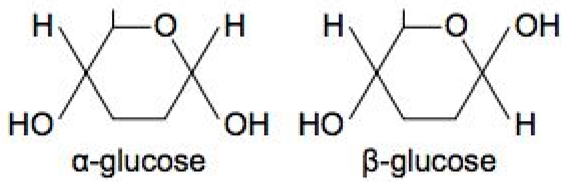
3.1.2 Carbohydrates

SPECIFICATION

- Monosaccharides are the monomers from which larger carbohydrates are made. Glucose, galactose and fructose are common monosaccharides.
- A condensation reaction between two monosaccharides forms a glycosidic bond.
- Disaccharides are formed by the condensation of two monosaccharides:
  - maltose is a disaccharide formed by condensation of two glucose molecules
  - sucrose is a disaccharide formed by condensation of a glucose molecule and a fructose molecule
  - lactose is a disaccharide formed by condensation of a glucose molecule and a galactose molecule.

SPECIFICATION CONTINUED

– Glucose has two isomers, α-glucose and β-glucose, with structures:



– Polysaccharides are formed by the condensation of many glucose units.
  - Glycogen and starch are formed by the condensation of α-glucose.
  - Cellulose is formed by the condensation of β-glucose.
– The basic structure and functions of glycogen, starch and cellulose.
– The relationship of structure to function of these substances in animal cells and plant cells.
– Biochemical tests using Benedict's solution for reducing sugars and non-reducing sugars and iodine/potassium iodide for starch.

Source: [AQA Spec]

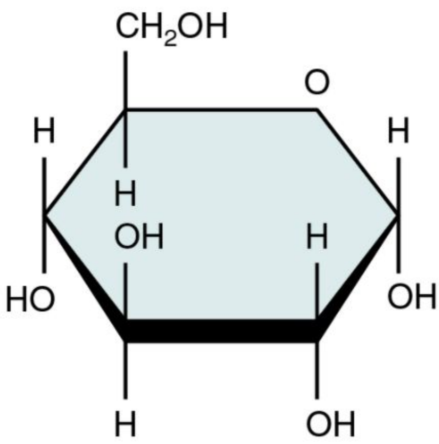
Monosaccharides and Disaccharides

Carbohydrates only contain the elements carbon, hydrogen and oxygen. They provide energy to the body, particularly through glucose - a simple sugar.

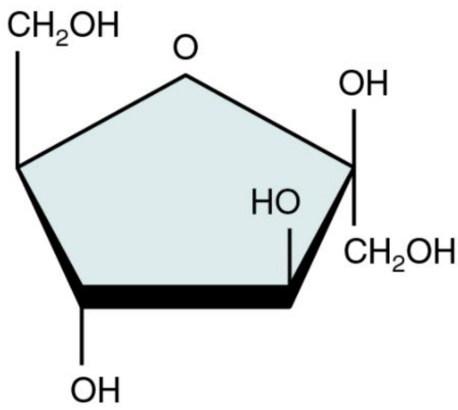
Carbohydrates have the formula $(CH_2O)_n$ where n is the number of carbons in the molecule.

Monosaccharides

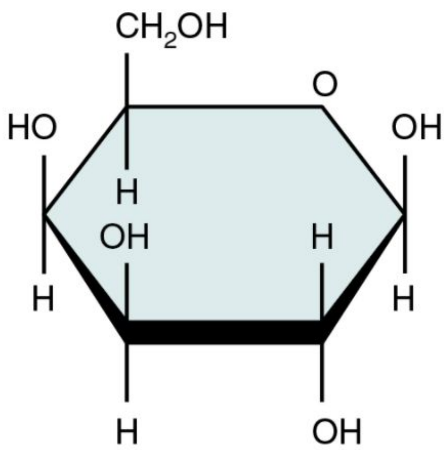
You need to know the structure of the three main monosaccharides: glucose, fructose, and galactose. **Learn to draw these in preparation of your exams**.



Glucose

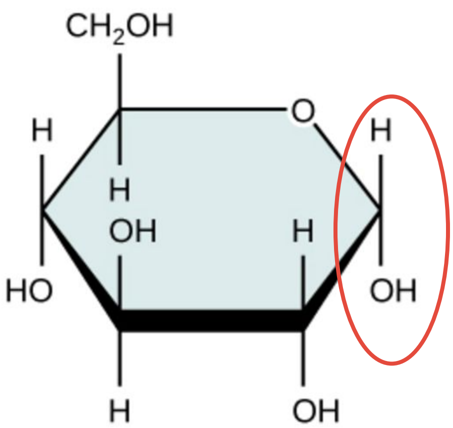


Fructose

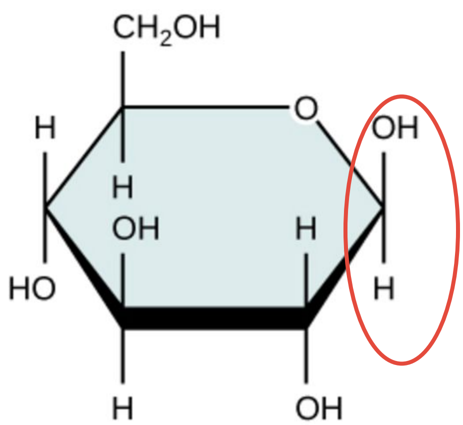


Galactose

More importantly, you also need to know the isomers of glucose, alpha and beta glucose (*note that the groups on the right are reversed*).



α Glucose



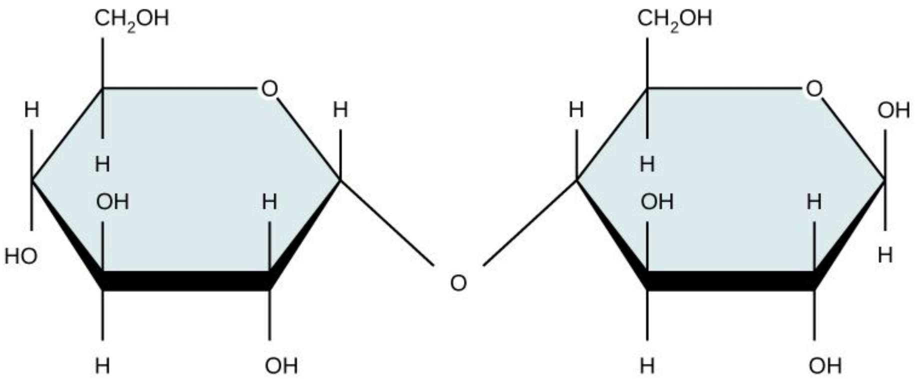
β Glucose

Disaccharides

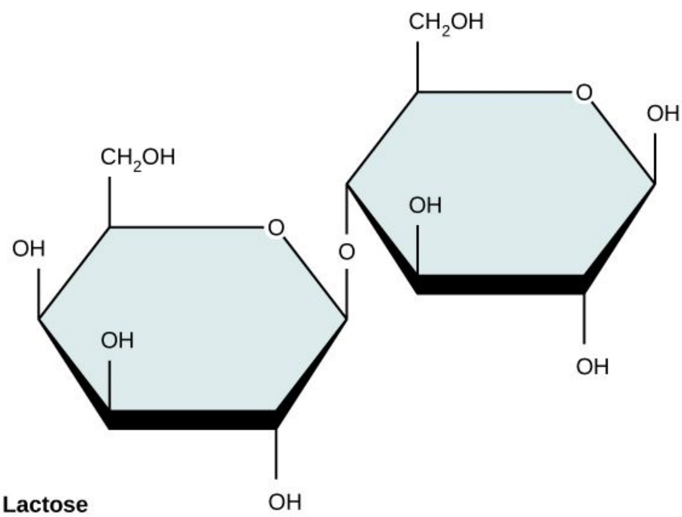
Disaccharides are formed when two monosaccharides are joined together by a glycosidic bond. This is a condensation reaction which involves the removal of a molecule of water (H2O).

The diagram below shows two glucose molecules joining together to form the disaccharide maltose. Because this bond is between carbon 1 of one molecule and carbon 4 of the other molecule it is called a 1-4 glycosidic bond. Bonds between other carbon atoms are possible, leading to different shapes, and branched chains.

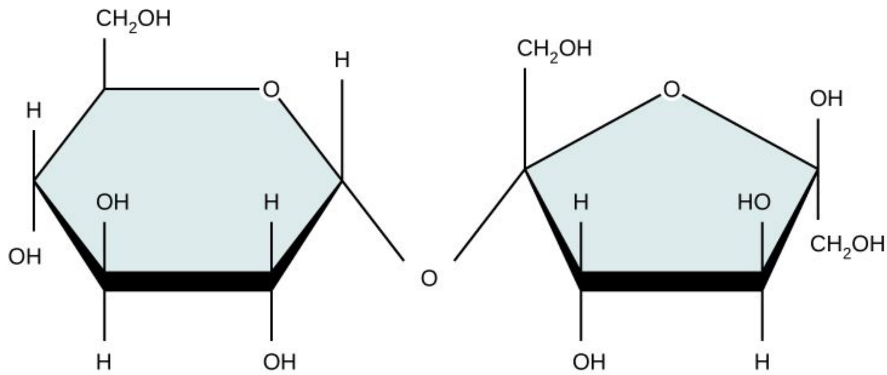
Three common disaccharides: **Sucrose** (Glucose + Fructose), **Lactose** (Glucose + Galactose), **Maltose** (Glucose + Glucose).



Maltose



Lactose



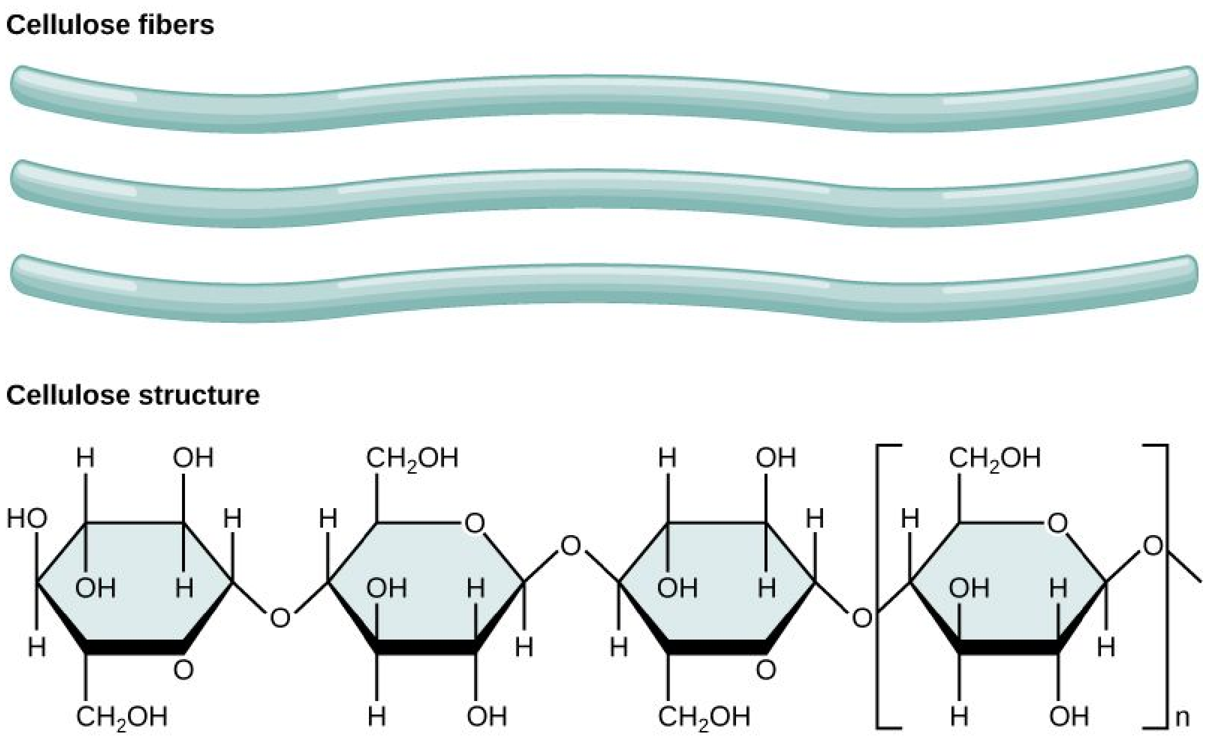
Sucrose

Polysaccharides: Cellulose, starch and glycogen

A long chain of monosaccharides that are linked by glycosidic bonds are known as a polysaccharide - *poly* meaning many.

Cellulose structure

- Cellulose is a polymer of β glucose - it's made of **long, unbranched** chains of **beta-glucose**.
- Condensation reactions link carbon atom 1 to carbon atom 4 on the next β glucose.
- The glucose subunits in the chain are oriented alternately upwards and downwards.
- The consequence of this is that the cellulose molecule is a **straight chain** rather than curved.



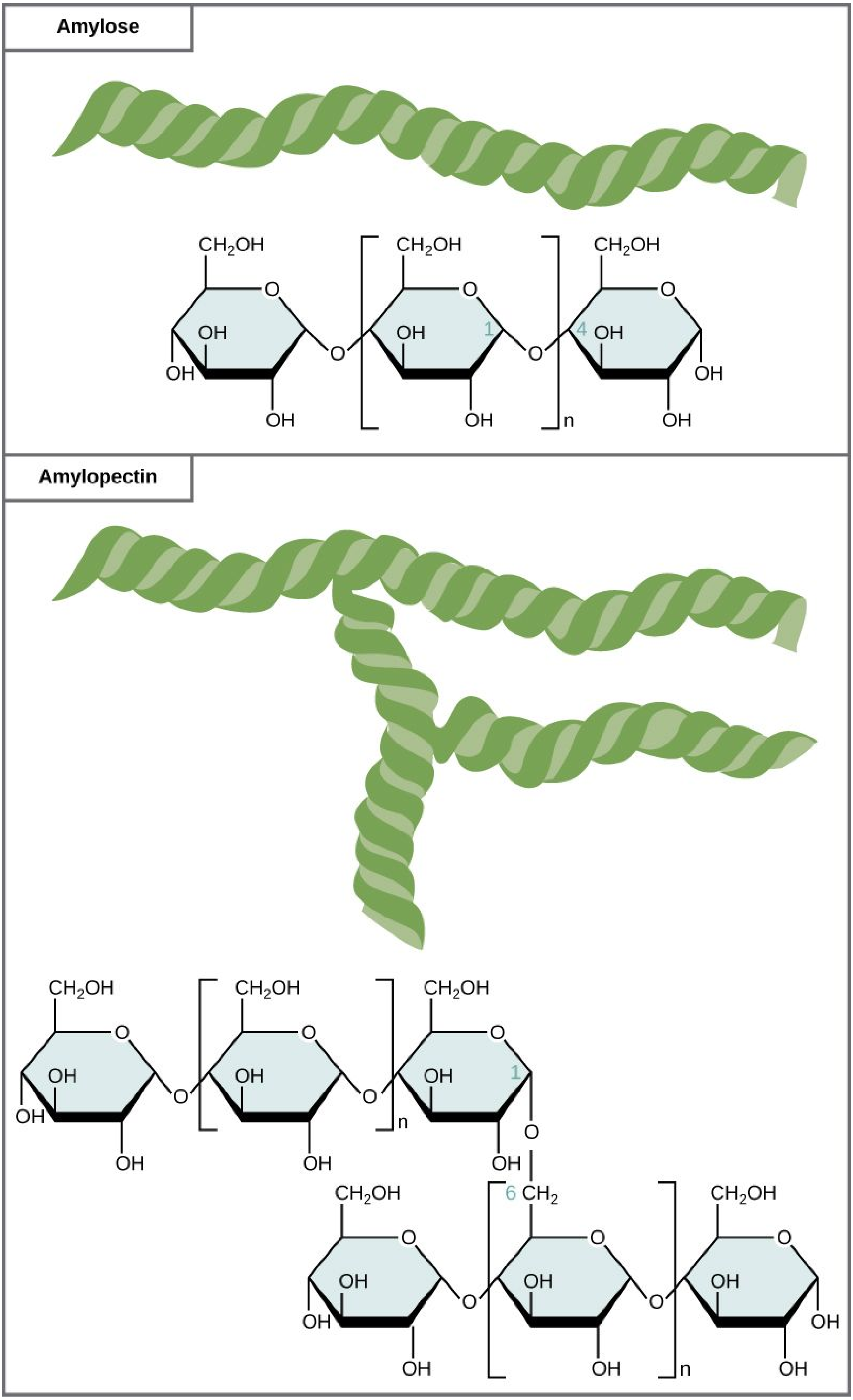
- The cellulose chains are linked together by hydrogen bonds to form strong fibres called cellulose microfibrils.
- Because of those fibres, the tensile strength of cellulose provides structural support for the cells (e.g the cell walls) and prevents plant cells from bursting - even under very high (water) pressure.

Starch structure

- Cells get their energy from **glucose**. Plants store excess glucose as **starch**.
- When a plant needs more glucose for energy, it will **break down** that starch to release the glucose.
- Starch is a mixture of two polysaccharides of alpha-glucose - **amylose** and **amylopectin**.
- Amylose is a long, **unbranched** chain of α-glucose. The angle of the glycosidic bonds give it a **coiled**, cylinder-like structure. This compact structure is good for storage because more glucose can be **stored in a small space**.
- Amylopectin is a long, **branched** chain of α-glucose. It has **side branches** which allow the enzymes that break the molecule down to access glycosidic bonds easily - meaning the glucose can be **released quickly**.
- Since starch is insoluble, water cannot enter the cells by **osmosis** - which makes it very good for **storage**.
- Condensation reactions link carbon atom 1 to carbon atom 4 on the next α-glucose.
- All the glucose molecules in starch can be orientated in the same way.
- The consequence of this is that the starch molecule is curved, rather than straight and the size of the molecule is not fixed.

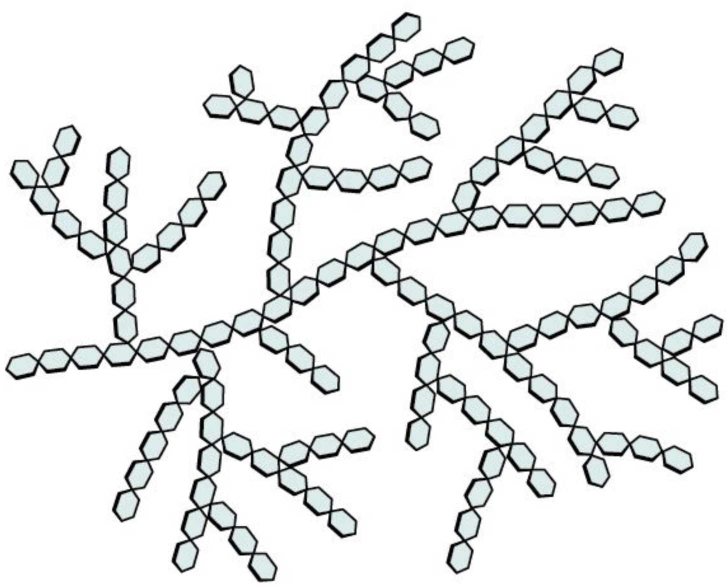
See next page for a diagram of **Amylose** and **Amylopectin**.

Diagram of Amylose and Amylopectin



Glycogen structure

- Glycogen is the main energy storage material in animals and is made by some fungi too.
- It's a polymer made from repeating glucose sub-units and varies in size, typically consisting of 30,000 units.
- Animals store excess glucose as glycogen - another polysaccharide of alpha-glucose. In humans, it is stored in the liver and some muscles.
- It's used in cells where large stores of dissolved glucose would cause osmotic problems.
- Glycogen has a similar structure to amylopectin but it has a lot more side branches. These extra branches mean the stored glucose can be released very quickly - something that is very important in animals.
- As a result of the branches, glycogen is very compact which makes it very good for energy storage.
- Glycogen does not affect the osmotic balance of cells - i.e. cause too much water to enter them.



Glycogen

Benedict's Test for Sugars

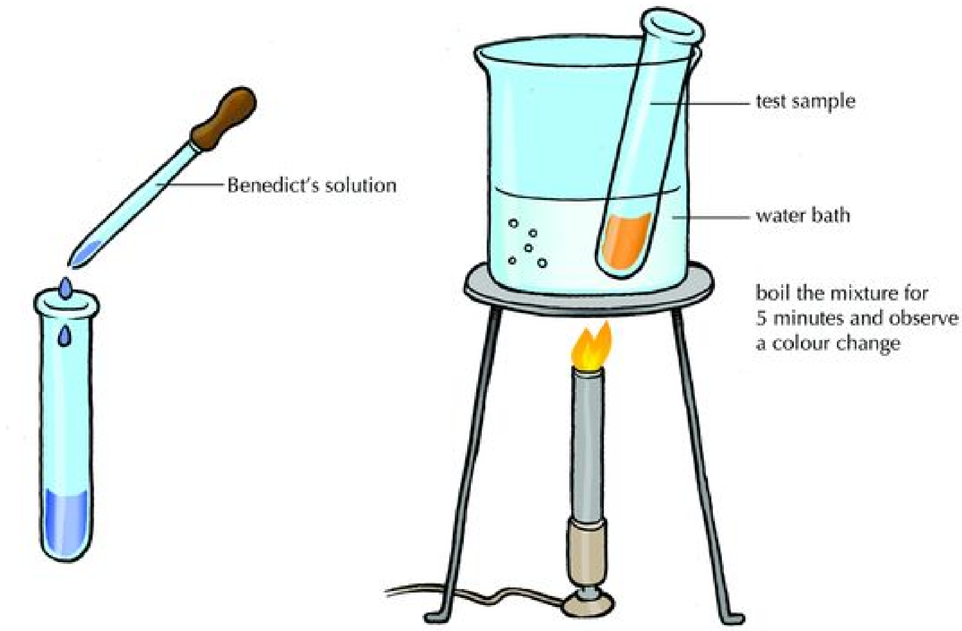
Sugar is a general term used to describe **monosaccharides** and **disaccharides**. All sugars can be classified as either **reducing** or **non-reducing**.

Testing for reducing sugars

- Reducing sugars include **all monosaccharides** (e.g glucose) and **some disaccharides** (e.g. maltose and lactose).
- Add **Benedict's reagent** (which is *blue*) to a sample and heat it in a water bath that boils the mixture for 5 minutes.
- If the test is positive, it will form a **coloured precipitate** (solid particles suspended in the solution).
- The higher the concentration of reducing sugar, the further the change of colour goes. You can use this to **compare the amount** of reducing sugars in different solutions.
- A more accurate way, though, is to filter the solution and **weigh the precipitate**.

The colour of the precipitate changes from:

None → Trace → Low → Moderate → High



Testing for non-reducing sugars

- If the result of reducing sugars is negative, there may still be non-reducing sugar present in the solution.
- To test for a non-reducing sugar (like sucrose) you first need to break them down into monosaccharides.
- Take a fresh sample of the solution and either heat it with diluted hydrochloric acid or hydrolyze using enzymes.
- You can then neutralise it with sodium hydrogencarbonate.
- Once you have done these, you can continue the Benedict's test in the same way you would for a reducing sugar.
- If the test is positive, it will form the coloured precipitate just the same as for a reducing sugar. If the test is negative, the solution stays blue and it means the solution does not contain any sugar (either reducing or non-reducing).

Iodine Test for Starch

Whenever you want to experiment on the digestion of starch and need to know if there is any left, you need the iodine test.

The test is very simple. Just add iodine dissolved in potassium iodide solution to the test sample.

If there is starch present, the sample changes from **brown-orange** to a dark **blue-black** colour.

Important: In your exams, make sure you always talk about “iodine dissolved in potassium iodide” and not just iodine alone.