OCR (A) Biology A-level

Topic 2.2: Biological molecules

Notes

Water

Water is a very important molecule which is a major component of cells, for instance:

- Water is a **polar molecule** due to **uneven distribution of charge** within the molecule – the hydrogen atoms are more positive than the oxygen atom causing one end of the molecule to be more positive than the other
- It is a **metabolite** in metabolic reactions such as **condensation and hydrolysis** which are used in forming and breaking of chemical bonds
- It is a **solvent** in which many metabolic reactions occur
- It has a **high heat specific capacity** meaning that a lot of energy is required to warm water up therefore **minimising temperature fluctuations** in living things therefore it acts as a **buffer**
- It has a **relatively large latent heat of vaporisation**, meaning evaporation of water provides a **cooling effect** with little water loss
- **Strong cohesion** between molecules enables effective transport of water in tube-like transport cells as the **strong cohesion supports columns of water**. As a result of strong cohesion **the surface tension at the water-air boundary is high**
- **Maximum density of water is at 4 degrees** – this means that **ice is less dense than water** and floats on top of it creating an **insulating layer**, this increases the chance of survival of organisms in large bodies of water as it prevents them from freezing
- Water is **incompressible** therefore it provides good **support**

Monomers and polymers

Monomers are small units which are the components of larger molecules, examples of include **monosaccharides** (such as **glucose)**, **amino acids** and **nucleotides**. **Polymers** are molecules made from monomers joined together. A **condensation** reaction is a reaction which joins monomers by chemical bonds and it involves the elimination of a water molecule. **Hydrolysis** is the opposite of condensation and it's when water is added to break a chemical bond between two molecules.

Carbohydrates

Carbohydrates are molecules which consist only of carbon, hydrogen and oxygen and they are long chains of sugar units called saccharides. There are three types of saccharides - **monosaccharides, disaccharides and polysaccharides**. Monosaccharides can join together to form disaccharides and polysaccharides by **glycosidic bonds** which are formed in **condensation reactions**.

Monosaccharides

Glucose is a monosaccharide containing six carbon atoms in each molecule, it is the main **substrate for respiration** therefore it is of great importance. It has two isomers – alpha and beta glucose with following structures:

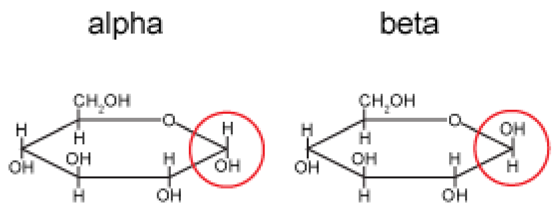


Figure 1 A dash of science

Disaccharides:

- **Maltose** is a disaccharide formed by condensation of **two glucose molecules**
- **Sucrose** is a disaccharide formed by condensation of **glucose & fructose**
- **Lactose** is a disaccharide formed by condensation of **glucose & galactose**

Polysaccharides are formed from many glucose units joined together and include:

- **Glycogen** and **starch** which are both formed by the condensation of **alpha glucose**
- **Cellulose** formed by the condensation of **beta glucose**

Glycogen is the main energy storage molecule in animals and it's formed from many molecules of **alpha glucose** joined together by **1, 4 and 1, 6 glycosidic bonds**. It has a **large number of side branches** meaning that glucose & therefore energy, can be released quickly. Moreover, it is a relatively **large but compact** molecule thus maximising the amount of energy it can store.

Starch stores energy in plants and it is a mixture of two polysaccharides called **amylose and amylopectin**:

- **Amylose** – amylose is an **unbranched chain** of glucose molecules joined **by 1, 4 glycosidic bonds**, as a result of that amylose is **coiled** and thus it is a very **compact** molecule meaning it can store a lot of energy

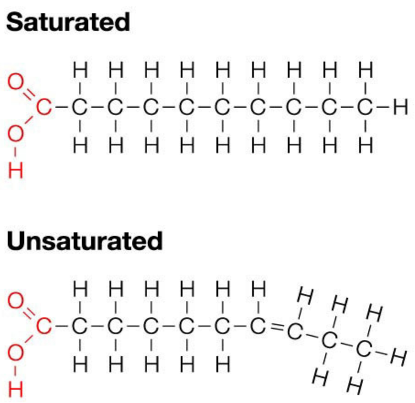
- **Amylopectin** is **branched** and is made up of glucose molecules joined by **1, 4 and 1, 6 glycosidic bonds**, due to the presence of many **side branches** it is **rapidly digested by enzymes** therefore energy is released quickly.

Cellulose is a component of cells wells in plants and it's composed of long, unbranched chains of **beta glucose** which are joined by glycosidic bonds. **Microfibrils** are strong threads which are made of long cellulose chains joined together by **hydrogen bonds** and they provide **structural support** in plants cells.

Lipids

Lipids are biological molecules which are only soluble in **organic solvents** such as alcohols.

There are two types of lipids:



- **Saturated lipids** such as those found in **animal fats** – saturated lipids don't contain any carbon-carbon double bonds

- **Unsaturated lipids** which can be found in **plants** – unsaturated lipids contain carbon-carbon **double bonds** and melt at lower temperatures than saturated fats.

Figure 2 Spark People

The greater the number of unsaturated bonds, the weaker the intermolecular bonds resulting in lower melting point, and as a result of that saturated fats which don't contain any double bonds are solid at liquid temperature and unsaturated lipids are liquid at room temperature.

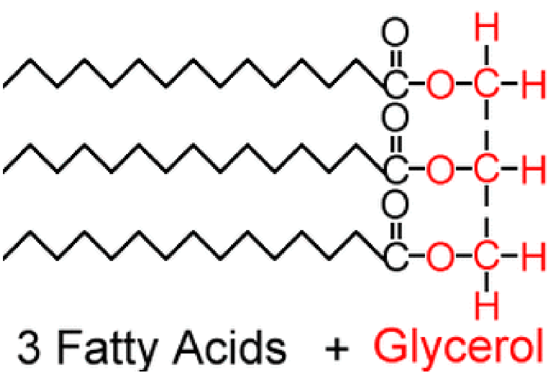


Figure 3 The Med Circle

Triglycerides are lipids made of one molecule of **glycerol** and **three fatty acids** joined by ester bonds formed in **condensation reactions**. There are many different types of fatty acids, they vary in chain length, presence and number of double bonds. Also, some triglycerides contain a mix of different fatty acids. Triglycerides are used as energy reserves in plant and animal cells.

In **phospholipids**, one of the fatty acids of a triglyceride is substituted by a phosphate-containing group. Phosphate heads are **hydrophilic** and the tails are **hydrophobic** and as a result phospholipids form **micelles** when they are in contact with water as heads are on the outside as they are attracted to water and tails are on the inside as they move away from water.

Inorganic ions

Inorganic ions occur in solution in the cytoplasm and body fluid of organisms, some in high concentrations and others in very low concentrations.

Some of the essential ions include:

- **hydrogen ions** which **determine the pH** of substances such as blood – **the higher the concentration of hydrogen ions the lower the pH**
- **Iron ions are a component of haemoglobin** which is an oxygen carrying molecule in red blood cells
- **Sodium ions** are **involved in co-transport of glucose and amino acids**
- **Phosphate ions** are a **component of DNA and ATP**

Proteins

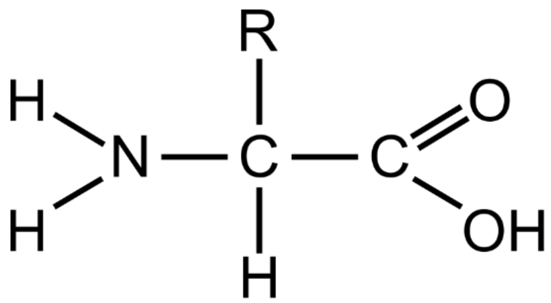


Figure 4 Geography Discipline Network

Amino acids are the monomers from which proteins are made. Amino acids contain an amino group – NH2, carboxylic acid group and a variable R group which is a carbon-containing chain. There are 20 different amino acids with different R groups. Amino acids are joined by peptide bonds formed in condensation reactions. A dipeptide contains two amino acids and polypeptides contain three or more amino acids.

Structure of proteins is determined by the order and number of amino acids, bonding present and the shape of the protein:

- **Primary structure** of a protein is the order and number of amino acids in a protein.
- The **secondary structure** is the shape that the chain of amino acids takes – **either alpha helix** or **beta pleated sheet**. The shape is determined by the **hydrogen bonding**.
- **Tertiary structure** of proteins is the 3D shape of the protein.It can be globular or fibrous. **Globular proteins** such as enzymes are compact whereas **fibrous proteins** such as keratin are long and thus can be used to form fibres.
- For instance, **collagen** is a **fibrous** protein of great strength due to presence of both **hydrogen and covalent bonds** in the structure. Collagen molecules wrap around each other and form fibrils which form strong collagen fibres. Collagen forms the structure of **bones, cartilage and connective tissue** and is a main component of **tendons** which connect muscles to bones.

- **Haemoglobin** is a **water soluble globular protein** which consists of two alpha and two **beta polypeptide chains each containing a haem group**. It **carries oxygen** in the blood as oxygen can bind to the haem (Fe^{2+}) group and oxygen is then released when required.

Tests

- **Benedict's test** for reducing and non-reducing sugars - a reducing sugar is one which can donate electrons and includes all monosaccharides and some disaccharides. An alkaline solution of blue copper (II) sulphate is added to the sugar and subsequently heated, in the presence of reducing sugar, a red precipitate of copper (I) oxide is formed. In the absence of reducing sugar, the Benedict's reagent does not change colour.

- The **biuret test** is used to **test for proteins**. Firstly, a sample of the solution is placed in a test tube and subsequently an equal amount of NaOH is added. Afterwards, a few drops of dilute copper (II) sulfate solution is added and gently mixed. In the presence of a protein, the solution turns lilac/ as an indicator of peptide bonds. In the absence of protein, the solution remains blue.

- The **emulsion test is used to test for lipids**. Firstly, 2ml of sample is added to 5ml of ethanol. Subsequently, the contents are mixed thoroughly by shaking to ensure that the lipids dissolved. Upon addition of 5ml of water and mixing, the solution turns cloudy indicating the presence of lipid due to the formation of an emulsion where the light is refracted as it passes from droplets of oil to droplets of water.

- **Starch** is tested for with the help of **iodine** – in the presence of starch, the colour of potassium iodide solution from yellow to black/blue.