

Water, carbohydrates and lipids

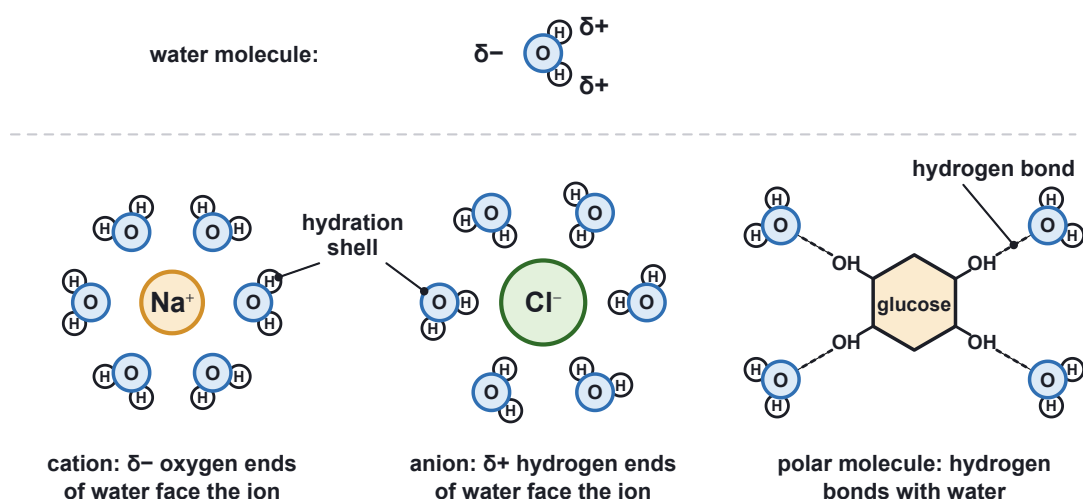
Revision notes · Water as a polar solvent, the structure of sugars, starch and glycogen, glycosidic and ester bonds, and the colour tests for sugars and starch.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Water, carbohydrates and lipids Spec 1.1-1.5

Water as a solvent in transport Spec 1.1

A water molecule (H_2O) has one oxygen atom bonded to two hydrogen atoms. Oxygen attracts the shared electrons more strongly than hydrogen does, so the oxygen end carries a small negative charge (δ^-) and each hydrogen end a small positive charge (δ^+). The molecule is overall neutral, but its charge is unevenly spread. This makes water a **dipole**, and a **polar** molecule.



Water is a dipole, so its charged ends surround ions and polar molecules and keep them **dissolved**.

Ions (for example Na^+ , Cl^- , HCO_3^-) and polar molecules (for example glucose, amino acids, urea) are attracted to the oppositely charged ends of water molecules. Water molecules cluster around each solute particle, separate it from its neighbours and keep it dispersed. The result is a **solution**, in which the solute particles move freely and can be carried along by the flow of the liquid.

Examples of dissolved substances transported in solution

Transport system	Substances carried in solution
Blood plasma	Glucose, amino acids, mineral ions, hydrogencarbonate ions, urea, hormones
Xylem sap in plants	Water with dissolved mineral ions
Phloem sap in plants	Sucrose and amino acids
Urine (excretion)	Urea and excess ions in solution

Non-polar molecules such as triglycerides and cholesterol are **hydrophobic**: they are not attracted to water, so they do not dissolve in blood plasma. They have to be carried in other ways (see lipoproteins, in the section on cholesterol, HDL and LDL).

Dipole	A molecule with a slightly positive end and a slightly negative end because its electrons are unevenly shared.
Solvent	A liquid in which other substances (solutes) dissolve to form a solution.

Exam tip: Link the dipole to the dissolving. Say that the charged ends of water molecules are attracted to ions or polar molecules and surround them. 'Water is polar' on its own does not earn the mark.

Monosaccharides, disaccharides and polysaccharides Spec 1.2

Carbohydrates contain carbon, hydrogen and oxygen. They are grouped by the number of sugar units in each molecule.

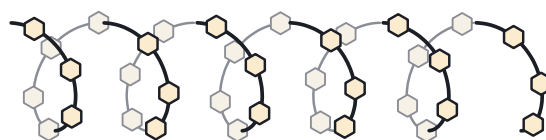
Three groups of carbohydrate			
Group	Size	Examples	Main features
Monosaccharide	One sugar unit (monomer)	Glucose, fructose, galactose (all $C_6H_{12}O_6$)	Small, soluble, sweet; glucose is the main respiratory substrate
Disaccharide	Two monosaccharides joined	Maltose, sucrose, lactose (all $C_{12}H_{22}O_{11}$)	Soluble, sweet; hydrolysed to monosaccharides before use
Polysaccharide	Many monosaccharides joined	Starch (amylose, amylopectin), glycogen	Large, insoluble, not sweet; hydrolysed to glucose when energy is needed

In **α -glucose**, the -OH group on carbon 1 sits below the ring. Starch and glycogen are both made only from α -glucose units. Fructose and galactose are isomers of glucose: they have the same formula but the atoms are arranged differently.

Starch and glycogen

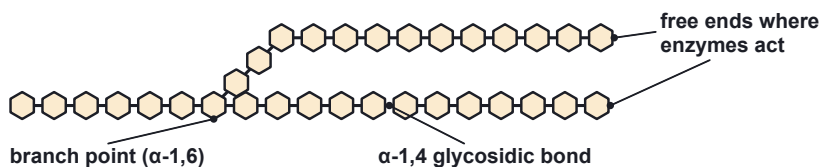
Comparing amylose, amylopectin and glycogen			
Feature	Amylose	Amylopectin	Glycogen
Found in	Plants (part of starch)	Plants (part of starch)	Animals (liver and muscle cells) and fungi
Monomer	α -glucose	α -glucose	α -glucose
Bonds	α -1,4 glycosidic only	α -1,4 and α -1,6 glycosidic	α -1,4 and α -1,6 glycosidic
Branching	Unbranched	Branched (a branch every 20 to 30 units)	Highly branched (a branch every 8 to 12 units)
Shape	Coiled into a helix	Branched, less tightly coiled	Very compact, granular
Role	Energy store	Energy store, hydrolysed quickly from many ends	Energy store, hydrolysed very quickly from many ends

Amylose

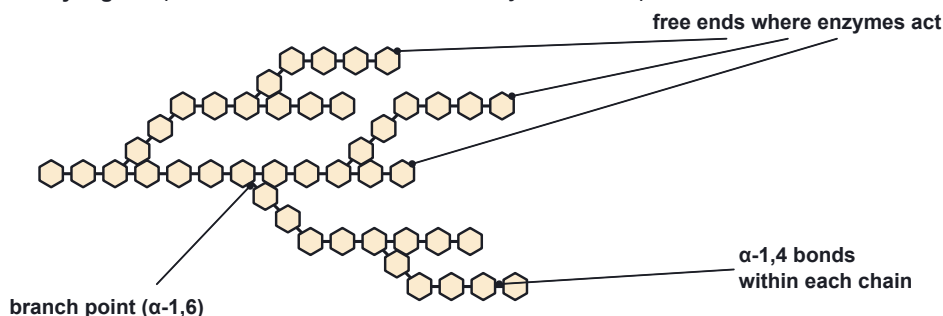


unbranched chain of α -glucose joined by α -1,4 glycosidic bonds, coiled into a helix

Amylopectin (a branch about every 20 to 30 glucose units)



Glycogen (more branched: a branch about every 8 to 12 units)



Amylose is unbranched and helical; amylopectin is branched; glycogen is **more highly branched**, so it has more free ends for enzymes.

How structure relates to role

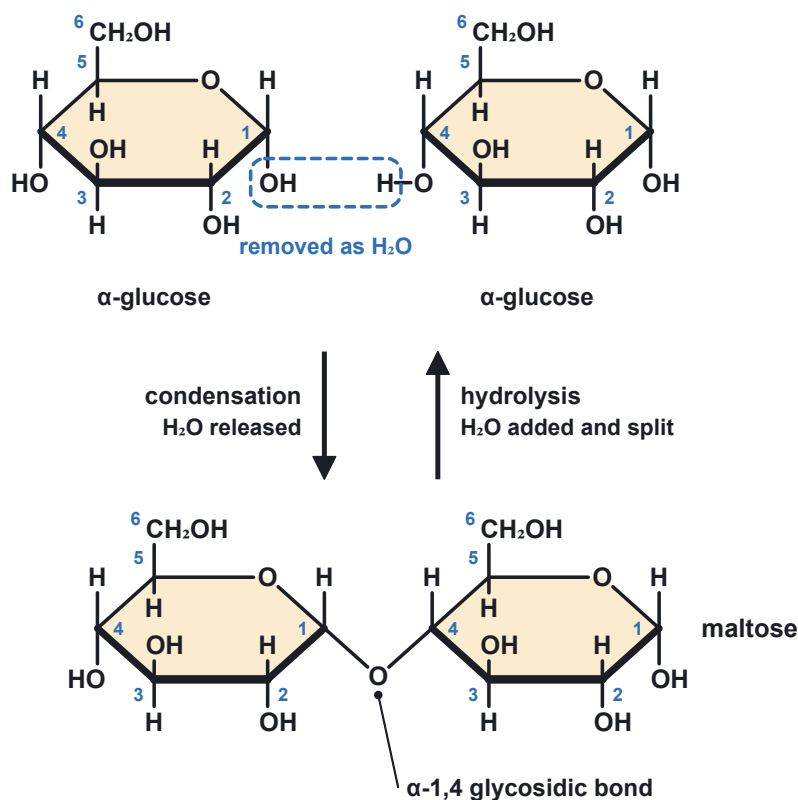
- Monosaccharides and disaccharides are small and soluble, so they are easily transported and glucose is quickly respired to release energy.
- Starch and glycogen are **insoluble** and too large to leave the cell, so they stay put as a store and do not change the water potential of the cell (no osmotic effect).
- The helical shape of amylose and the branching of amylopectin and glycogen make the molecules **compact**, so a large amount of glucose is stored in a small space.
- Branching gives many free ends. Enzymes can hydrolyse glucose from many ends at once, so glucose is released **rapidly**. This suits glycogen in animals, which have a high metabolic rate and need glucose quickly.

Common mistake: Starch is the plant store and glycogen is the animal store. Do not call glycogen 'animal starch' without saying it is more branched and so releases glucose faster.

Glycosidic bonds: condensation and hydrolysis Spec 1.4

In a **condensation reaction**, an -OH group on one monosaccharide and an -H on another are removed. They form a molecule of water, and the two sugars are joined by a C-O-C link called a **glycosidic bond**. In starch and glycogen the main chain is held together by α -1,4 glycosidic bonds (between carbon 1 of one glucose and carbon 4 of the next). Branches are made by α -1,6 glycosidic bonds.





Condensation forms an **α-1,4 glycosidic bond** and releases water; hydrolysis uses water to break it.

The disaccharides you need to know

Disaccharide	Made from	Found in
Maltose	Glucose + glucose	Germinating seeds; produced when starch is digested
Sucrose	Glucose + fructose	Sugar cane, sugar beet; the main sugar transported in phloem
Lactose	Glucose + galactose	Milk

A polysaccharide is made by repeating condensation many times. A chain of n monosaccharides contains $n - 1$ glycosidic bonds along the main chain, and $n - 1$ molecules of water are released when it forms.

Hydrolysis is the reverse reaction. A molecule of water is added across the glycosidic bond, which breaks it and releases the monosaccharides. In living organisms the reaction is catalysed by enzymes, for example amylase on starch and lactase on lactose.

Exam tip: Name the reaction and the bond, and say what happens to water. Condensation forms a glycosidic bond and releases water. Hydrolysis uses water to break the bond.

Core practical 1: Benedict's reagent and iodine solution Spec 1.3

Core practical: Core practical 1: use a semi-quantitative method with Benedict's reagent to estimate the concentration of reducing sugars, and with iodine solution to estimate the concentration of starch, using colour standards.

Semi-quantitative means the answer is an estimate from comparing colours, not an exact measurement. You make a set of **colour standards** (solutions of known concentration), treat them in exactly the same way as the unknown, and match the unknown to the closest standard. The reducing

sugars you meet are glucose, fructose, galactose, maltose and lactose. Sucrose and starch are not reducing sugars.

Method: reducing sugar with Benedict's reagent

1. Make colour standards from a stock solution of glucose (for example 2.0 % glucose) by dilution with distilled water, to give about five known concentrations plus a water-only blank.
2. Put the same volume of each standard (for example 2 cm³) into a labelled boiling tube. Do the same with the unknown solution.
3. Add the same volume of Benedict's reagent (for example 2 cm³) to every tube.
4. Heat all the tubes together in a water bath at the same temperature (a hot water bath, about 90 °C or above) for the same length of time (for example 3 minutes).
5. Remove the tubes, let any precipitate settle and compare the colours against a white background. Record colours: blue (none), green, yellow, orange, brick-red (highest concentration).
6. Match the unknown to the closest colour standard and state the estimated concentration. Repeat the unknown at least three times.

Method: starch with iodine solution

Prepare standards of starch (for example 0.0 to 1.0 %). Put the same volume of each standard and the unknown in a spotting tile or tube, add the same number of drops of iodine solution (iodine in potassium iodide) and mix. No heating is needed. The colour goes from yellow-brown (no starch) to **blue-black** (high starch). Match the unknown to the closest standard.

Variables in the Benedict's test

Type	Variable
Independent	Concentration of glucose solution (the standards)
Dependent	Colour of the solution after heating, judged against standards
Controlled	Volume of sample, volume of Benedict's reagent, water bath temperature, heating time, same batch of reagent, same background and lighting for comparing colours

Risks: hot water and hot glassware can scald, so use a water bath, tongs and heat-resistant gloves rather than heating the tubes directly. Benedict's reagent contains copper(II) sulfate and can irritate the eyes, so wear eye protection. Iodine solution stains skin and clothing.

Limitations: judging colour by eye is subjective. It improves reliability to use the same observer, a white background, more standards at smaller concentration steps and repeats. A colorimeter measuring the colour of the filtrate would make the method quantitative.

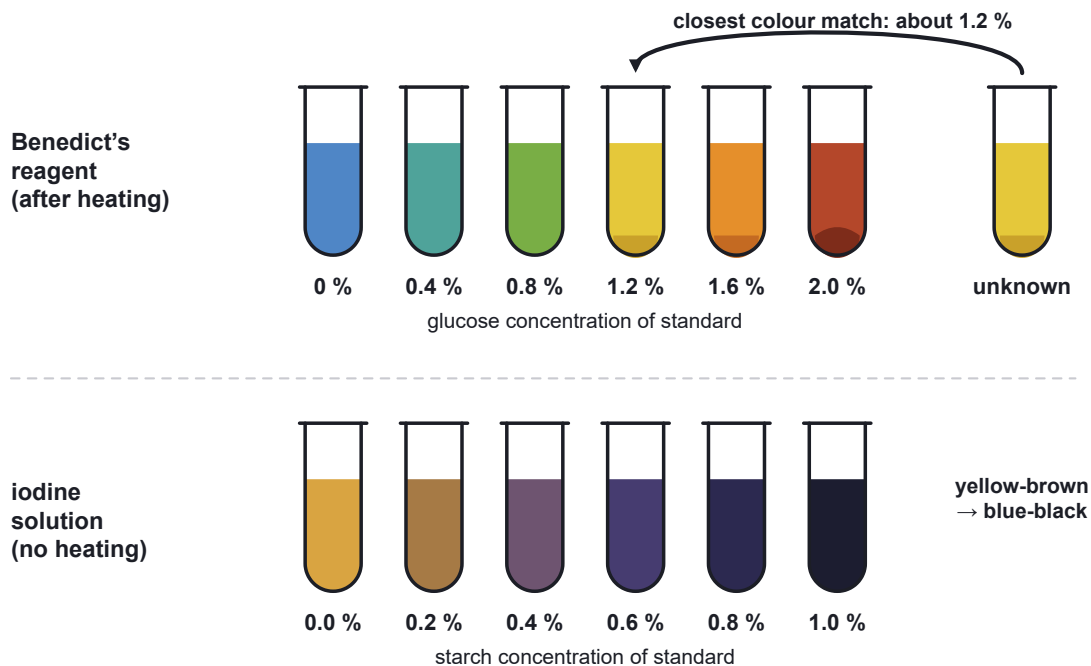
Making a colour standard by dilution

You have a 2.0 % glucose stock solution. Describe how to make 10 cm³ of a 0.4 % standard.

1. Dilution factor = stock concentration ÷ required concentration = 2.0 ÷ 0.4 = 5
2. Volume of stock needed = final volume ÷ dilution factor = 10 ÷ 5 = 2 cm³
3. Volume of distilled water needed = 10 – 2 = 8 cm³

Answer: Mix 2 cm³ of the 2.0 % stock with 8 cm³ of distilled water.

Maths skill: Use concentration × volume to plan dilutions: required volume of stock = (required concentration ÷ stock concentration) × final volume. Always show the working and give units.



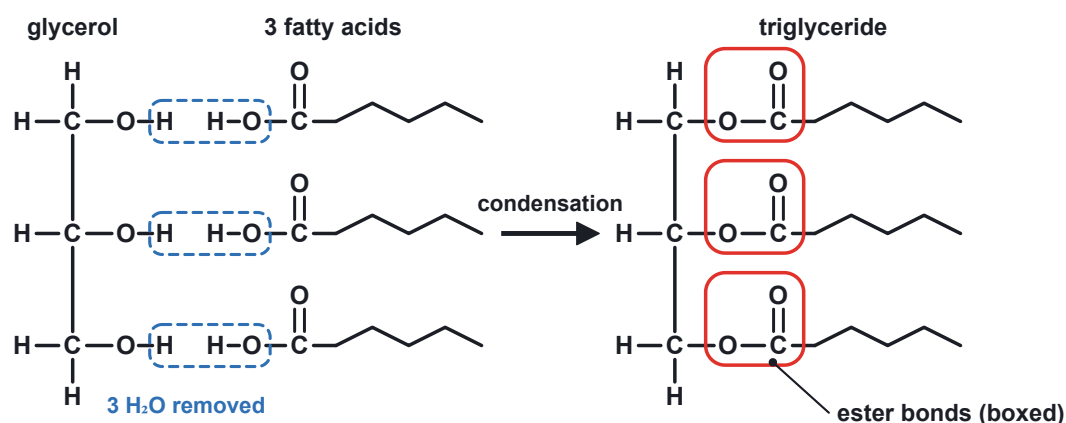
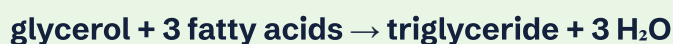
Core practical 1: match the unknown to the **closest colour standard** to estimate its concentration.

Triglycerides and ester bonds Spec 1.5(i)

Lipids contain carbon, hydrogen and oxygen, but far less oxygen than carbohydrates. They are **hydrophobic** and do not dissolve in water. Triglycerides are the most common lipids in the diet and in fat stores.

- **Glycerol** is a small molecule with three carbon atoms, each carrying an -OH (hydroxyl) group.
- A **fatty acid** has a carboxyl group (-COOH) at one end and a long hydrocarbon chain (R) of typically 14 to 20 carbon atoms.

In each condensation reaction, the -OH of glycerol and the -OH of the carboxyl group of a fatty acid react. A molecule of water is removed and an **ester bond** (-COO-) forms between them. This happens three times, once at each -OH group of glycerol, so three water molecules are released. The three fatty acids in a triglyceride can be the same or different.



Three condensation reactions release **three water molecules** and form three ester bonds.

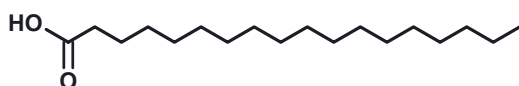
Hydrolysis of the ester bonds (catalysed by lipase) uses three water molecules and releases glycerol and three fatty acids.

Exam tip: The bond is an ester bond, not a glycosidic bond. Quote the numbers: three fatty acids, three ester bonds, three molecules of water.

Saturated and unsaturated lipids Spec 1.5(ii)

Saturated and unsaturated lipids compared		
Feature	Saturated	Unsaturated
C=C double bonds in the hydrocarbon chain	None: every carbon holds the maximum number of hydrogen atoms	One (monounsaturated) or more than one (polyunsaturated)
Shape of the chain	Straight	Bent (kinked) at each double bond
Packing of molecules	Pack closely together	Pack less closely
Melting point	Higher, so usually solid at room temperature	Lower, so usually liquid at room temperature
Typical sources	Butter, lard, animal fats	Olive oil, sunflower oil, oily fish

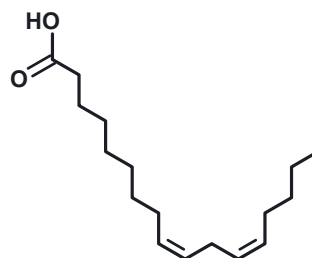
Saturated: no C=C, straight chain



Monounsaturated: one C=C, one bend



Polyunsaturated: two or more C=C, more bends



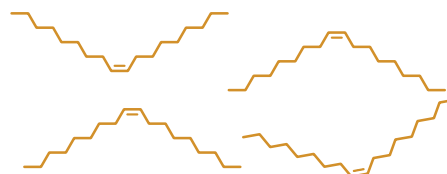
Each chain has 18 carbons; C1 is the carboxyl carbon (–COOH).

Straight chains pack tightly



solid fat (higher melting point)

Bent chains pack loosely



liquid oil (lower melting point)

A C=C double bond puts a kink in the chain, so unsaturated chains pack less closely and melt at a lower temperature.

Because straight chains pack closely, there are more intermolecular attractions between them, so more energy is needed to separate the molecules. This explains why saturated fats have a higher melting point than unsaturated oils.

Health link: diets high in saturated fat tend to raise the concentration of low-density lipoprotein (LDL) cholesterol in the blood, which raises the risk of cardiovascular disease (see the section on dietary risk factors).

Common mistake: Unsaturated means at least one C=C double bond in the hydrocarbon chain. Do not write 'unsaturated fats have no hydrogen' or confuse the term with the number of ester bonds.

Quick check

- 1 . What is a dipole?
- 2 . Name the two types of bond in amylopectin.
- 3 . Which two monosaccharides join to make sucrose?
- 4 . How many water molecules are released when a triglyceride forms?
- 5 . What colour change shows starch with iodine solution?

Quick check answers

Water, carbohydrates and lipids

1. A molecule with a slightly positive end and a slightly negative end because its electrons are shared unevenly.
2. α -1,4 glycosidic bonds (main chain) and α -1,6 glycosidic bonds (branch points).
3. Glucose and fructose.
4. Three, one for each ester bond formed.
5. Yellow-brown to blue-black.