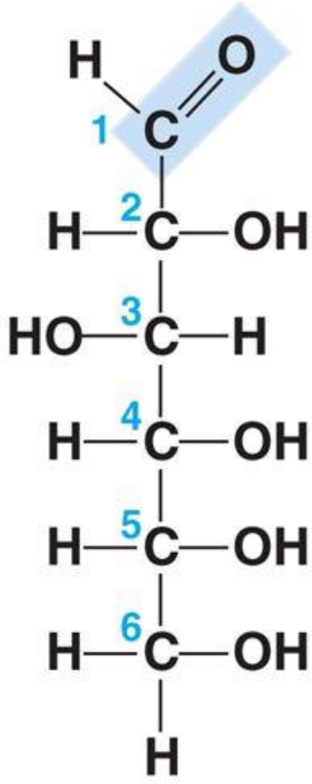


- Ribose
- 2-Deoxyribose

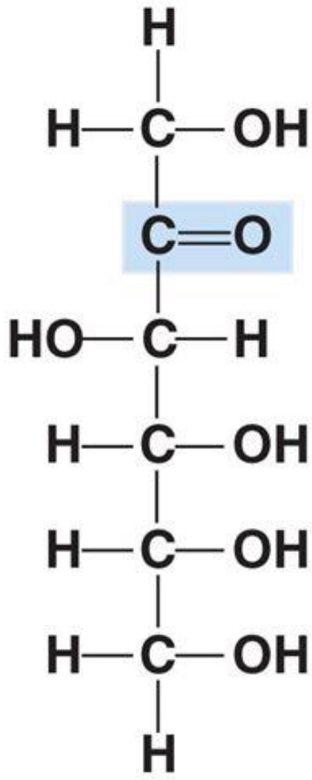
- Ribulose

Part of RNA and DNA, respectively

hexose



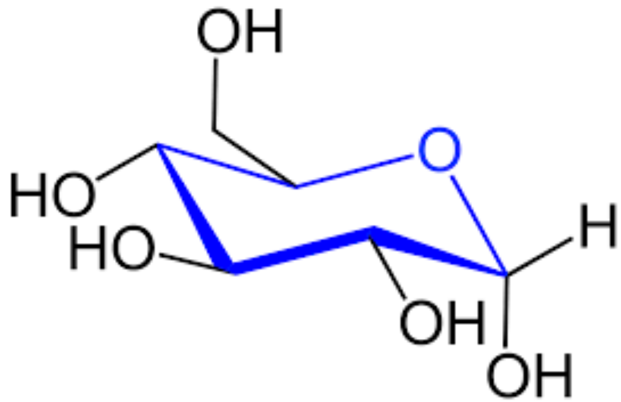
Glucose
(an aldose)

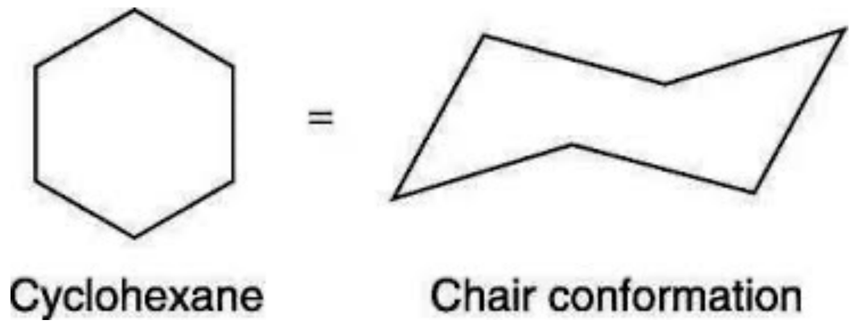


Fructose
(a ketose)

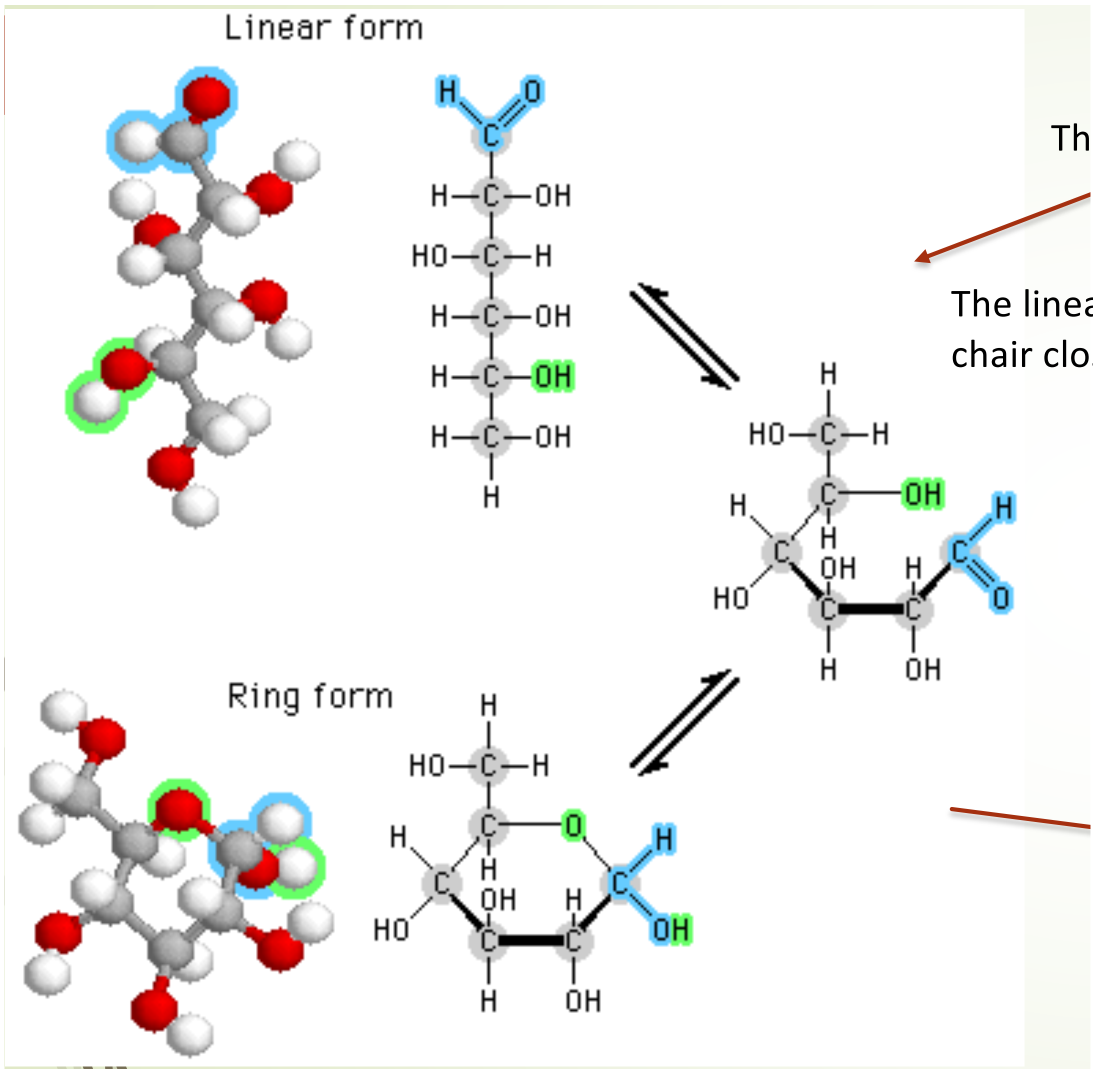
However, when we look at the formula of monosaccharides, they are often represented like :

The chair conformation



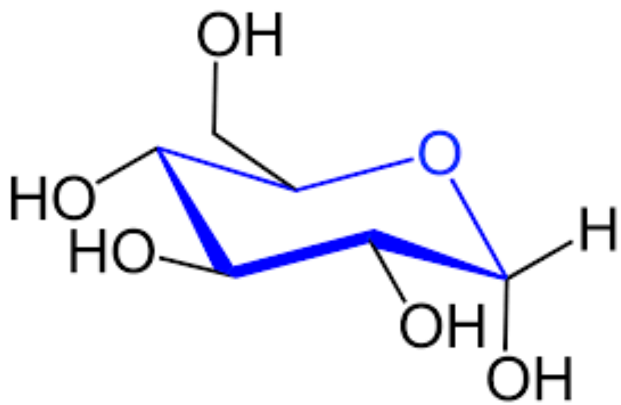


....Why?



The formation of the ring form in monosaccharides

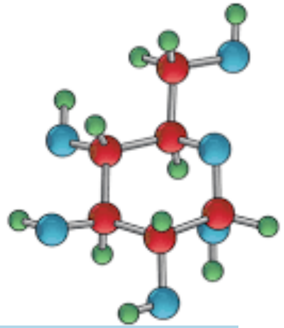
The linear hexose or pentose monosaccharide can cyclize in a chair closed conformations

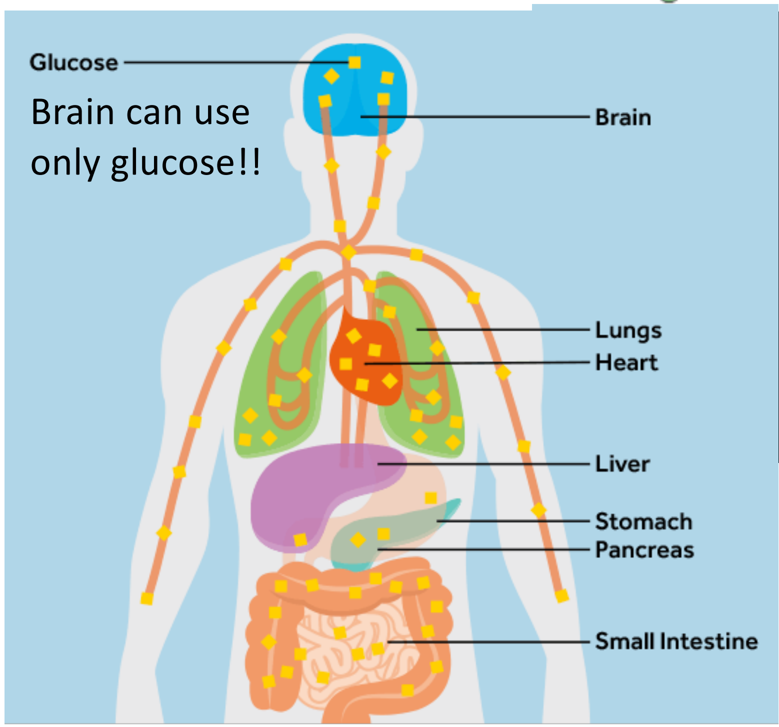


Glucose

- Glucose is the main source of metabolic energy in cells. Energy is stored in the chemical bonds of the glucose molecules. Once glucose is transported to the cells, **metabolic processes called glycolysis and cellular respiration releases the stored energy and converts it to energy that your cells can use.**

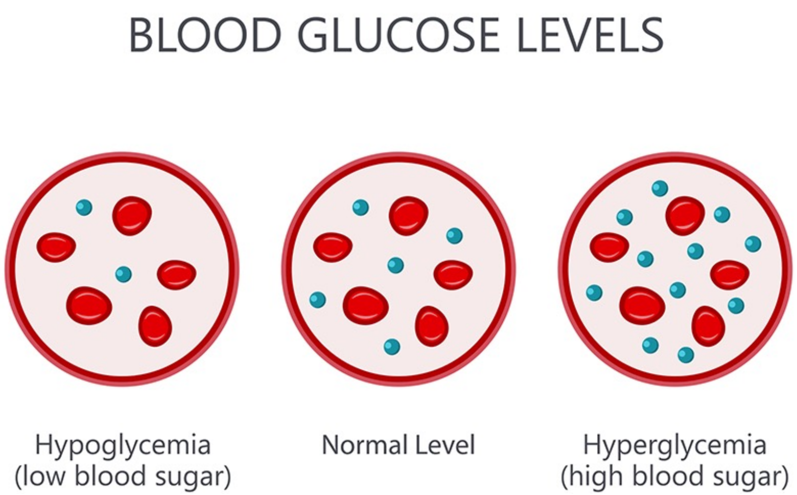
In humans, the brain accounts for ~2% of the body weight, but it consumes ~20% of glucose-derived energy making it the main consumer of glucose



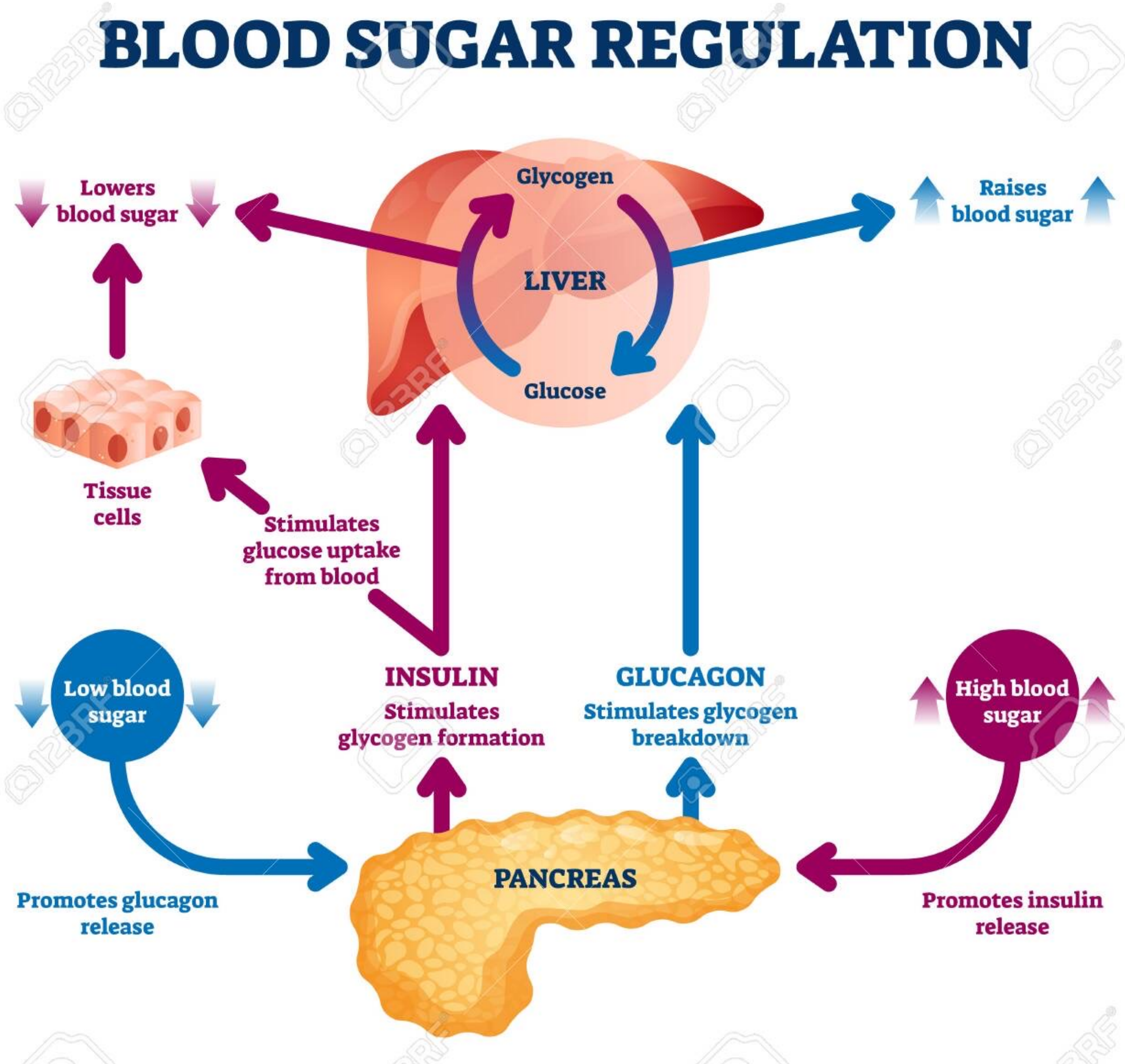


Every cell in the body uses glucose for energy

Glucose levels in the blood are highly regulated

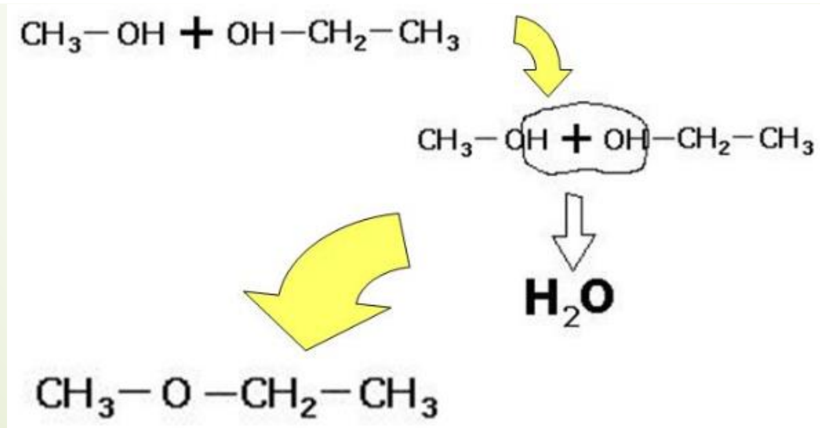


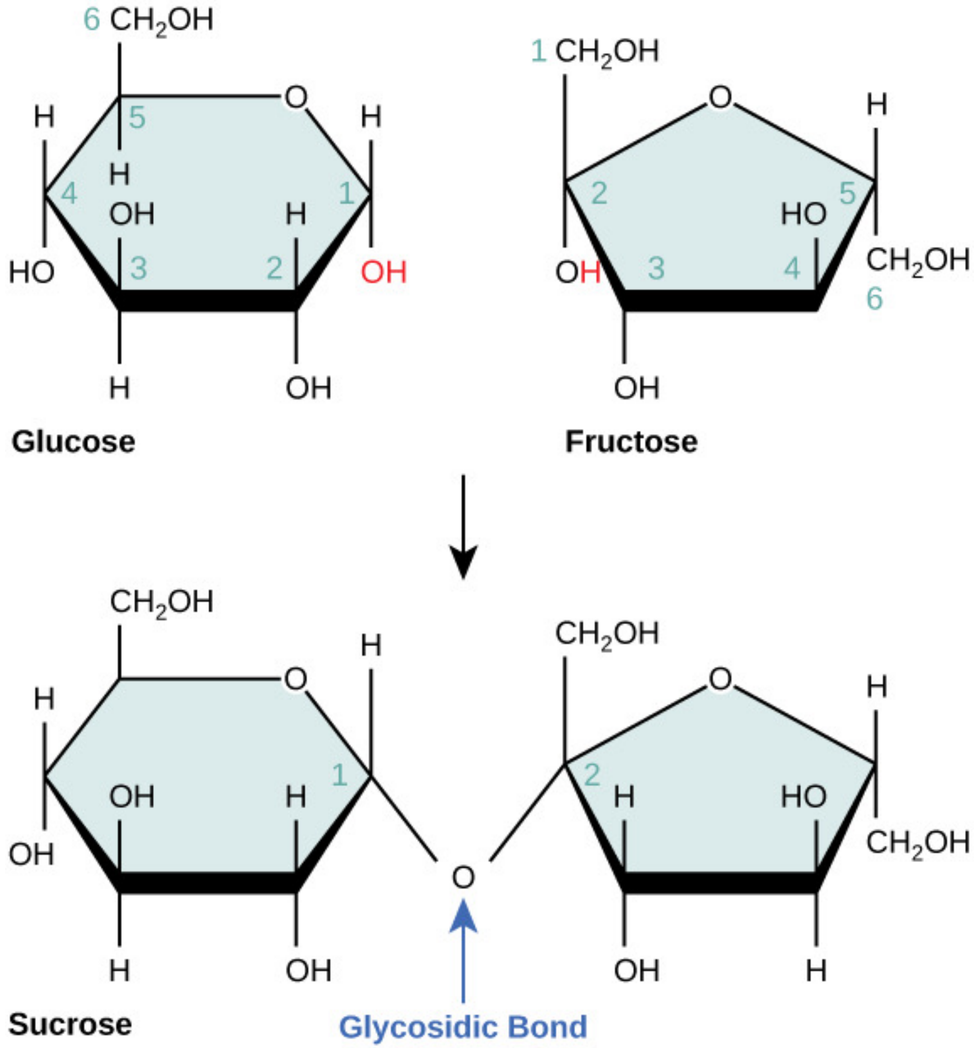
Glucose is stored as the polymer Glycogen, and disposed in liver, and muscles. When in strong excess it is converted in fat and stored in fat tissue



Disaccharides

They are formed by two monosaccharides, that bind covalently through the Glycosidic bond. This is an ether bond, that is formed through the reaction of two alcohols and the elimination of a water molecule as follows:





1,2

Examples of disaccharides

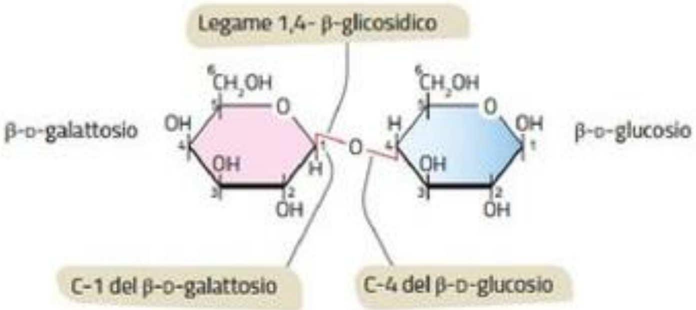
Digested by lactase, a β-glycosidase present only in neonates

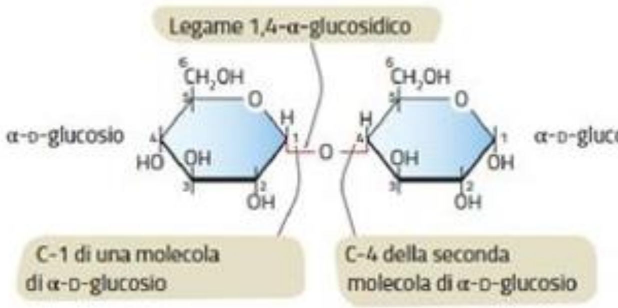
Lactose

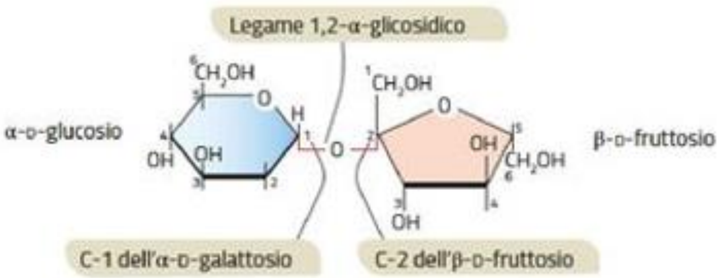
Transported in sap, the fluid which circulates in the vascular system of a plant

Maltose

Saccharose





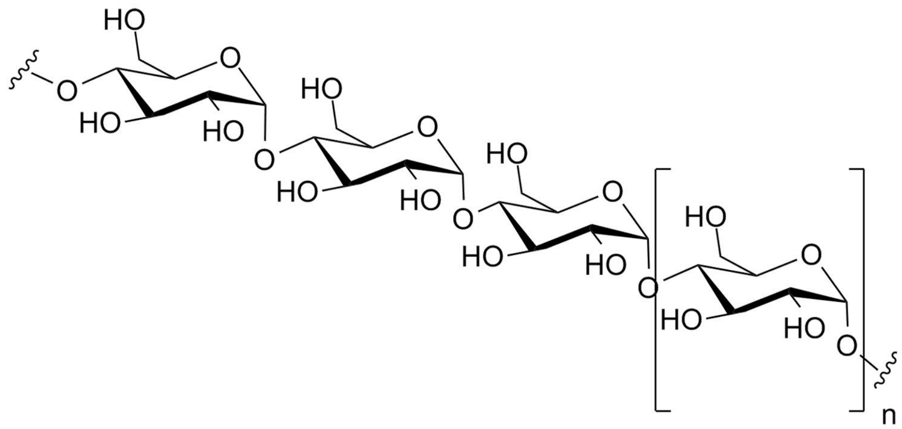


The glycosidic bond nomenclature includes the n of C that are involved (e.g. 1,4 in lactose), and the stereoisomery of the C4, that defines the α, or β bond

α or β glycosidase are enzymes capable of breaking the α or β bond, respectively.
α glycosidase are more diffused in nature than the β.

Polysaccharides

- They are long polymeric chain composed of monosaccharide units bound together by glycosidic linkages
- Very big molecules, sometimes ramified, they lose their water solubility
- Respond to the need for storing the glucose in excess (**storage polysaccharides**)
- Constitute strong fibers to provide plants with physical and mechanical resistance (**structural polysaccharides**)
- Glycosidic bonds are typically α–bond for storage and β for structural polysaccharides, respectively. Why?



Types of Polysaccharides

Storage

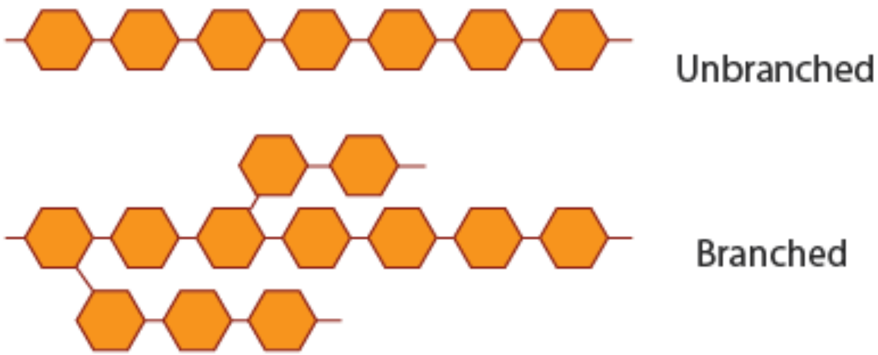
Examples:
Starch
Glycogen

Structural

Examples:
Cellulose
Chitin

Storage polysaccharides

- Storage of excess glucose
- All made of glucose, in animals and plants
- The type of bond is α–glycosidic
- Linkages differ for the presence of ramifications

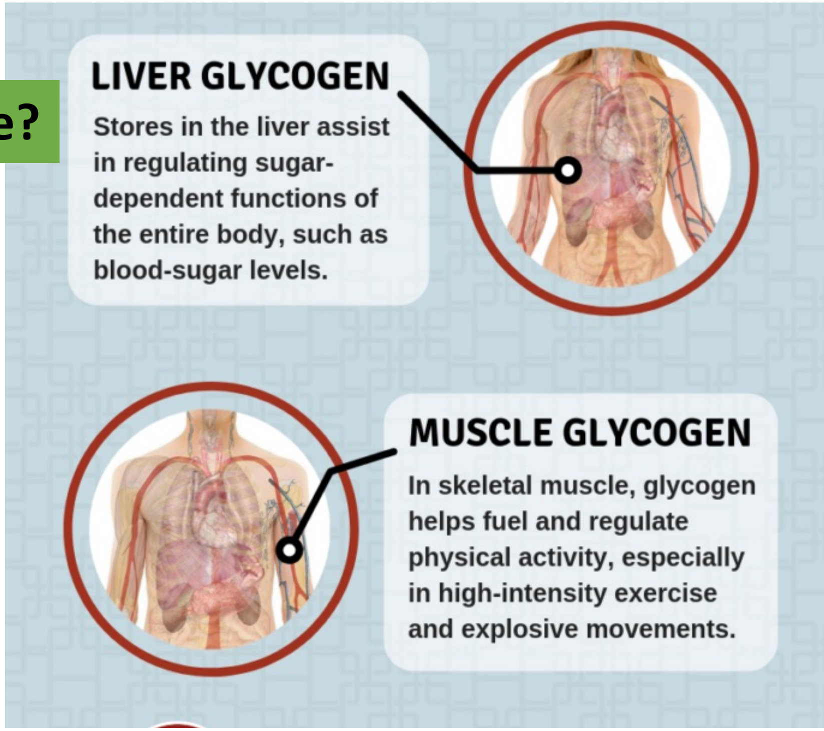


Main storage polysaccharides:
1. In plants: **Starch**
2. In animals: **Glycogen**

Storage polysaccharides in animals

Glycogen

Where?

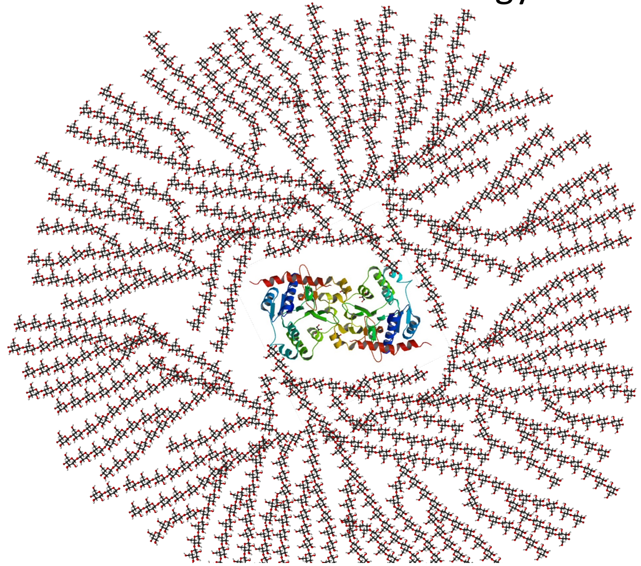


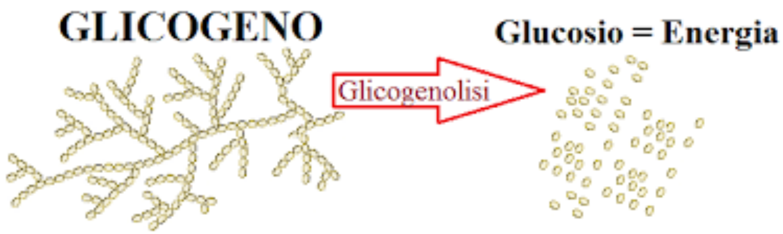
Found in liver and muscles. It contains the energy required for the short-term storage. For long term glucose is converted in fat

Structure

- Monomer: α-glucose.
- Linkage: α–glycosidic 1-4 and 1-6 (only at branches)

Super ramified! To store maximum energy in minimum space





Storage polysaccharides in plants

Starch

Where?

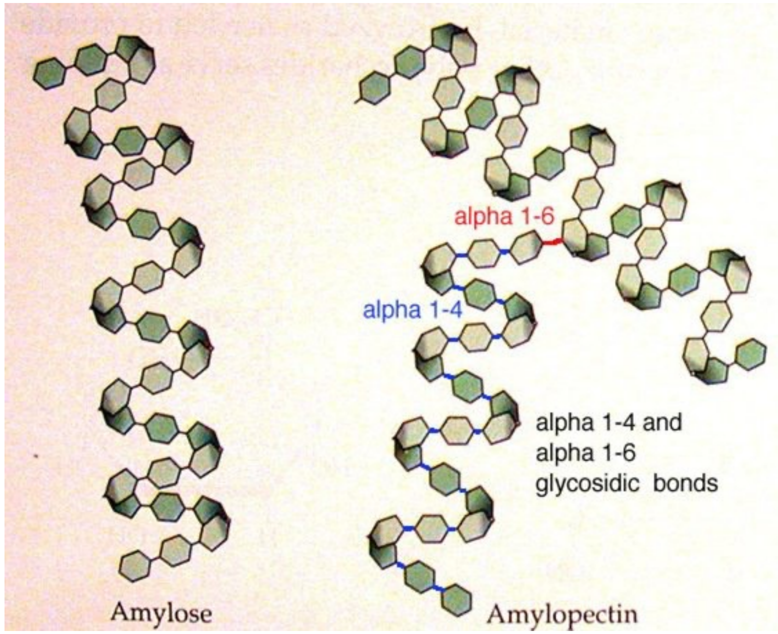
20% weight of a potato!

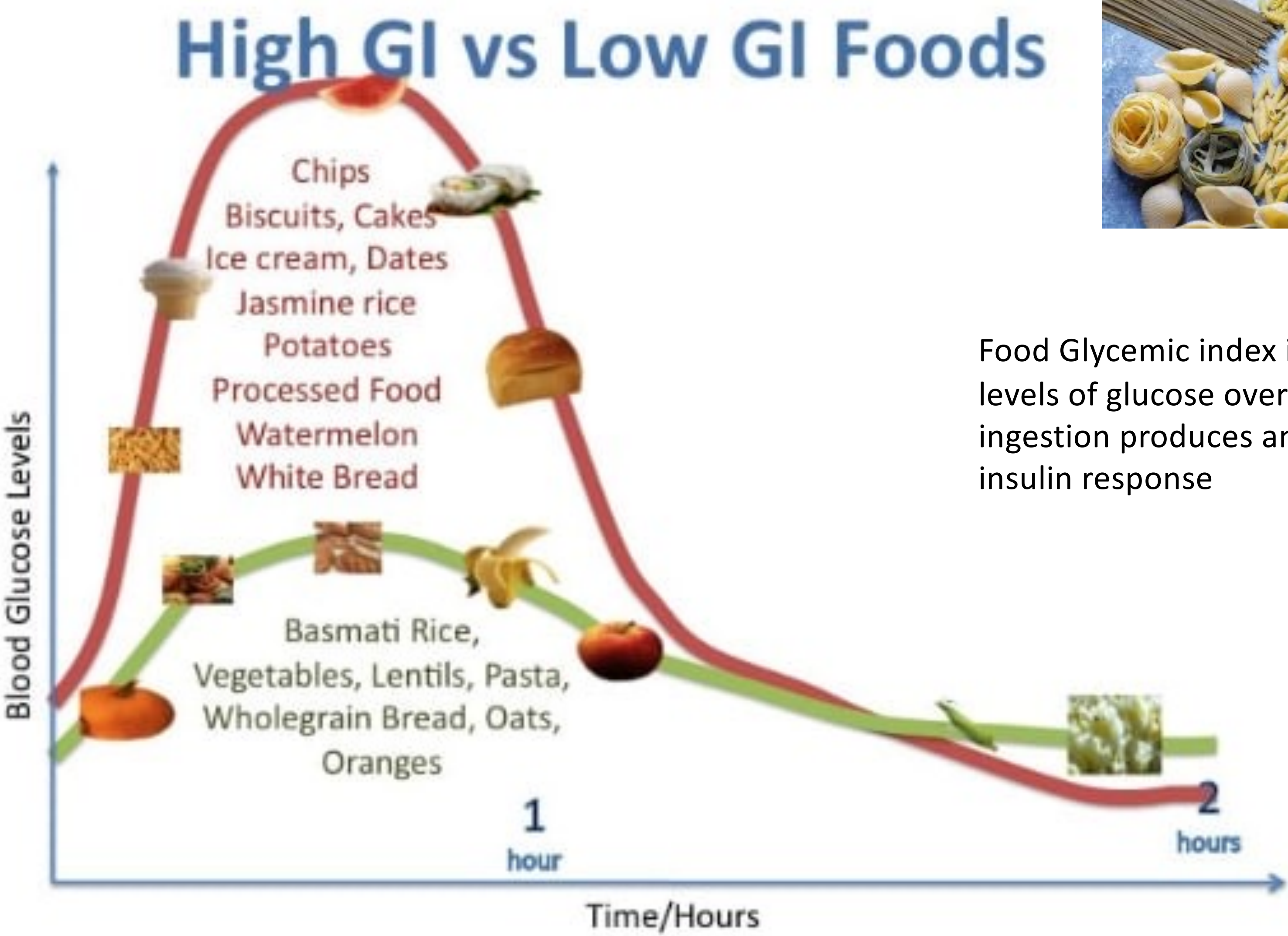
Found in roots, tubers and seeds. It contains the energy required for the plant development

Structure

- Monomer: α-glucose.
- Linkage: α–glycosidic 1-4 and 1-6 (only at branches)

Mixture of amylose (linear) and amylopectin (branched)



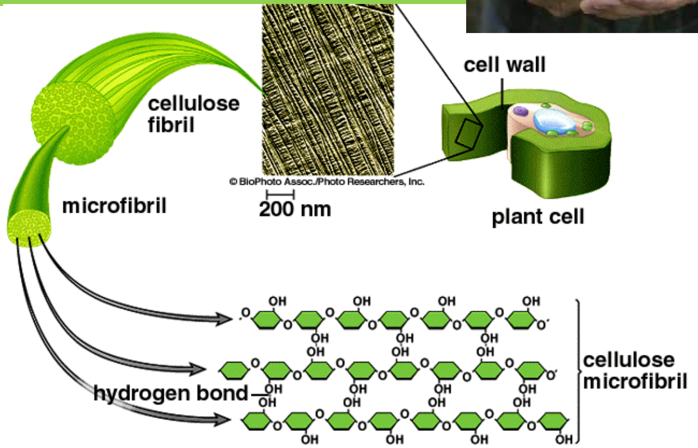


Food Glycemic index indicates the blood levels of glucose over time that the food ingestion produces and thus the type of insulin response

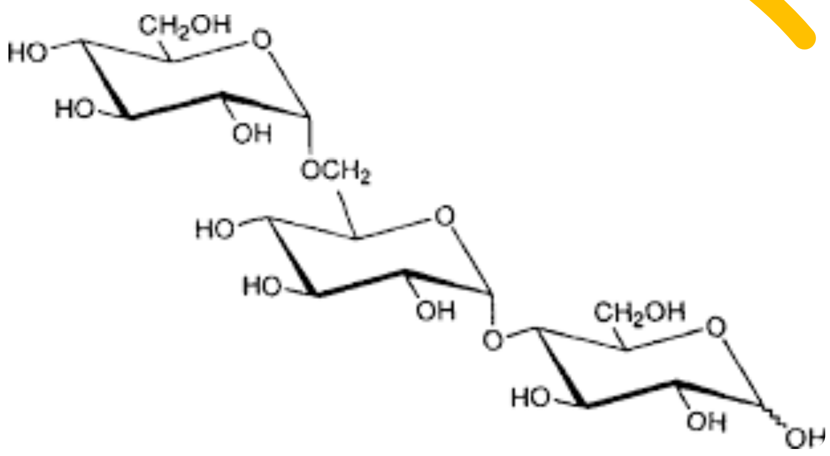
Structural polysaccharides

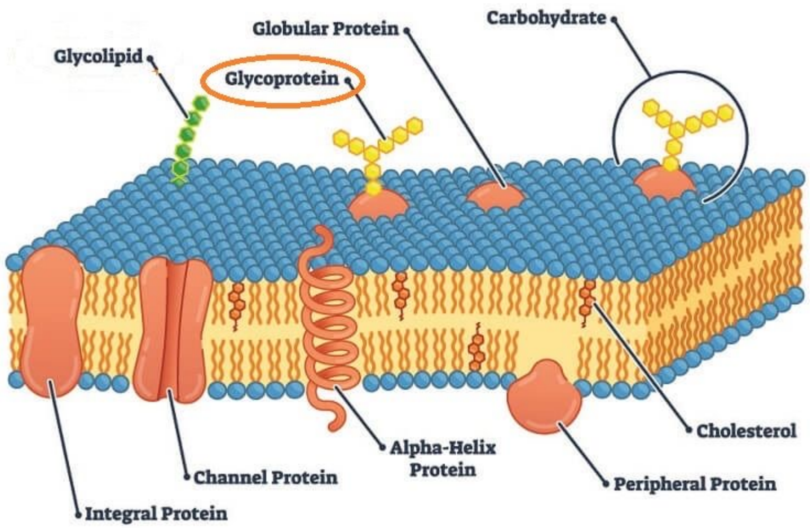
- Confer mechanical resistance
- Most found in plants (e.g. cellulose) and non-vertebrates (e.g. chitin in exoskeleton
- The type of bond is β–glycosidic

Cellulose



- most abundant carbohydrate in nature
- Structure: linear polymer of β-glucose bond
- Parallel filaments are kept together by weak bonds to form microfibrils, that in turn hierarchically coils together to form fibrils and fibers
- Humans and many animals lack cellulase, an enzyme capable of breaking the beta-linkages, so they do not digest cellulose. Certain animals such as termites or herbivore can digest cellulose, because bacteria possessing the enzyme are present in their gut.



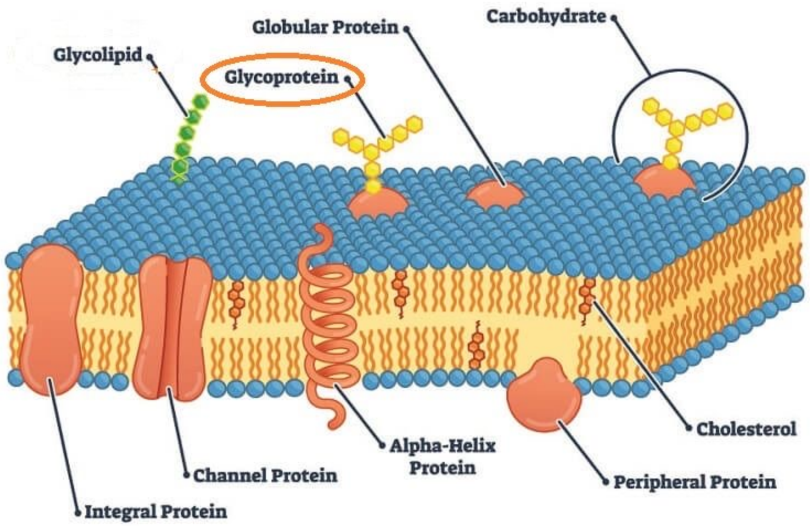


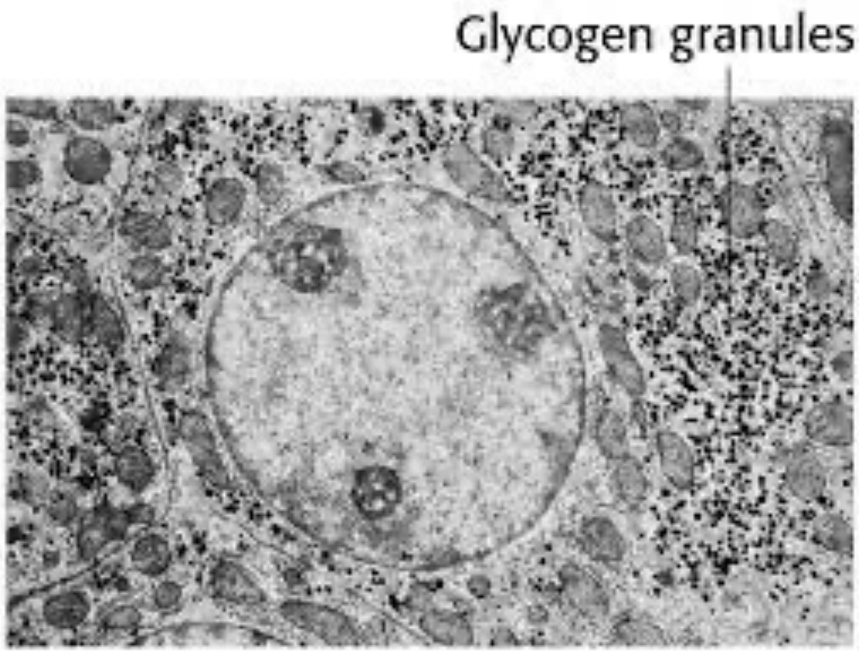
Oligosaccharides

- They are short polymeric chain composed of 3-10 monosaccharide units
- Big variety of units composition
- In animal cells they represent functional residues linked to bigger proteinic (glycoproteins) or lipidic (glycolipids) molecules.
- Big variety of functions, usually signaling or antigen molecules for recognition of cells (e.g. the AB0 types on red blood cells membrane)

Recap: the role of carbohydrates in the physiology of animal cell

- energy metabolism and storage (glucose and glycogen).
- Signalling functions when bound to proteins (glycoproteins), or lipids (glycolipids).





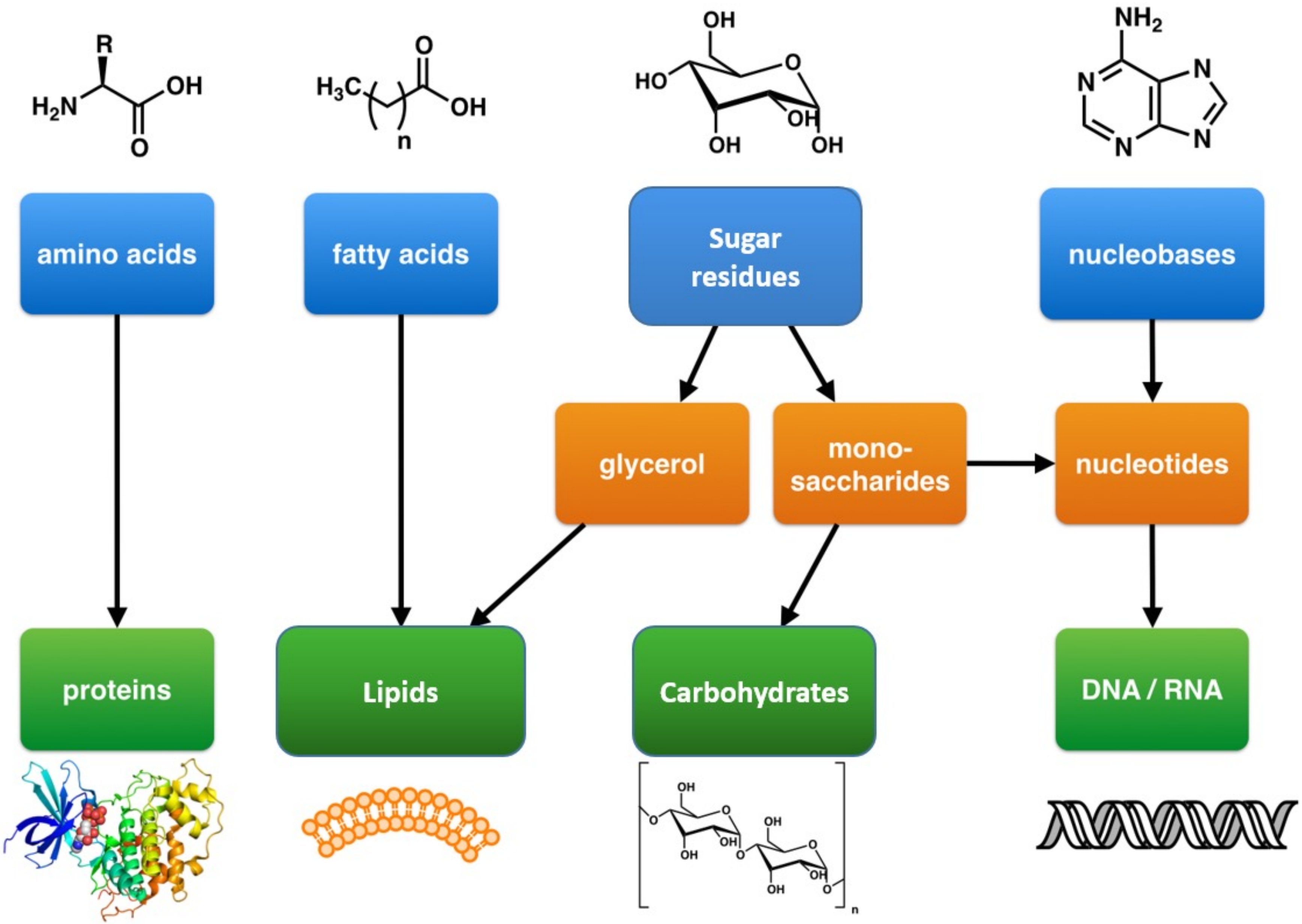
Lipids

- Heterogeneous group of macromolecules, for chemical structure and function
- Common feature: high hydrophobicity (high number of C-H bonds). Soluble in nonpolar solvents
- In living systems, they are segregated in specific compartments
- They are classified based on their functions rather than structure

Triglycerides

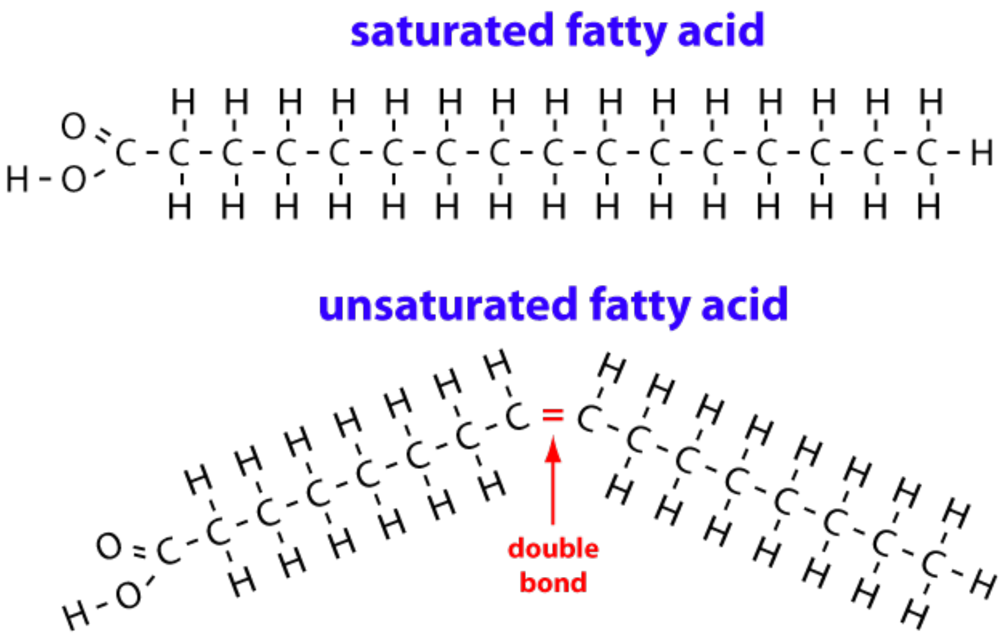
Phosphoglycerides

Steroids


amino acids
fatty acids
Sugar residues
nucleobases
glycerol
mono-saccharides
nucleotides
proteins
Lipids
Carbohydrates
DNA / RNA

Fatty acids: the lipids building block

Chemistry: carboxylic acid (polar) followed by a long hydrocarbon chain (20 C or more; highly non-polar). This gives the molecules “amphipathic properties”.



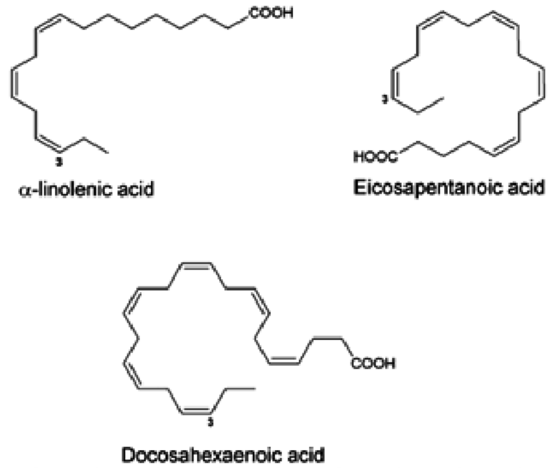
The position of the unsaturation is indicated with “omega”, followed by the number representing the C position where the unsaturation is located (starting from the end)

As example, this is an ω-8 fatty acid

Functions:

- Structural component of triglycerides and phosphoglycerides
- Energy storage. The longer the C chain, the higher the amount of stored energy
- Signalling molecules (for special unsaturated fatty acids)

Omega-3 fatty acids



Docosahexaenoic acid (DHA) is the predominant polyunsaturated fatty acid (PUFA) in the brain (90% of brain PUFA)
DHA is collected in the brain during gestation and first neonatal period through maternal reservoirs
Modern diet content of DHA is scarce.

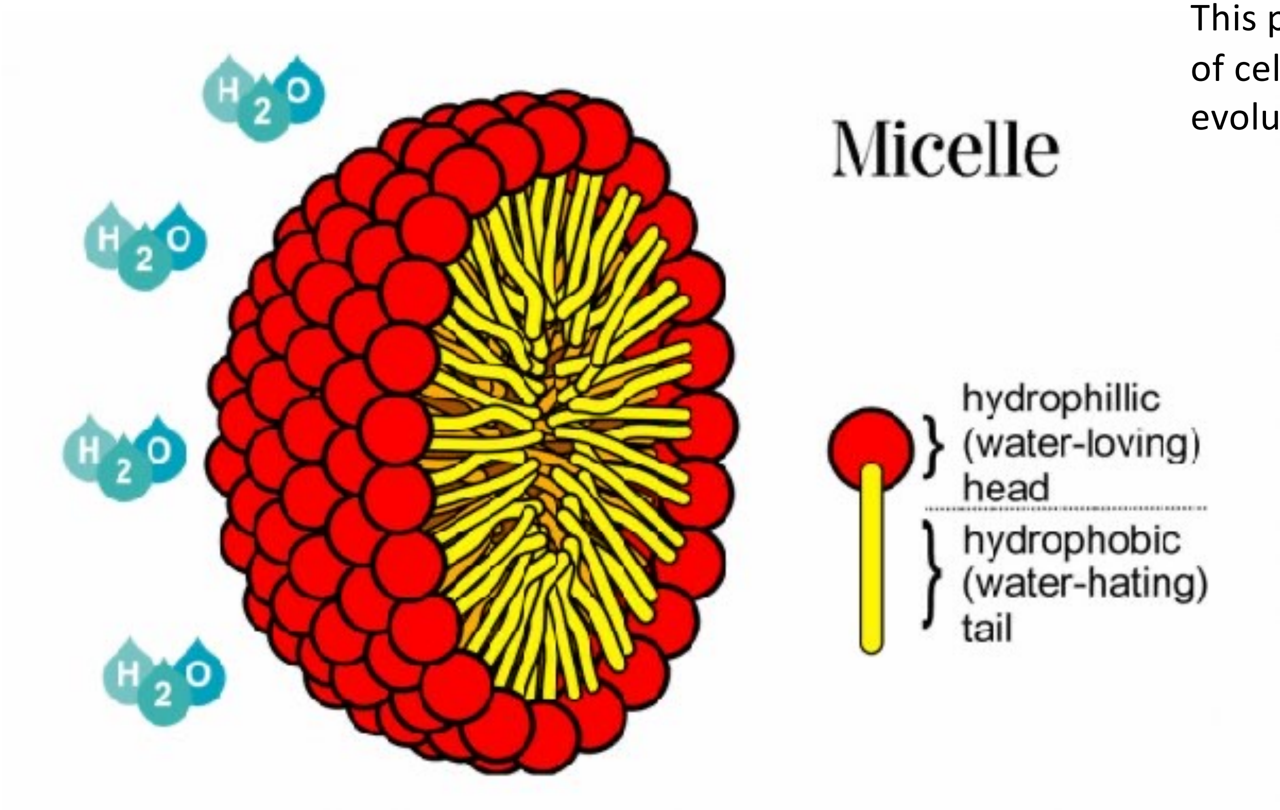
The human brain is about 60% fat. Around 20% of brain fat is made up of poli-unsaturated fatty acids (PUFA)— and they are mandatory for proper brain functions and development

- Omega 3 fatty acids are essential constituents of the brain membranes, providing them with the proper fluidity
- They are important anti-inflammatory and signaling molecules
- Prevent cognitive decline

Fatty acids: the amphipathic properties

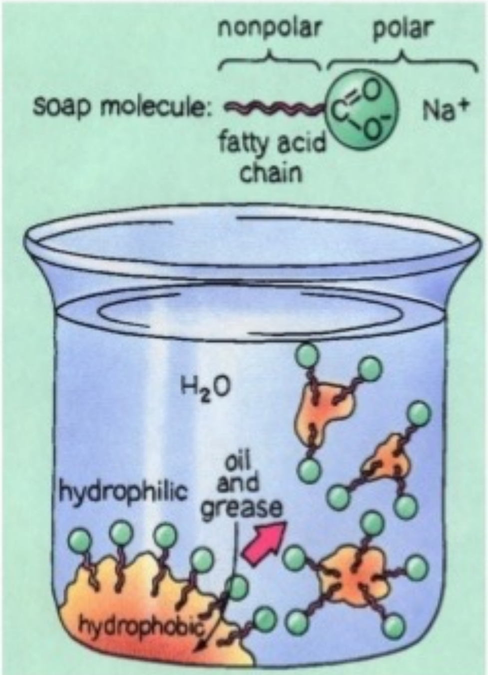
When immerse in aqueous environment, amphipathic molecules aggregate in “micelles”

This phenomenon can explain the origin of cells compartments in the process of evolution of organisms



The use of fatty acids as soaps

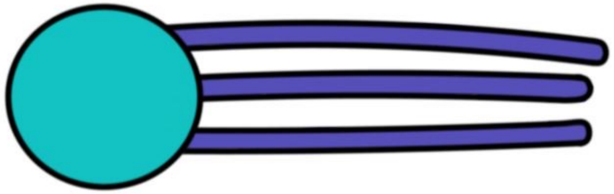
MECHANISM OF SOAPS

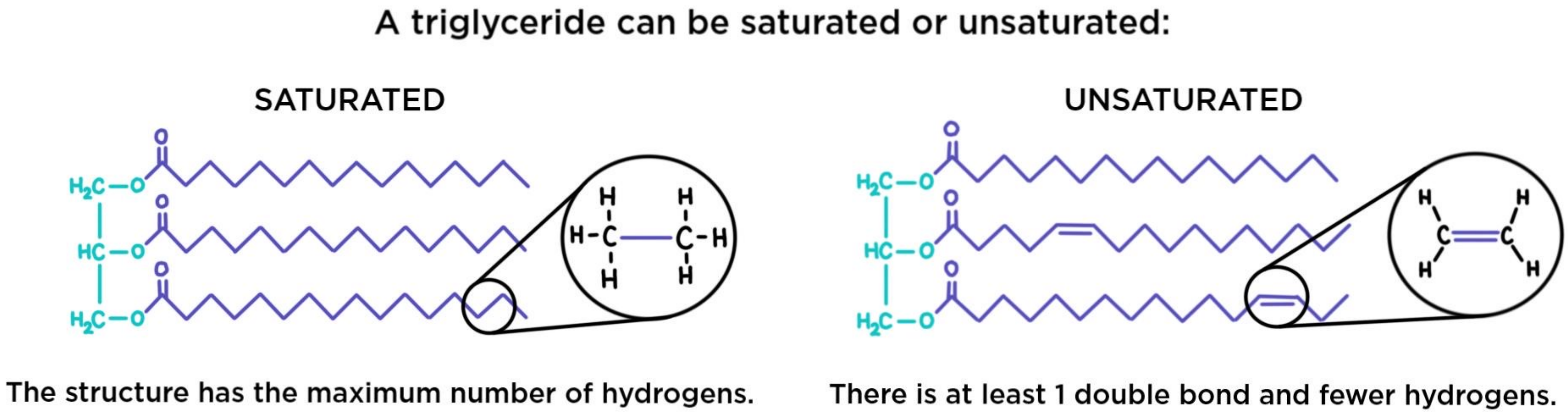


- When a dirty cloth is put is put in water containing soap than the hydrocarbon ends of the soap molecule in the micelle attach to the oil or grease particles present on the surface of dirty cloth. In this way the soap micelles entraps the oily particles by using the hydrocarbon ends. The ionic ends of the soap molecules remain attached to the water when the dirty cloth is agitated in soap solution. The oily particles presents on its surface gets dispersed in the water due to which the cloth gets clean.

Triglycerides

Structure: 3 fatty acids attach to a glycerol backbone.
Very hydrophobic

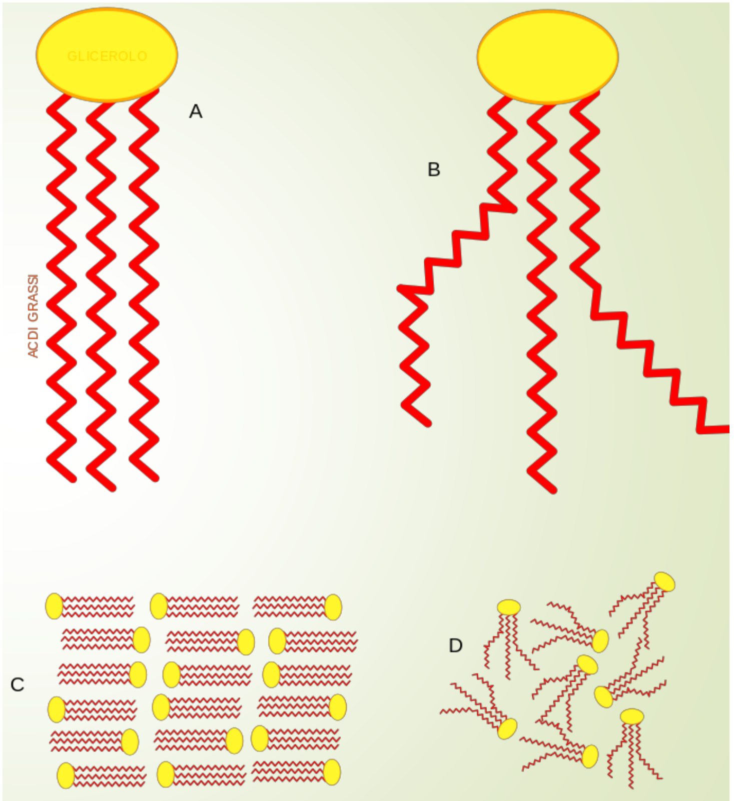




The presence of unsaturations determine important physical properties in the triglycerides

Saturated fat:

- The molecules can tightly pack
- Bonds that links molecules together are strong
- Confer high rigidity in structures
- High density and solid at environmental T



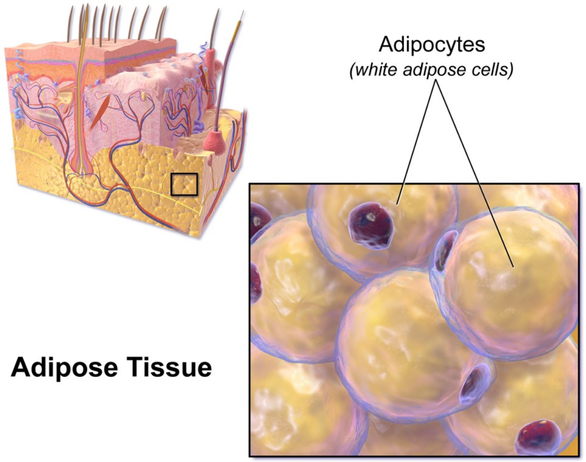
Unsaturated fat:

- The molecules cannot pack tightly
- Bonds that links molecules together are loose
- Confer fluidity in structures
- Low density and liquid at environmental T
- Fragile chemical structure

Triglyceride functions

- Long-term energy storage
- Fatty acids store more energy than glycogen (9 Kcal/g vs 4 Kcal/g for sugars)
- Their metabolism is slower than that of carbohydrates
- Their metabolism can occur only in presence of Oxygen (while for glucose also in anaerobiosis)

→ Slower energy release but more efficient storage

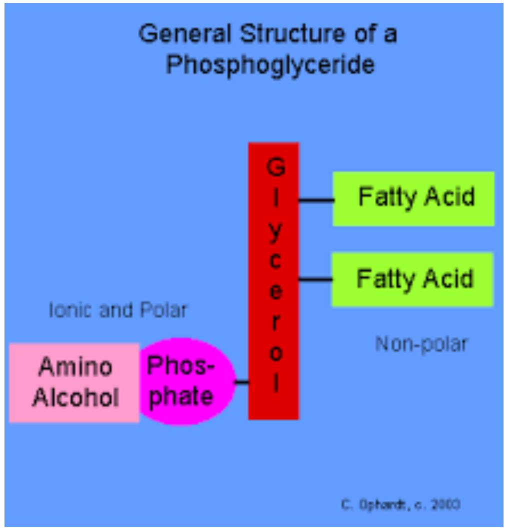


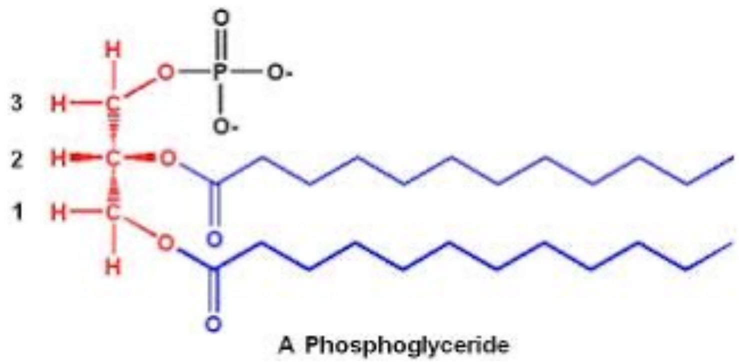
Where are triglycerides located in the body?

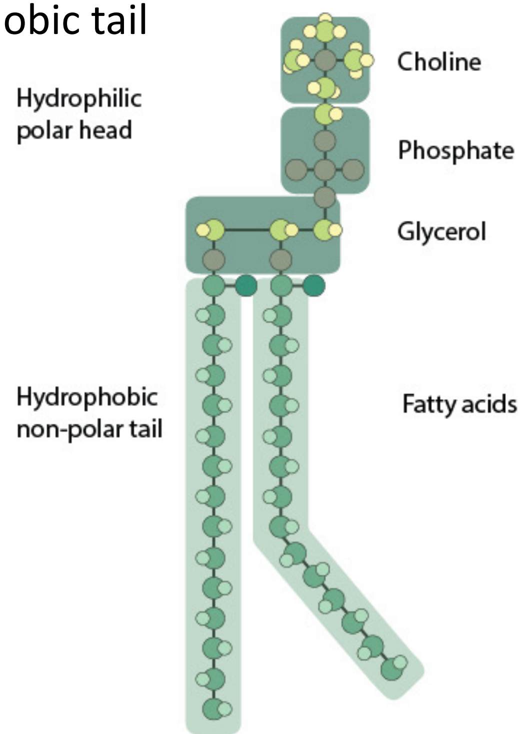
Triglycerides are stored in the adipocytes, also known as lipocytes or fat cells, the cells that primarily compose adipose tissue.

Phosphoglycerides or phospholipids

- Structure: glycerol backbone with 2 fatty acids and one polar group on the third position. Thus, they are “**amphipathic**” molecules, with hydrophilic head and hydrophobic tail





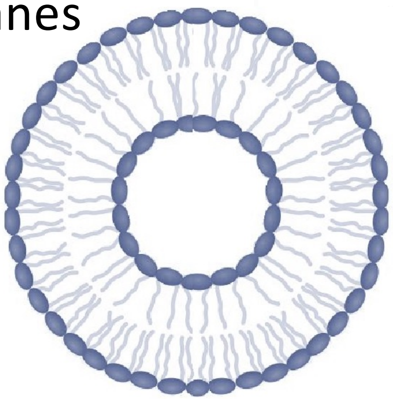


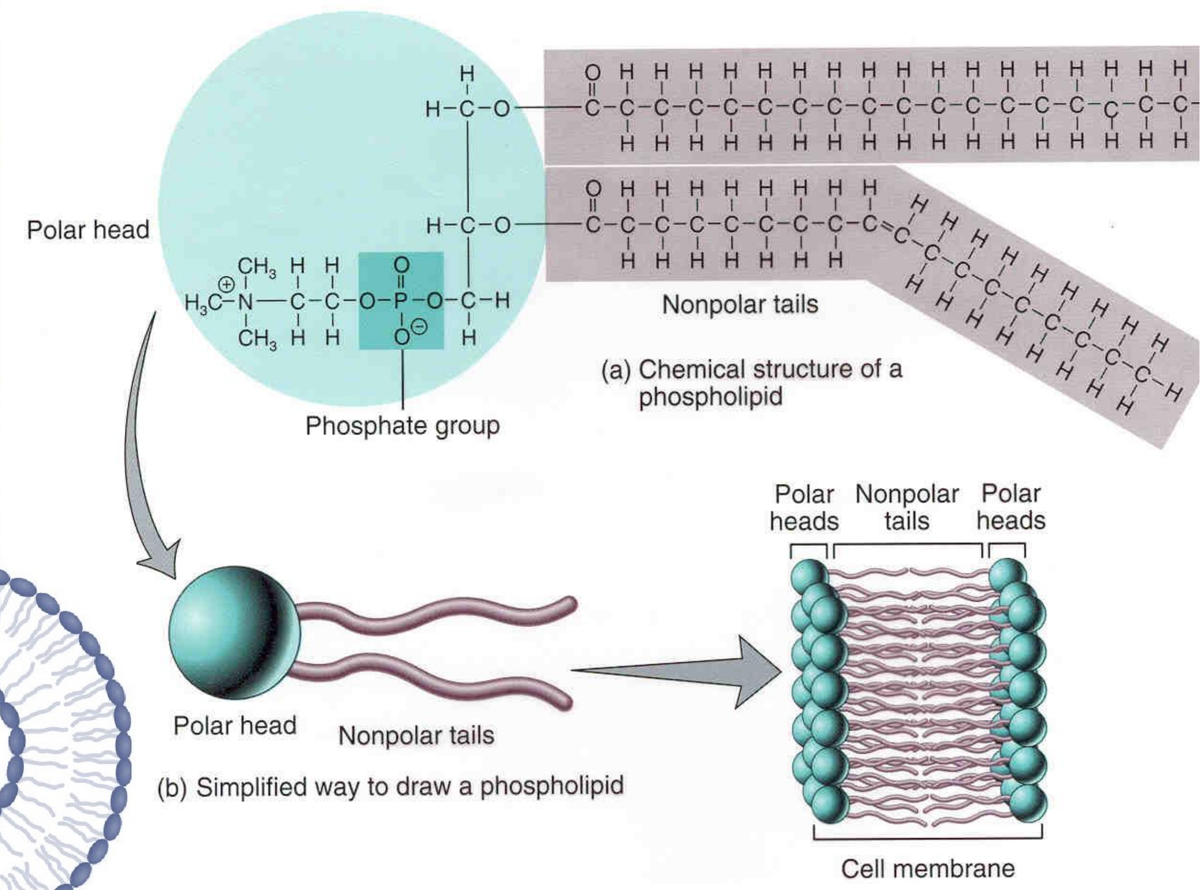
They are formed by the “esterification” of one molecule of glycerol, 2 molecules of fatty acids, and one phosphate group that carries a polar compound.

Phosphatydil-choline

Phospholipids are the principal constituents of cell membranes!

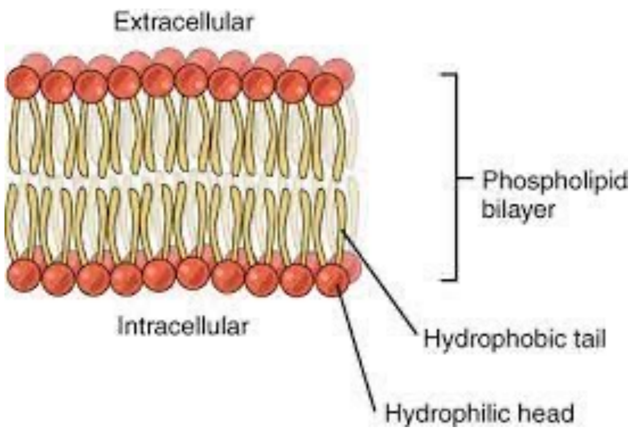
While fatty acids spontaneously form micelles in aqueous environment, bigger amphipathic molecules (like for phospholipids) form a double-layer vesicle, with polar heads exposed to both external and internal aqueous phase. The bi-layer is the basal organization of membranes surrounding cells and organelles.

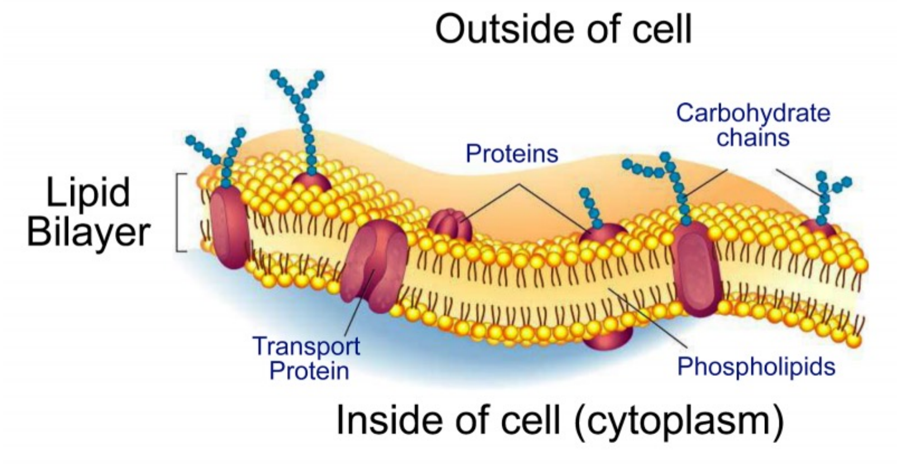




Lipidic bilayers: properties

- High stability. Broken up only by detergents
- Highly impermeable to polar molecules, like ions. Transporters are required. This property allows the generation of the membrane potential and the neuronal electrical transmission
- Highly fluid structure at environmental temperature.





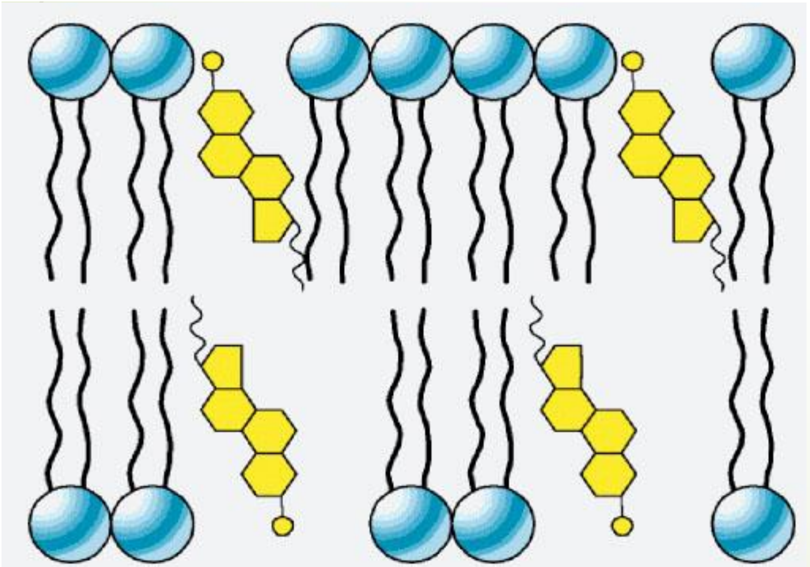
Steroids: cholesterol

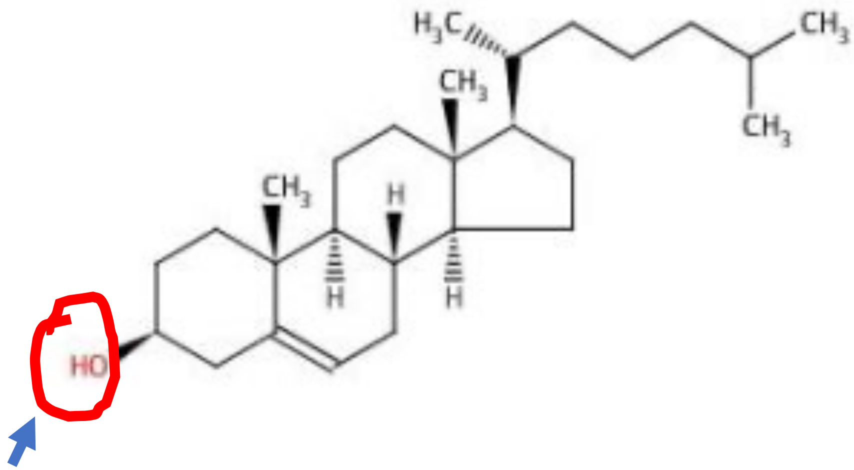
Structure: complex structure characterized by the presence of 4 poli-carbon rings (hydrophobic), and an alcohol group. Amphipathic molecule

Location: component of the cell membranes (same percentage than phospholipids)

Source: food or endogenous synthesis in the liver

Functions





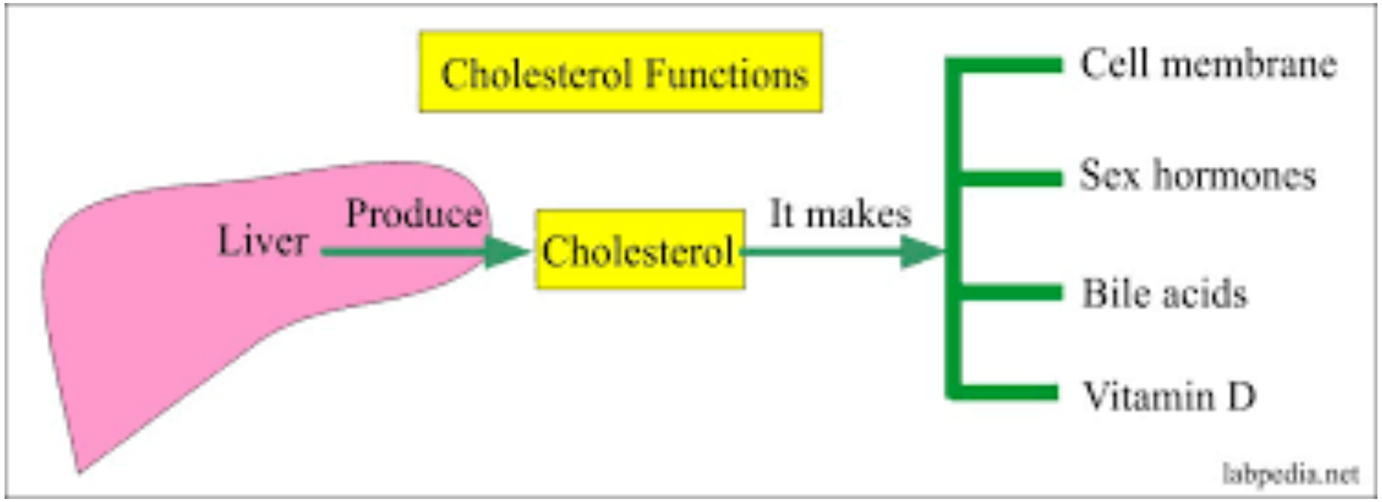
Polar head

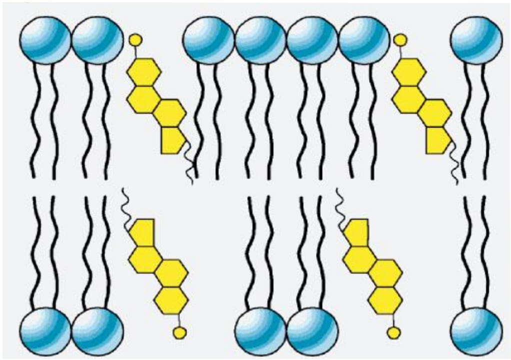
Steroids: cholesterol

Despite often demonized, cholesterol has very important functions:

1. Component of cell membranes, decreases fluidity contrary to unsaturated fatty acids. Membrane fluidity is a highly regulated property

2. Cholesterol functions as a precursor molecule in the synthesis of vitamin D, steroid hormones (e.g., cortisol and aldosterone), and sex hormones (e.g., testosterone, estrogens, and progesterone).

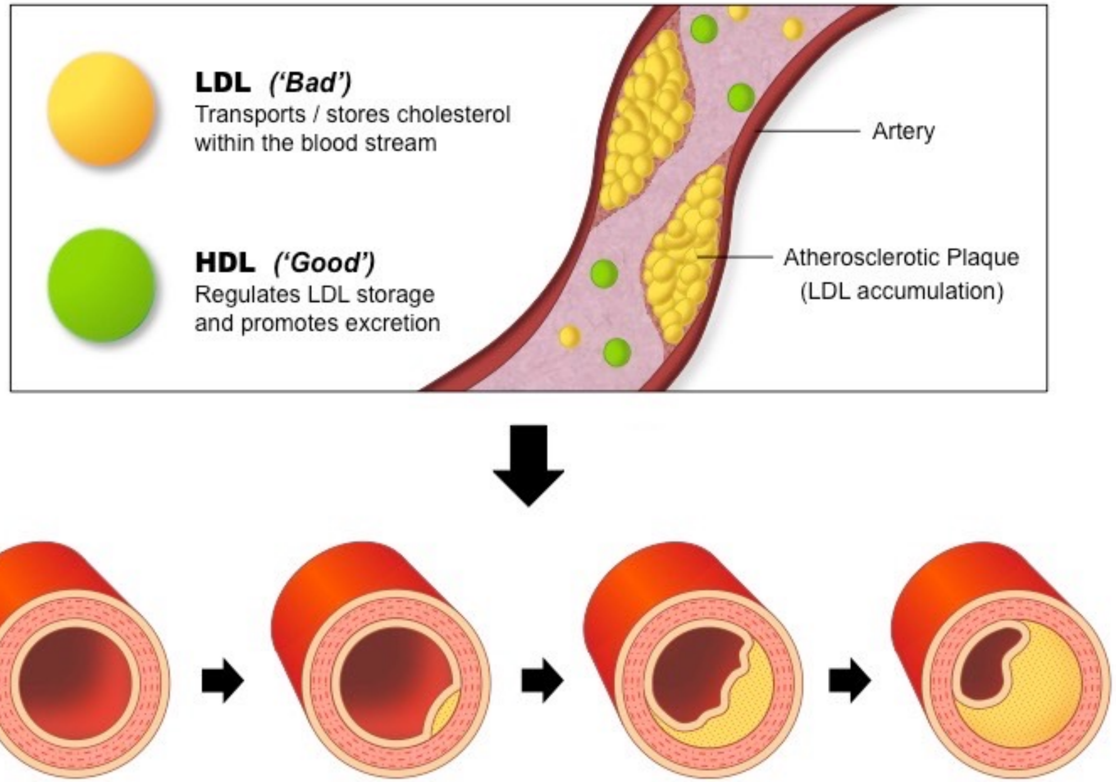




Cholesterol concentration in the blood is highly regulated

Why is it considered a BAD molecule?

Cholesterol is produced in the liver and released in the blood, to reach all different cell tissues. The blood transport is organized through lipoproteins of two types: low density (LDL) or high density (HDL)
When in excess, low-density lipoproteins LDL) can aggregate in atherosclerotic plaques, leading to occlusion artery occlusion (ischemia)



Serum cholesterol level and depression

Psychiatry Research 10

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LDL cholesterol relates to depression, its severity, and the prospective course

Claudia Johanna Wagner*, Cornelia Musenbichler, Lea Böhm, Katharina Färber, Anna-Isabell Fischer, Felicitas von Nippold, Merle Winkelmann, Tanja Richter-Schmidinger, Christiane Mühle, Johannes Kornhuber, Bernd Lenz

Serum cholesterol levels and mood symptoms in the postpartum period

Alfonso Troisi[a,*], Anna Moles[b], Lea Panepuccia[c], Domenica Lo Russo[c], Giampaolo Palla[c], Stefano Scucchi[d]

[a]Department of Neurosciences, University of Rome Tor Vergata, via G.A. Guattani 14, 00161 Rome, Italy
[b]Institute of Psychobiology and Psychopharmacology, CNR, Rome, Italy
[c]Department of Obstetrics and Gynecology, UCSC, Rome, Italy
[d]Laboratory of Nutrition, ISS, Rome, Italy

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RESEARCH ARTICLE

Low serum levels of High-Density Lipoprotein cholesterol (HDL-c) as an indicator for the development of severe postpartum depressive symptoms

Raji Ramachandran Pillai[1‡], Anand Babu Wilson[2‡], Nancy R. Premkumar[3], Shivanand Kattimani[4], Haritha Sagili[5], Soundravally Rajendiran[6]*

- During pregnancy, the total serum cholesterol concentration rises up to 43%, followed by a rapid fall after delivery.
- Mild depressive symptoms ('postpartum blues') are a common complication of the puerperium and affect 30-85% of women in the early postpartum period.
- low levels of serum HDL-c is correlated with the development of severe depressive symptoms in postpartum women.

Recap: lipids

Functions in the cell:
- Long-term energy storage
- Structural components of cell and nuclear membrane
- Regulation of membrane fluidity
- Signalling molecules (hormones)

Fatty acids

- Monomers
- amphipathic
- Saturated and unsaturated
- PUFA in cell membranes
- Form micelles

Triglycerides

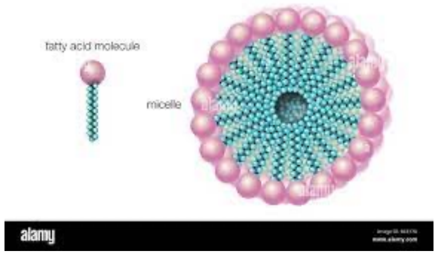
- Highly hydrophobic
- Saturated and unsaturated
- Long-term energy storage
- Stored in adipocytes

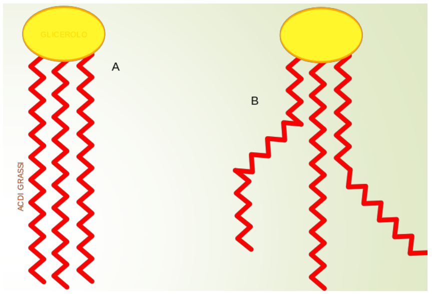
Phosphoglycerides

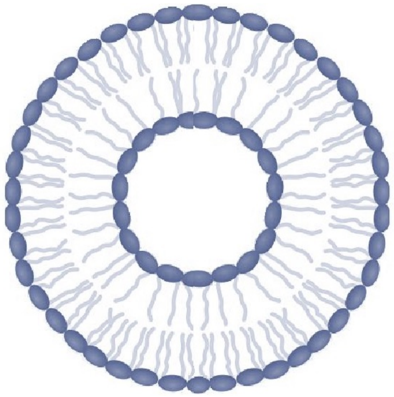
- amphipathic
- Saturated and unsaturated
- Principal components of cell membranes (bilayers)

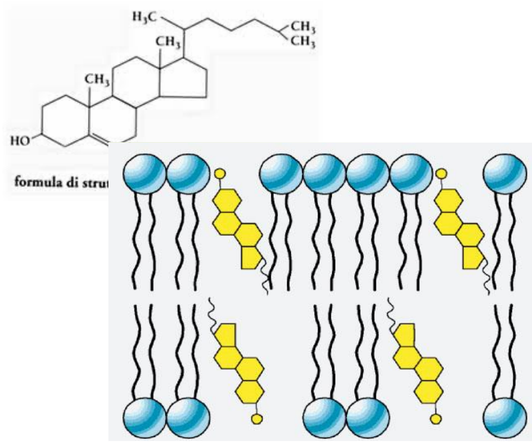
Steroids

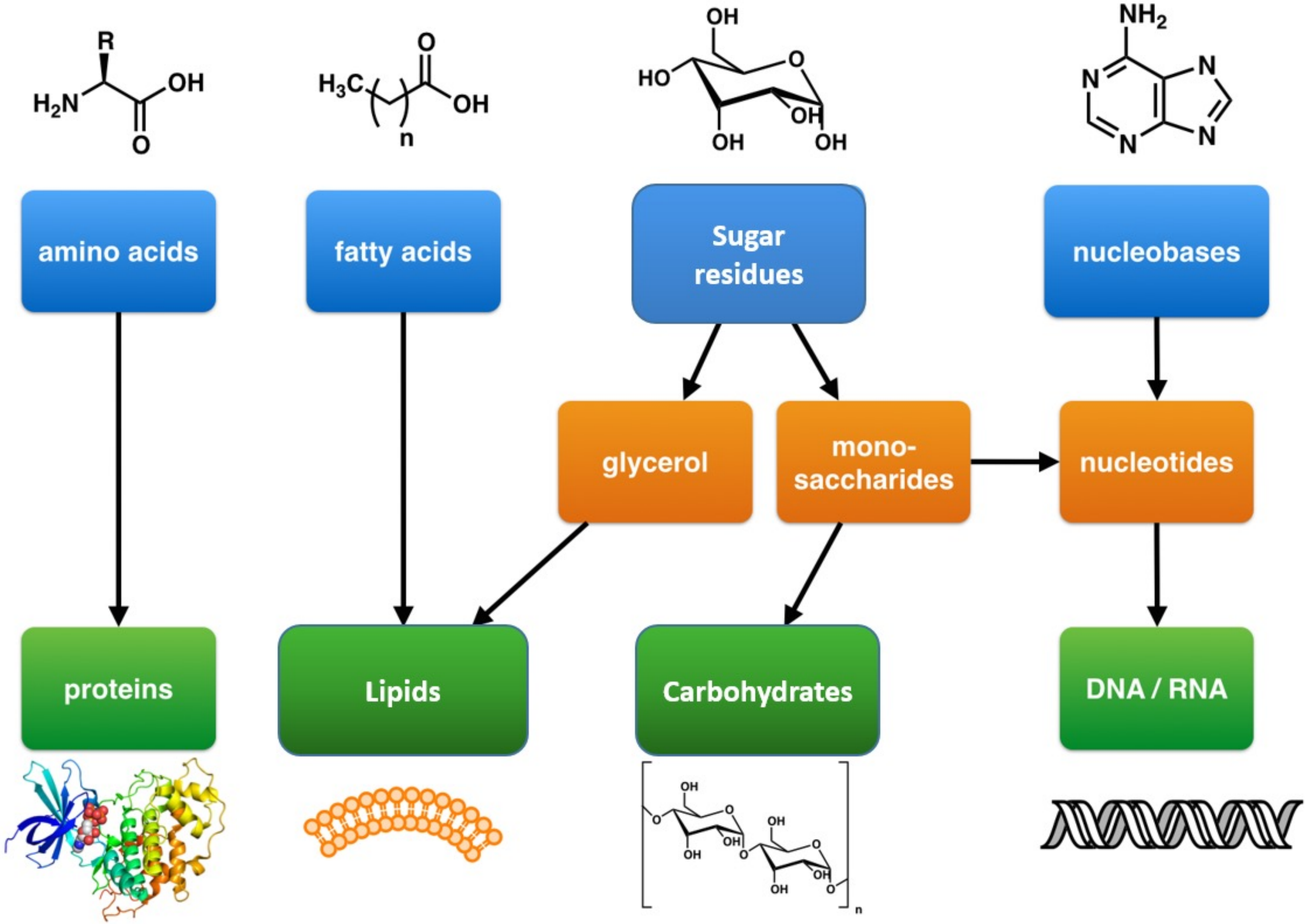
- amphipathic
- Cholesterol
- Confer rigidity to cell membranes











amino acids
fatty acids
Sugar residues
nucleobases
glycerol
mono-saccharides
nucleotides
proteins
Lipids
Carbohydrates
DNA / RNA