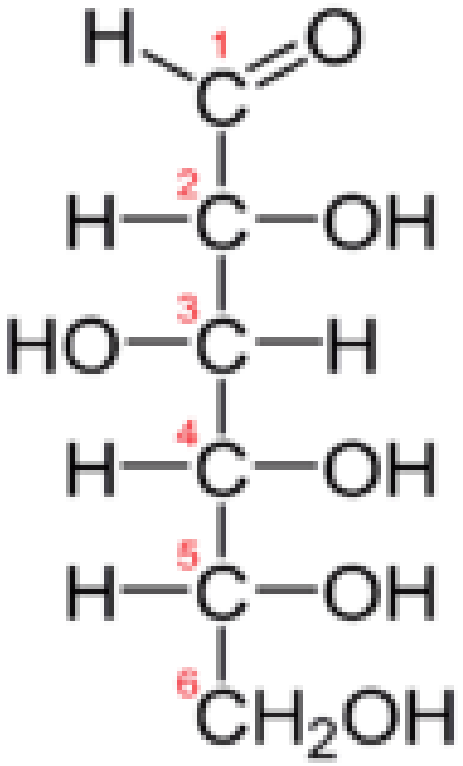
Chapter Two

Biological Molecules

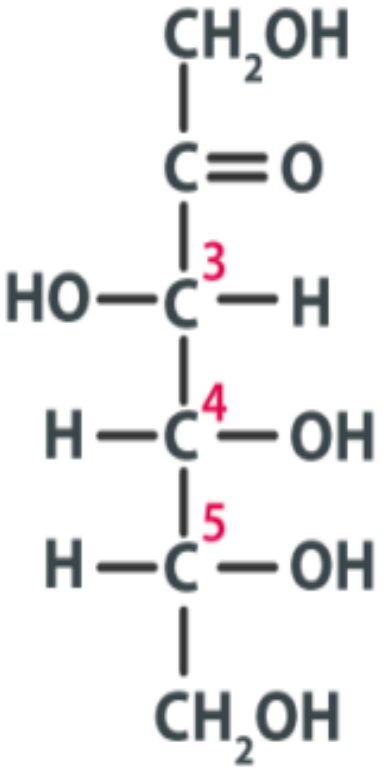
Carbohydrates

- A carbohydrate molecule is made of atoms of carbon, hydrogen and oxygen.
- They are an important source of energy and they also provide structural support for cells and help with communication between cells (cell-cell recognition).
- They are found in the form of either a sugar or many sugars linked together, called saccharides.
- Based on the number of sugar units they contain, they are categorized into three, as follows.
  - A single sugar molecule containing carbohydrate is known as a monosaccharides,
  - two sugar molecule containing carbohydrate is known as disaccharides and
  - More than two sugar molecule containing carbohydrate is known as polysaccharides
    - Each of the sugar molecules are bonded together through the glycosidic linkage/s.
- The three different types of carbohydrates are all important for different reasons

- Carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield these compounds on hydrolysis. Example: Glucose is an aldehyde while fructose is a ketone.
- Monosaccharides - simple sugars with multiple OH groups. Based on number of carbons (3, 4, 5, 6), a monosaccharide is a triose, tetrose, pentose or hexose.
- Disaccharides - 2 monosaccharides covalently linked
- Oligosaccharides - a few monosaccharides covalently linked.
- Polysaccharides - polymers consisting of chains of monosaccharide or disaccharide



Fischer projection of D-glucose



Fischer projection of D-fructose

Fig: Structures of monosaccharides (glucose and fructose)

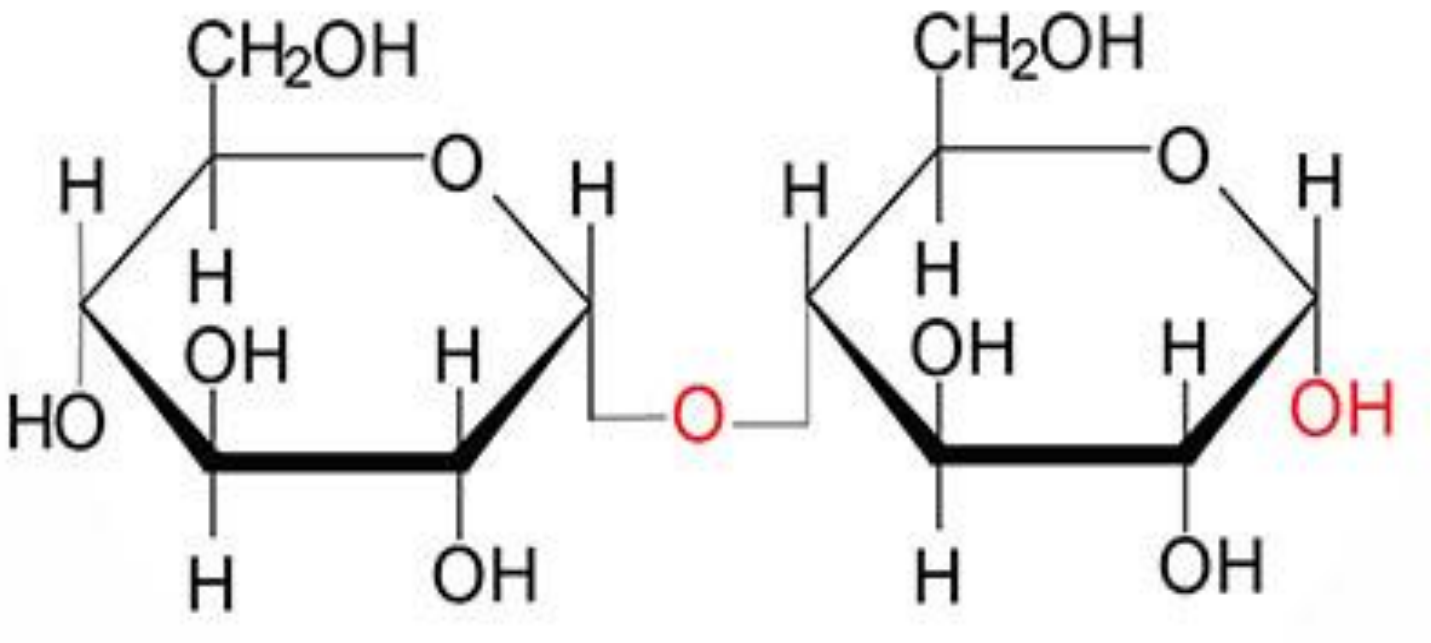


Fig: 2.2. A structure of maltose (disaccharide)

Monosaccharides

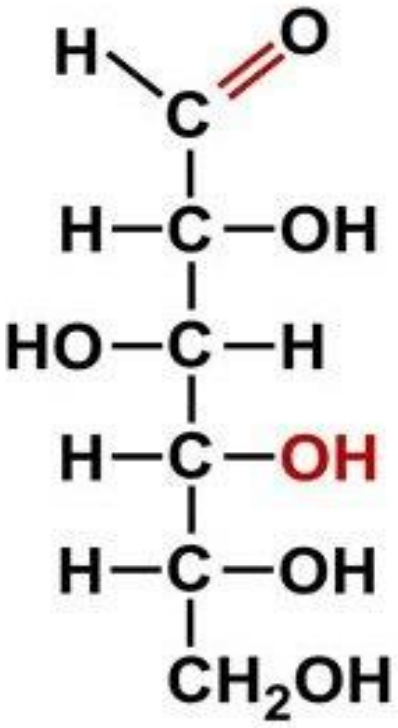
- Monosaccharides containing the aldehyde group are classified as aldoses, and those with a ketone group are classified as ketoses.
- Aldoses are reducing sugars; ketoses are non-reducing sugars.
  - This is important in understanding the reaction of sugars with Benedict's reagent. However, in water pentoses and hexoses exist mainly in the cyclic form, and it is in this form that they combine to form larger saccharide molecules.

Glucose

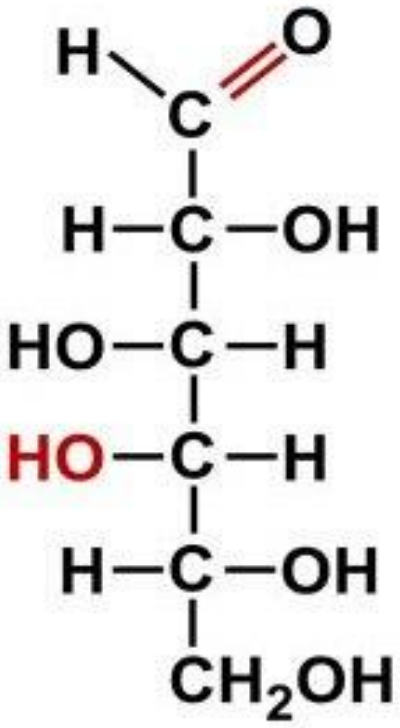
- Glucose is the most important carbohydrate fuel in human cells.
- Its concentration in the blood is about 1 gdm^{-3} .
- The small size and solubility in water of glucose molecules allows them to pass through the cell membrane into the cell.
- Energy is released when the molecules are metabolized.
- Two glucose molecules react to form the dissacharide maltose.
- Starch and cellulose are polysaccharides made of glucose units.

Galactose

- Galactose molecules look very similar to glucose molecules.
- They can also exist in α and β forms.
- Galactose reacts with glucose to make the dissacharide lactose.
- However, glucose and galactose cannot be easily converted into one another.
- Galactose cannot play the same part in respiration as glucose.
- This comparison of glucose and galactose shows why the precise arrangement of atoms in a molecule (shown by the displayed formula) is so important.



Glucose



Galactose

Fructose

- Fructose, glucose and galactose are all hexoses.
- However, whereas glucose and galactose are aldoses (reducing sugars), fructose is a ketose (a non-reducing sugar).
- It also has a five-atom ring rather than a six-atom ring.
- Fructose reacts with glucose to make the dissacharide sucrose.

Ribose and deoxyribose

- Ribose and deoxyribose are pentoses.
- The ribose unit forms part of a nucleotide of RNA.
- The deoxyribose unit forms part of the nucleotide of DNA.

Disaccharides

- Monosaccharides are rare in nature.
- Most sugars found in nature are disaccharides.
- These form when two monosaccharides react.
- Disaccharides are soluble in water, but they are too big to pass through the cell membrane by diffusion.
- They are broken down in the small intestine during digestion to give the smaller monosaccharides that pass into the blood and through cell membranes into cells.
  - $C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$

- This is a hydrolysis reaction and is the reverse of a condensation reaction and it releases energy.
- A condensation reaction takes place by releasing water.
  - This process requires energy.
- A glycosidic bond forms and holds the two monosaccharide units together.
- The three most important disaccharides are sucrose, lactose and maltose.
- They are formed from the a forms of the appropriate monosaccharides.
- Sucrose is a non-reducing sugar.
- Lactose and maltose are reducing sugars.

- Monosaccharides are used very quickly by cells.
- However, a cell may not need all the energy immediately and it may need to store it.
- Monosaccharides are converted into disaccharides in the cell by condensation reactions.
- Further condensation reactions result in the formation of polysaccharides.
  - These are giant molecules which, importantly, are too big to escape from the cell.
  - These are broken down by hydrolysis into monosaccharides when energy is needed by the cell.

Polysaccharides

- Monosaccharides can undergo a series of condensation reactions, adding one unit after another to the chain until very large molecules (polysaccharides) are formed.
- This is called condensation polymerisation, and the building blocks are called monomers. The properties of a polysaccharide molecule depend on:
  - Its length (though they are usually very long)
  - The extent of any branching (addition of units to the side of the chain rather than one of its ends)
  - Any folding which results in a more compact molecule
  - Whether the chain is 'straight' or 'coiled'

Starch

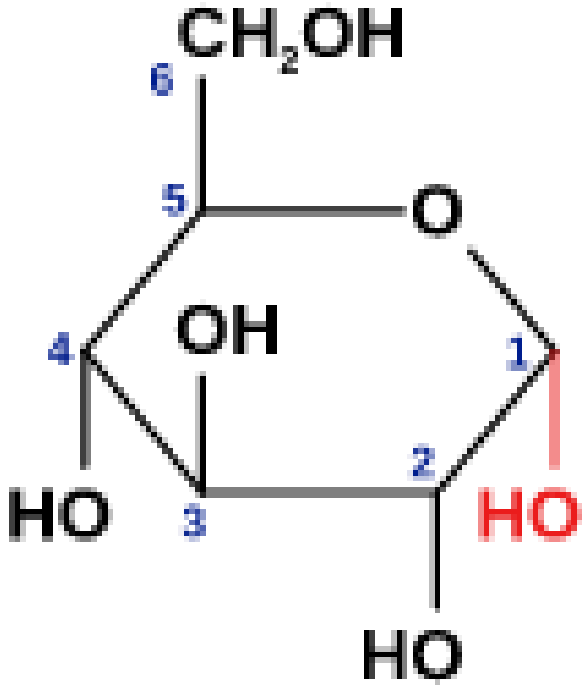
- Starch is often produced in plants as a way of storing energy.
- It exists in two forms: amylose and amylopectin. Both are made from α-glucose. Amylose is an unbranched polymer of α glucose. The molecules coil into a helical structure. It forms a colloidal suspension in hot water. Amylopectin is a branched polymer of α-glucose. It is completely insoluble in water.

Glycogen

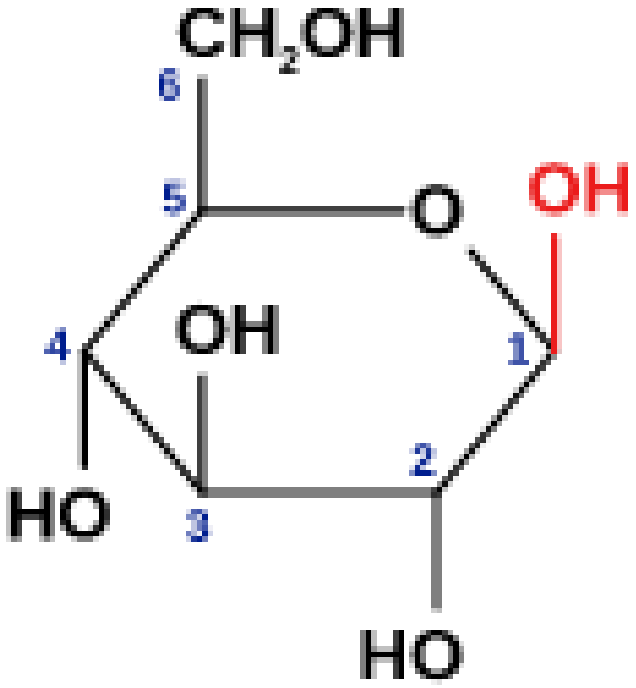
- Glycogen is amylopectin with very short distances between the branching side-chains.
- Starch from plants is hydrolysed in the body to produce glucose.
- Glucose passes into the cell and is used in metabolism.
- Inside the cell, glucose can be polymerised to make glycogen which acts as a carbohydrate energy store.

Cellulose

- Cellulose is a third polymer made from glucose.
- But this time it's made from β-glucose molecules and the polymer molecules are 'straight'.
- Cellulose serves a very different purpose in nature to starch and glycogen.
- It makes up the cell walls in plant cells.
- These are much tougher than cell membranes.
- This toughness is due to the arrangement of glucose units in the polymer chain and the hydrogen-bonding between neighboring chains.
- Cellulose is not hydrolysed easily and, therefore, cannot be digested so it is not a source of energy for humans.
- The stomachs of Herbivores contain a specific enzyme called cellulase which enables them to digest cellulose.



Alpha-(α) Glucose



Beta-(β) Glucose

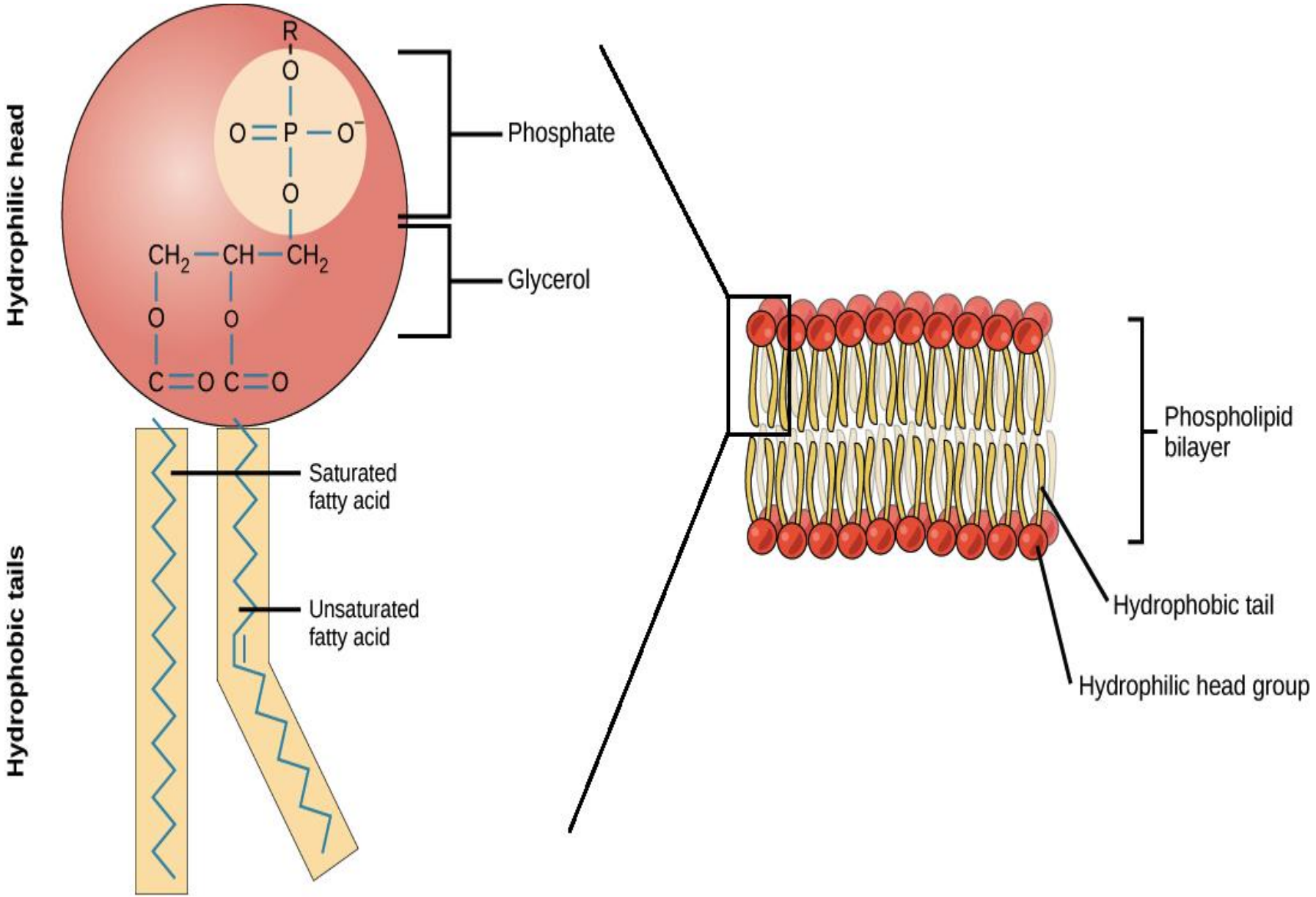
Lipids

- Lipids are a highly variable group of molecules that include fats, oils, waxes and some steroids.
- They are esters of fatty acids and alcohol (glycerol or chains of alcohols).
- Fatty acids are made mostly from chains of carbon and hydrogen and they bond to a range of other types of atoms to form many different lipids.
- The primary function of lipids is to store energy.

- A lipid called a triglyceride is a fat if it is solid at room temperature and oil if it is liquid at room temperature.
- In addition, triglycerides are stored in the fat cells, also called adipocytes or lipocytes, and are responsible in storing fats and lipids which will facilitate energy store in animals‘ body.
- Fat cells are categorized in white fat cells and brown fat cells.
- The difference is made from their ways of storing lipids.
- White fat cells store one large lipid drop while brown fat cells store smaller and multiple droplets of lipids spreading in the whole body of the cell.

- Various types of lipids occur in the human body, namely
  - triacylglycerol,
  - cholesterol, and
  - polar lipids, which include phospholipids, glycolipids and sphingolipids.
- Plant leaves are coated with lipids called waxes to prevent water loss, and the honeycomb in a beehive is made of beeswax.

- The basic structure of a lipid includes fatty acid tails as shown in Figure in the next slide.
- Each tail is a chain of carbon atoms bonded to hydrogen and other carbon atoms by single or double bonds.
- Lipids that have tail chains with only single bonds between the carbon atoms are called saturated fats because no more hydrogens can bond to the tail.
- Lipids that have at least one double bond between carbon atoms in the tail chain can accommodate at least one more hydrogen and are called unsaturated fats.
- Fats with more than one double bond in the tail are called polyunsaturated fats.


Hydrophilic head
Hydrophobic tails
R
O
O = P – O⁻
O
CH2 – CH – CH2
O O
C = O C = O
Phosphate
Glycerol
Saturated fatty acid
Unsaturated fatty acid
Phospholipid bilayer
Hydrophobic tail
Hydrophilic head group

Properties of lipids

- Insoluble in water
- Longer chains
  - More hydrophobic, less soluble
- Double bonds increase solubility
- Melting points:
  - Depend on chain length and saturation
  - Double bonds lead acyl chain disorder and low melting temperatures
  - Unsaturated fatty acids are solid at room temperature.

Importance of lipids

  - As the main component of cell membranes (phospholipids)
  - Insulation of heat and water,
  - Storing energy, protection and cellular communication.

Proteins

- A protein is a compound made of small carbon compounds called amino acids.
- Amino acids are small compounds that are made of carbon, nitrogen, oxygen, hydrogen, and sometimes sulfur.
- All amino acids share the same general structure.

- Amino acids have a central carbon atom like the one shown in Fig. below.
- Recall that carbon can form four covalent bonds. One of those bonds is with hydrogen. The other three bonds are with an amino group (–NH2), a carboxyl group (–COOH), and a variable group (–R).
- The variable group makes each amino acid different.
- There are 20 different variable groups, and proteins are made of different combinations of all 20 different amino acids.
- Several covalent bonds called peptide bonds join amino acids together to form proteins, which are also shown in Fig. below.
- A peptide forms between the amino group of one amino acid and the carboxyl group of another.

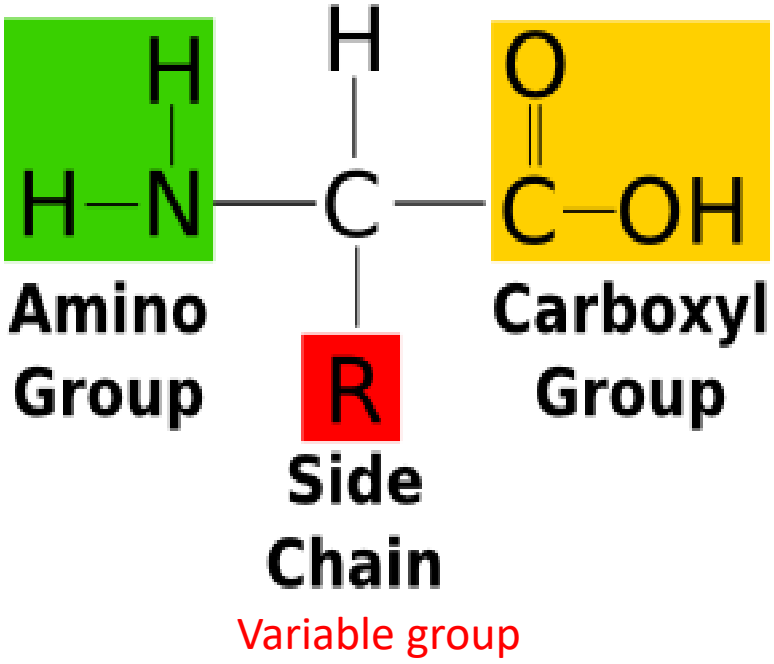


Fig: Basic structure of amino acid

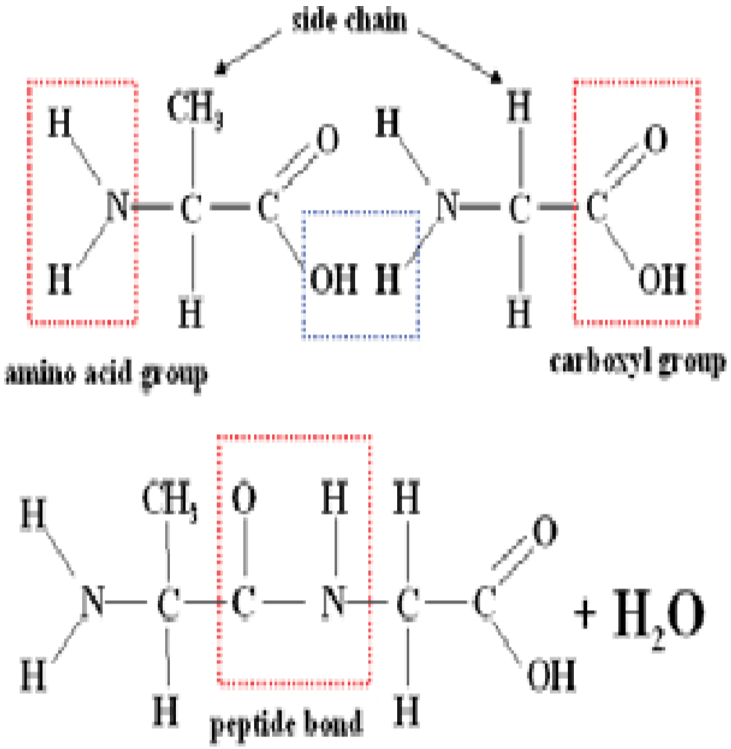


Fig: peptide bond b/n amino acids

- Based on the variable groups contained in the different amino acids, proteins can have up to four levels of structure.
- The number of amino acids in a chain and the order in which the amino acids are joined define the protein‘s primary structure.
- After an amino acid chain is formed, it folds into a unique three-dimensional shape, which is the protein‘s secondary structure.
- A protein might contain many helices, pleats, and folds. The tertiary structure of many proteins is globular, such as the hemoglobin protein, but some proteins form long fibers.
- Some proteins form a fourth level of structure by combining with other proteins.

- Proteins make up about 15% of your total body mass and are involved in nearly every function of your body.
- For example, your muscles, skin, and hair all are made of proteins. Your cells contain about 10,000 different proteins that provide structural support, transport substances inside the cell and between cells, communicate signals within the cell and between cells, speed up chemical reactions, and control cell growth.

Nucleic acids

- Nucleic acids are complex macromolecules that store and transmit genetic information.
- Nucleic acids are made of smaller repeating subunits called nucleotides.
- Nucleotides are composed of carbon, nitrogen, oxygen, phosphorus, and hydrogen atoms.
- There are six major nucleotides, all of which have three units a phosphate, a nitrogenous base, and a ribose sugar, as shown in Fig. below

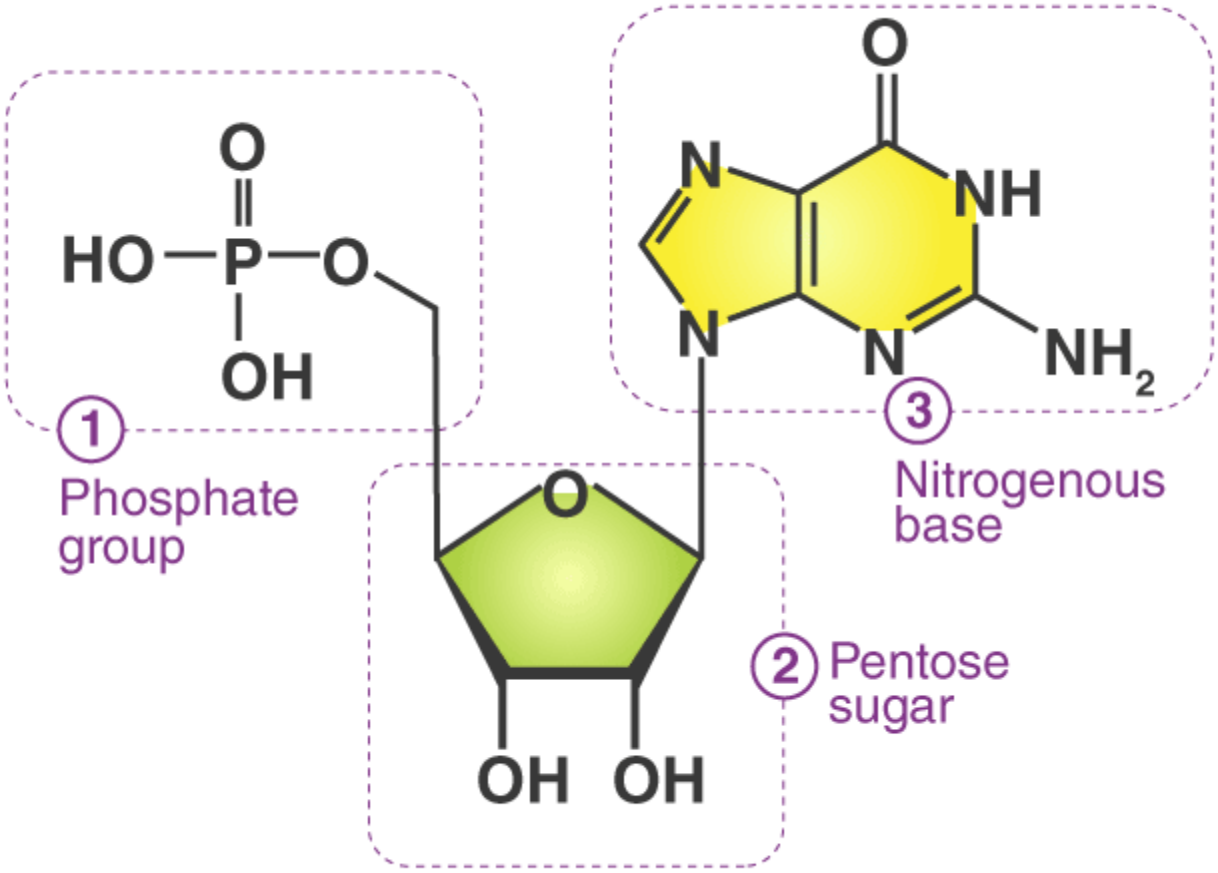


Fig. Basic structure of nucleotide

- There are two types of nucleic acids in living organisms: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
- In nucleic acids such as DNA and RNA, the sugar of one nucleotide bonds to the phosphate of another nucleotide.
- There are five different bases found in nucleotide subunits that make up DNA and RNA, Adenine, Cytosine, Guanine, Thymine and Uracil.
- Each of these nitrogenous base that sticks out from the chain is available for hydrogen bonding with other bases in other nucleic acids.

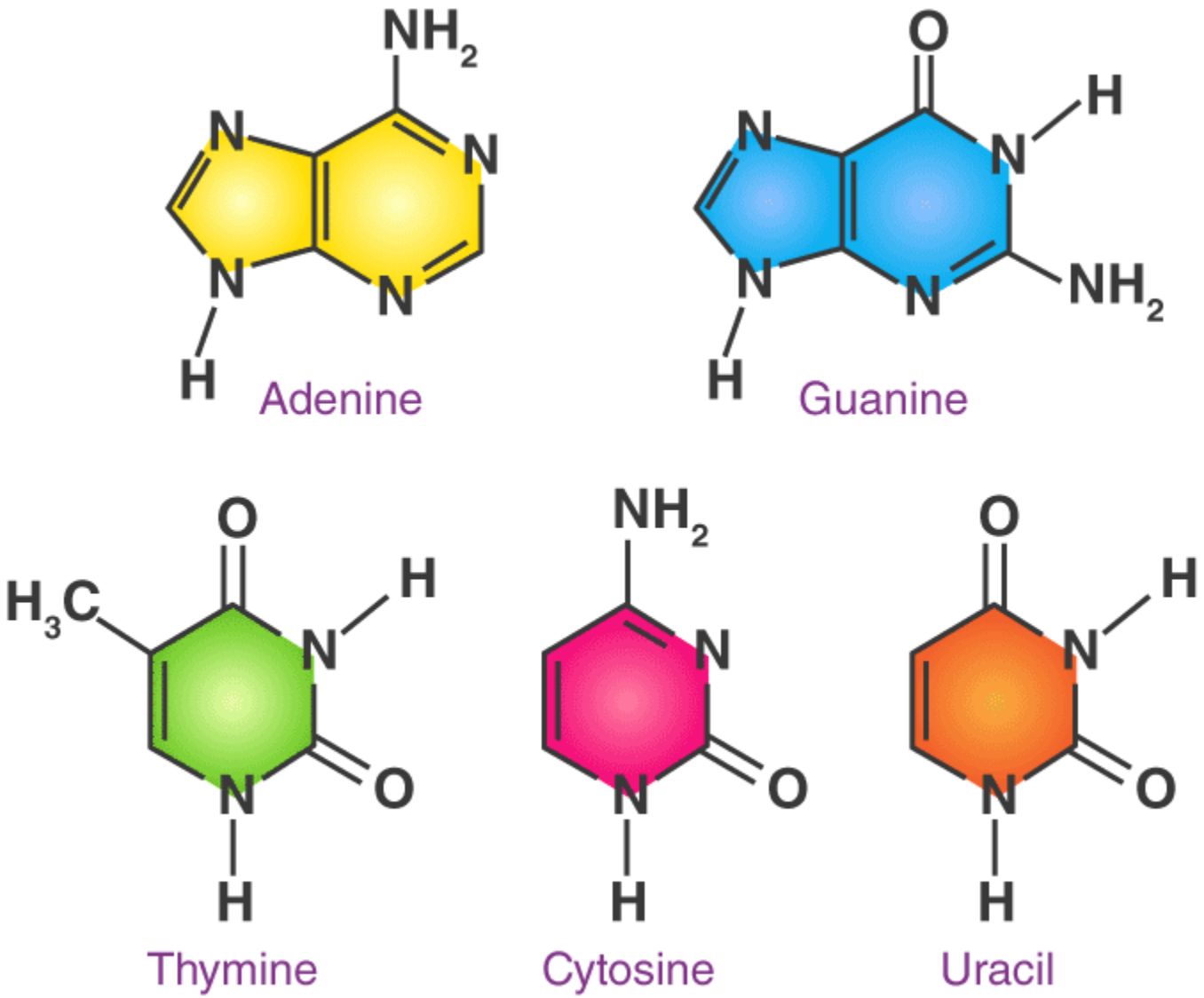


Fig: Nitrogenous bases

- A nucleotide with three phosphate groups is adenosine triphosphate (ATP).
- ATP is a storehouse of chemical energy that can be used by cells in a variety of reactions.
- It releases energy when the bond between the second and third phosphate group is broken.

Vitamins

- Vitamins are organic compounds that are needed in small amounts for metabolic activities.
- Many vitamins help enzymes function well.
- Vitamin D is made by cells in your skin.
- Some B vitamins and vitamin K are produced by bacteria living in the large intestine.
- Sufficient quantities of most vitamins cannot be made by the body, but a well-balanced diet can provide the vitamins that are needed.
- Some vitamins that are fat-soluble can be stored in small quantities in the liver and fatty tissues of the body.
- Other vitamins are water-soluble and cannot be stored in the body.
- Foods providing an adequate level of these vitamins should be included in a person‘s diet on a regular basis.

Water

- Water molecules are formed by covalent bonds that link two hydrogen (H) atoms to one oxygen (O) atom, and each water molecule has the same structure.
- It is one of the most plentiful and essential of compounds, which is a tasteless and odorless, existing in gaseous, liquid, and solid states.
- It has the important ability to dissolve and as a media for transportation of many other substances.
- In reality, the versatility of water as a solvent is essential to living organisms, as well.
- Water molecules have an unequal distribution of charges and are called polar molecules, meaning that they have oppositely charged regions.

Minerals

- Minerals are inorganic compounds used by the body as building material, and they are involved with metabolic functions.
- For example, the mineral iron is needed to make hemoglobin and it binds to hemoglobin in red blood cells and is delivered to body cells as blood circulates in the body.
- Calcium, and other minerals, is an important component of bones and is involved with muscle and nerve functions and they serve as cofactors for enzymes.
- Magnesium is an important component of the green pigment, chlorophyll, involved in photosynthesis.

Thank you!