CAIE Biology A-level

Topic 2: Biological molecules

Notes

Biochemical tests

- Benedict's solution can be used to test for the presence of reducing sugars. Reducing sugars include all monosaccharides and some disaccharides. Therefore it can be used to test for glucose, fructose and maltose. It does not test for sucrose, however. The test involves heating the sugar with Benedict's solution – if the colour changes from blue to brick red then glucose is present.
  - If there is no colour change it could be that there is a non-reducing sugar present (e.g. sucrose). You can break the glycosidic bonds by acid hydrolysis.
    1. Add dilute HCl to the test solution and heat in a water bath
    2. Neutralise with sodium hydrogencarbonate
    3. Heat with Benedict's solution
  - You can also carry out this experiment semi-quantitatively.
    - You can do this by measuring the time it takes for the colour change to happen. The different times can help estimate the concentration.
    - You could also use the different colour changes and work out the concentration of glucose using colorimetry.
    - (Higher glucose concentration means lower absorbance of the solution)
      1. Do Benedict's test
      2. Calibrate colorimeter with plain water and use this as your control
      3. Remove precipitates from each test tube by using a centrifuge (or let it settle for 24 hours)
      4. Measure the absorbance using a colorimeter
      5. Create a calibration curve of concentration of glucose vs absorbance (this can be used to find glucose concentrations of different unknowns)

- A chemical test for starch is done using iodine/potassium iodide. If the solution turns blue/black in colour then starch is present.

- A chemical test for lipids is the emulsion test. This is done by adding ethanol to the test substance and shaking. You then mix that with water. A milky colour will show a positive result for lipids.

- The biuret test can be done to check for the presence of proteins. You first add a few drops of sodium hydroxide solution and then some copper (II) sulphate solution. If the colour changes from blue to purple then proteins are present.

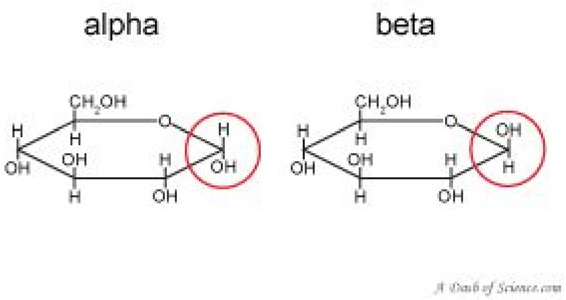
Carbohydrates

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 are single units that can join together to form disaccharides and polysaccharides by **glycosidic bonds** which are formed in **condensation reactions**.

Monosaccharides

Monosaccharides are small organic molecules used as building blocks of complex carbohydrates. Monosaccharides have a varying number of carbon atoms, for instance:

- **Glyceraldehyde** is a triose used in metabolic reactions
- **Ribose** is a pentose sugar which is a component of nucleic acid



- **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.

Disaccharides

Disaccharides are formed in a condensation reaction between two monosaccharides.

- **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

Polysaccharides are formed from many monosaccharides joined together by **glycosidic bonds** 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 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 in a small space.

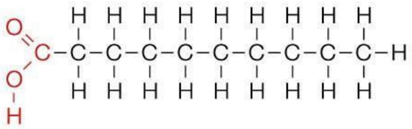
- Amylopectin is branched and is made up of glucose molecules joined by 1, 4 and 1, 6 glycosidic bonds, due to the presence of many side branches it is rapidly digested by enzymes therefore energy is released quickly.

Cellulose is a component of cell 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 plant cells.

Lipids

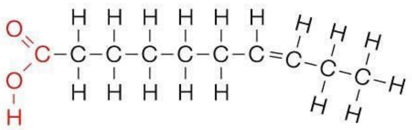
Lipids are biological molecules which are only soluble in organic solvents such as alcohols. There are two types of lipids:

Saturated



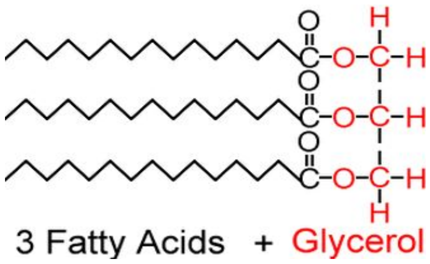
- Saturated lipids such as those found in animal fats – saturated lipids don't contain any carbon-carbon double bonds. Too much saturated fat can increase the cholesterol levels in blood thus increasing the risk of coronary heart disease.

Unsaturated



- Unsaturated lipids which can be found in plants – unsaturated lipids contain carbon-carbon double bonds and melt at lower temperatures than saturated fats. Unsaturated fats are healthy as they provide essential fatty acids.

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.

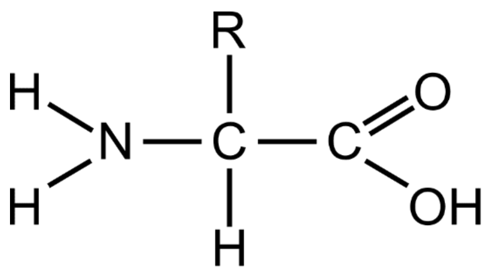


Triglycerides are non-polar and hydrophobic molecules. They are lipids composed of one molecule of **glycerol** and **three fatty acids** joined by ester bonds formed in **condensation reactions**. There are many different types of fatty acids, they vary in chain length, presence and number of double 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. The hydrophobic/hydrophilic nature of phospholipids is what makes cell membranes selectively membrane.

Proteins



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.

The **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 chains – **either alpha helix** or **beta pleated sheet.** The shape is determined by the type of bonding present such as:
  - **Hydrogen bonding** - **weak** bonds between a **slightly positively-charged hydrogen atom** and another **slightly negatively-charged atom** (usually nitrogen, oxygen or fluorine).
  - **Ionic bond** - attraction between **oppositely charged R groups**

- Disulphide bridges - when 2 cysteine amino acids come into close contact and the sulfur in each cysteine forms a bond.

- Tertiary structure of proteins is the 3D shape of the protein, it can be globular or fibrous.
    - Globular proteins such as enzymes are compact. They are also soluble.
    - Whereas fibrous proteins such as keratin are long and thus can be used to form fibres. These are insoluble.
    - For instance, collagen is a fibrous protein of great strength due to the 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.

- Quaternary structure of proteins consists of 2 or more subunits (polypeptide chains) closely packed together.
    - Haemoglobin carries oxygen in the blood. It has a quaternary structure consisting of 2 alpha subunits and 2 beta subunits. Each polypeptide chain contains a prosthetic (non-protein) group - haem (Fe^{2+}).
    - The oxygen can bind to the haem group and be released when required.

Peptide bonds can be hydrolysed (broken) with the addition of water in a hydrolysis reaction.

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 specific heat 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.

- There is **strong cohesion** between molecules enabling effective transport of water in tube-like transport cells as the **strong cohesion supports columns of water** (capillary action), as a result of strong cohesion **the surface tension at the water-air boundary is high**.