

Biology Notes 2013

Chemicals of Life

Introduction

Biological molecules are large, complex molecules produced by living organisms. Includes:

- ✚ Carbohydrates
- ✚ Lipids
- ✚ Proteins
- ✚ Nuclei acids

Water is also a major component of the cell.

Carbohydrates

Made up of elements: C, H, O. General formula of carbs is $C_x(H_2O)_y$, where $x = y$.

Ratio of H:O = 2:1.

There are 3 types of carbohydrates:

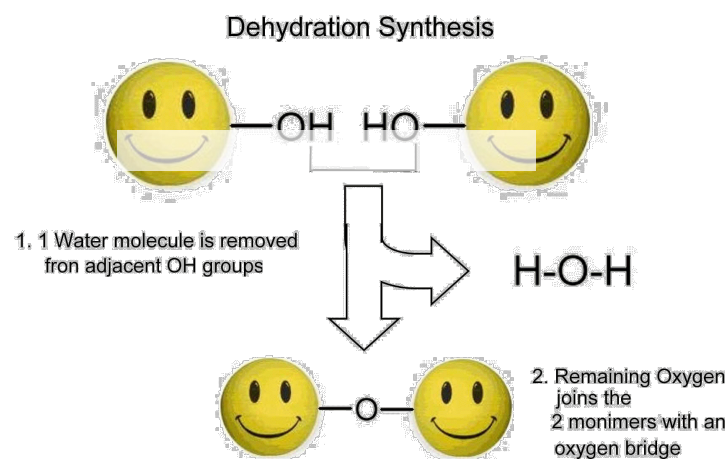
- ✚ Monosaccharides
- ✚ Disaccharides
- ✚ Polysaccharides

The Monosaccharides

The monosaccharides are inclusive of glucose, fructose, and galactose. All three have the molecular formula $C_6H_{12}O_6$.

Dehydration Synthesis

Dehydration synthesis is also called condensation reaction. Simply put, dehydration synthesis is the formation of a complex molecule with the removal of a molecule of water.



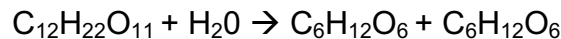
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The Disaccharides

Some examples of disaccharides include:

- ✚ Sucrose [cane sugar] glucose + fructose
- ✚ Lactose [milk sugar] glucose + galactose
- ✚ Maltose [malt sugar] glucose + glucose

All three have the molecular formula $C_{12}H_{22}O_{11}$. Disaccharides can be broken down by hydrolysis reaction.



[sucrase, dilute acid]

The Polysaccharides

Polysaccharides are macromolecules [polymers] of a few hundred or thousand monosaccharides which are formed by linking monomers in enzyme-mediated dehydration synthesis.

Polysaccharides have 2 important biological functions:

- ✚ Energy storage
- ✚ Structural Support

The Polysaccharides

Polysaccharides are also called glycans.

They differ in the:

- ✚ Nature of recurring monosaccharides
- ✚ Length of their chains
- ✚ Degree of branching/no branching

Storage Polysaccharides

Ideal storage material would be reasonably compact and inert; mobilized quickly when food materials are unavailable from the environment. Examples of such storage material are starch in plants and glycogen in animals.

Starch and glycogen are convenient storage molecules for several reasons:

- ✚ Large size makes them more or less insoluble in water, so they exert no osmotic or chemical influence in the cell
- ✚ They fold into compact shapes
- ✚ They are easily converted to sugars by hydrolysis when required

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Carbohydrates:

Energy value → 1g of carbohydrates yields 16 kJ of energy

Sources → Bread, potato, sweets, sugar, cereals, flour

Functions:

- ✚ Source of energy
- ✚ To form supporting structures [eg cellulose cell walls]
- ✚ Formation of nucleic acids [DNA and RNA]
- ✚ To synthesize lubricants, eg mucus which is carbohydrate and protein
- ✚ To produce nectar in flowers to attract insects for pollination

Test of reducing sugars:

Reducing sugars are able to reduce Cu^{2+} ions into Cu^+ ions, forming a brick red precipitate in the copper [I] oxide.

Steps for Benedict's test:

- ✚ To test sample of an unknown solution, add an equal volume of Benedict's reagent. Shake. Heat in a boiling water bath.
- ✚ Positive test: A coloured precipitate is seen, with different colours indicating different concentrations of reducing sugars.
- ✚ Green ppt → yellow ppt → orange ppt → red ppt → brick-red ppt [increasing amount of reducing sugar[s]]

All monosaccharides and disaccharides are reducing sugars except sucrose [non-reducing sugar]. To test for sucrose, a negative test will indicate presence of sucrose.

Test for starch:

To test for starch, the iodine test is used.

Steps:

- ✚ Drop iodine onto test sample[s].
- ✚ Presence of starch will turn iodine solution blue-black in colour.

Overconsumption of carbohydrates leads to obesity as excess carbohydrates can be converted into fats and stored in adipose tissues beneath the skin and around internal organs.

Lipids

Lipids aka fats or what Zhu Deng has excessively, is made up of the elements: C, H, O.

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Unlike carbohydrates, lipids have no:

- ✚ No fixed molecular formula
- ✚ No fixed ratio of H:O [contains much more hydrogen than oxygen atoms]
- ✚ Energy value: 1g of fat yields 38 kj of energy

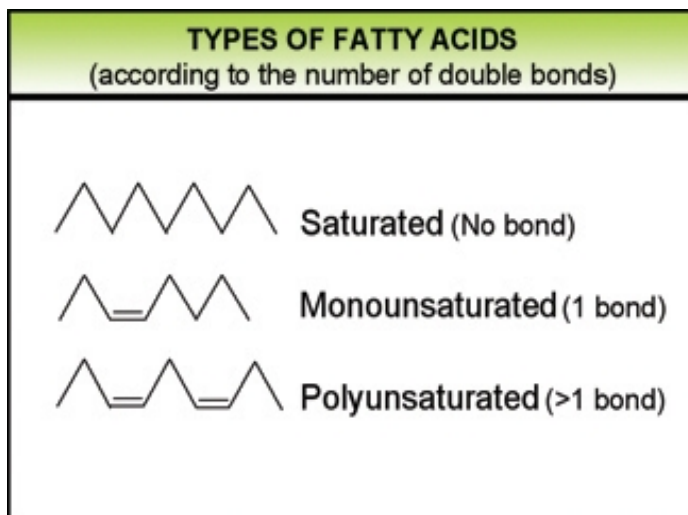
Types of lipids:

- ✚ Animal and vegetable fats [triglycerides]
- ✚ Phospholipids
- ✚ Steroids [eg cholesterol]

Triglyceride molecules

Triglycerides are formed by dehydration synthesis, and broken down by hydrolysis.

Types of Fatty Acids



Saturated Fats:

No double bonds; present in fatty acid chain.

Monounsaturated fats:

Presence of 1 double bond in fatty acid chain.

Polyunsaturated fats:

Presence of 2 or more double bonds in fatty acid chain.

Sources:

Saturated fats → Animal fats such as pork fat, beef fat

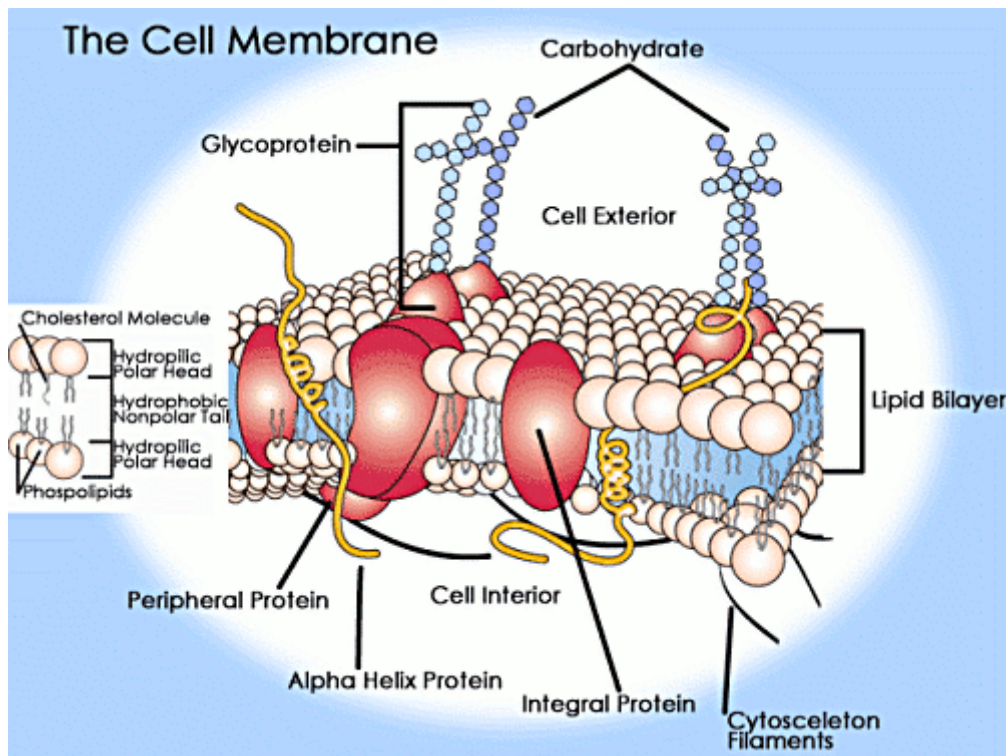
Monounsaturated fats → Olive bound, peanut oil, avocado, cold-water fish such as salmon, mackerel, trout.

Polyunsaturated fats → Vegetable oils such as sunflower, corn, soybean, many nuts and seeds such as almonds, cashews, walnuts, macadamia nuts.

Functions:

Lipids are a source and store of energy. They also act as insulating material, especially beneath the skin to prevent excessive heat loss. Lipids also are a solvent for fat-soluble vitamins and are constituents of cell membranes.

Phospholipid Bilayer:



Overconsumption of Fats:

- ✚ Increase in blood levels of cholesterol
- ✚ Excess cholesterol deposits on inner walls of arteries leading to hardening and narrowing of arteries → atherosclerosis
- ✚ Results in high blood pressure and blood clot formation
- ✚ Blood clot gets swept into coronary arteries supplying oxygenated blood to the heart muscles → blockage in these arteries → heart attack\

Ethanol-emulsion Test:

To test for lipids, the ethanol-emulsion test is used.

- ✚ Add 2 cm³ of ethanol to a drop of oil in a test tube.
- ✚ Shake mixture thoroughly [oil will be seen to dissolve in ethanol to form a clear solution].
- ✚ Add 2 cm³ of water to the mixture and shake. A white emulsion is formed and heat is evolved [test tube feels warm].
- ✚ Negative test: no white emulsion seen on shaking with water.

Explanation:

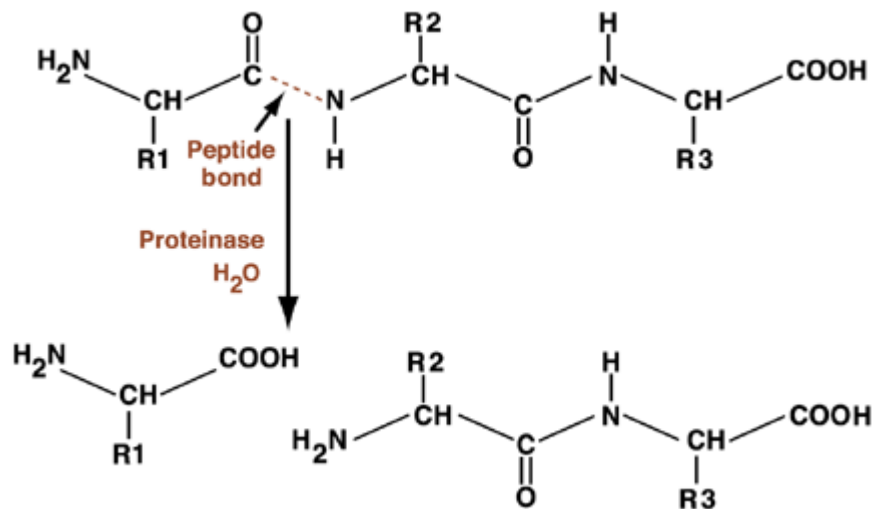
Oil is insoluble and less dense and will usually float in water. Oil is first dissolved in alcohol with which water is miscible. When water is added, the alcohol, laden with oil, mixes with water. The oil itself does not mix but is left as minute droplets dispersed

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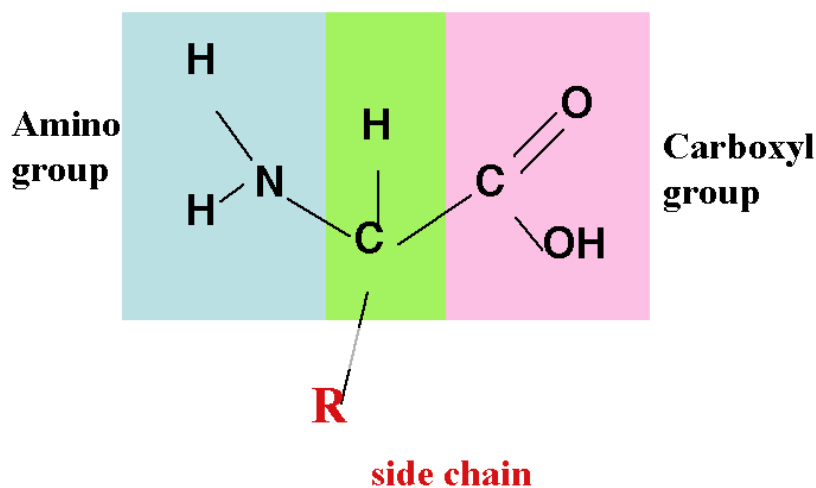
throughout water. Light passing through is scattered in all directions as a result and gives the suspension a milky white appearance.

Proteins

Proteins are made up of the elements: C, H, O, N (some proteins may also contain S and P). The basic unit of protein is amino acid. By dehydration synthesis, amino acids can be joined to form larger structures like dipeptides, oligopeptides, polypeptides. Proteins can be broken down into their respective amino acids by hydrolysis.



Structure of Amino Acid:



Energy Value:

1 gram of protein yields 17 kJ of energy.

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In times of starvation, the body uses stored fats first for energy. Proteins would be last energy source to be used since muscles and tissue consists largely of proteins.

Sources:

Animal sources:

- ✚ Meat, eggs, milk, seafood, liver

Plant sources:

- ✚ Peas, beans, nuts

Functions of Proteins:

Proteins are used for synthesis of protoplasm [nucleus, cytoplasm and cell membrane], hence it is needed for growth and repair of worn out body cells. Synthesis of enzymes, some hormones, antibodies to combat diseases all require proteins. Lastly, proteins are a source of energy.

Types of Proteins:

Globular proteins include:

- ✚ Transport Protein – haemoglobin which transports oxygen from lungs to all parts of body.
- ✚ Enzymes – Protein that speeds up the rate of chemical reactions in the body.
- ✚ Antibodies – Protein involved in immunity

Structural Protein:

- ✚ Collagen [component of bone, tendon, teeth, skin], keratin [found in nails and hair]

Test for Proteins:

To test for proteins, the biuret's test is deployed.

Steps:

- ✚ Add 2cm^3 of protein solution in a test tube, add 1 cm^3 of sodium hydroxide solution
- ✚ Shake mixture thoroughly
- ✚ Add copper sulphate solution to the mixture, drop by drop, shaking after each drop
- ✚ Positive test: a violet/purple colouration is seen
- ✚ Negative test: solution remains blue [colour of copper sulphate solution]

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Water

Importance of Water:

- ✚ 70-80% of cell contents made up of water
- ✚ Universal solvent, hence it is the medium in which many chemical reactions of an organism occur e.g. hydrolytic reactions of digestion
- ✚ Transporting agent for digested food substances, hormones and excretory products from one part of the body to another
- ✚ An essential component of lubricant found in the joints, blood and digestive juices
- ✚ Raw material for photosynthesis
- ✚ Temperature-regulation → excess body heat removed by evaporation of sweat from skin surface