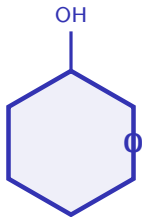


Biological Molecules

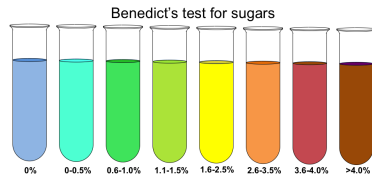
A-Level Biology ■ Topic 2

A-Level Biology



What we will cover

- 1 Food tests
- 2 Carbohydrates
- 3 Polysaccharides
- 4 Lipids
- 5 Proteins
- 6 Water



Benedict's colour scale



Food tests

Benedict's

reducing sugar → brick-red

iodine

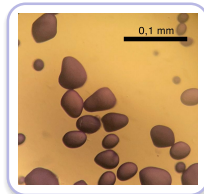
starch → blue-black

emulsion

lipid → white emulsion

biuret

protein → purple

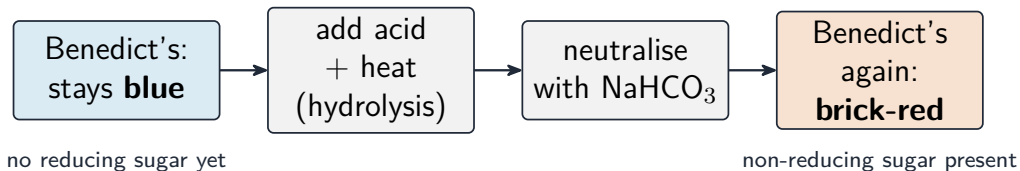


Starch grains

Testing for a non-reducing sugar

A **non-reducing sugar** (sucrose) gives a negative Benedict's.

Hydrolyse it first with acid & heat, neutralise, then re-test – a brick-red shows it was present.



Semi-quantitative Benedict's test

The normal Benedict's test only tells you “yes or no”.

- the **time to the first colour change** (more sugar changes colour faster), or
- comparing the final colour to your set of colour standards.

Making Benedict's test semi-quantitative

the plain test

tells you only **yes or no** – reducing sugar present, or not

semi-quantitative

gives a rough **amount**

the method

heat, then let the precipitate **stand and settle**, and compare the colour or filter and dry the precipitate to weigh it

colour order

blue → green → yellow → orange → brick red, as the **concentration** rises

more precise

filter off the precipitate and measure the **remaining blue** with a colorimeter

non-reducing sugar

first boil with **hydrochloric acid**, then neutralise, then test – the acid hydrolyses it

“Semi-quantitative” means comparing against a colour standard. It is not a measurement, and the exam expects you to say so.

Standardising a colour test

Standardise first

You **standardise** the test by running it on solutions of known **concentration** and recording the result for each.

Then compare

An unknown is read against that series – which turns a colour into a number, with limits you can state.

Better still

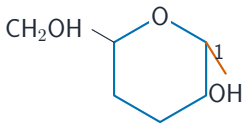
A colorimeter measures the transmission instead of the eye judging it, removing the observer from the measurement.

Semi-quantitative means the comparison is real but the scale is coarse. Say which, and say why, when you evaluate a method.

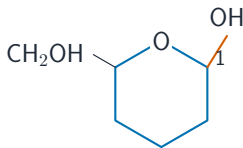


Carbohydrates and the two glucose forms

α -glucose



β -glucose



only carbon 1 differs: the OH points **down** in α , **up** in β

Monosaccharide (glucose) $\rightarrow$
disaccharide $\rightarrow$
polysaccharide .

The two ring forms differ only at carbon 1:
—OH points **down** in α -**glucose** α -, **up** in β -**glucose** β - — deciding which polymer it builds.

Monomers, polymers and macromolecules

- a **monomer** is a small molecule that is a single unit.
- a **polymer** is a long molecule made of many monomers joined together.
- a **macromolecule** is any very large molecule.
- a **monosaccharide** is a single sugar unit, such as **glucose** and fructose.

Joining and breaking sugars

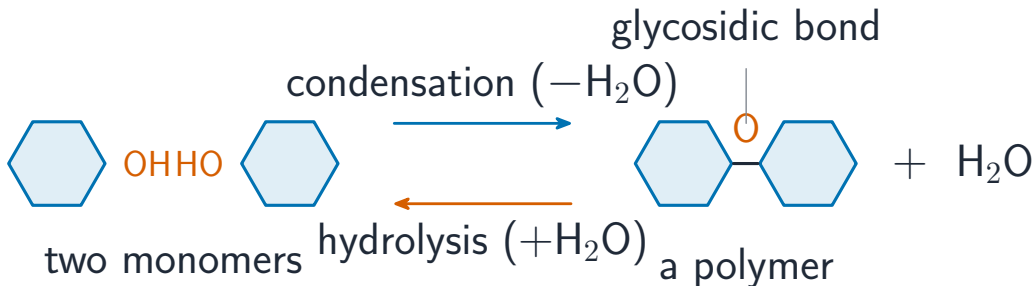
Monomers are joined by strong **covalent bonds** .

When two sugars join, a **glycosidic bond** forms between them.

Condensation and hydrolysis

Two sugars join by a **glycosidic bond** .

- **condensation** – removes water to join
- **hydrolysis** – adds water to split



Polysaccharides – shape fits the job

- **starch** (**amylose** coil + **amylopectin** branched) – plant store
- **glycogen** – animal store, more branched
- **cellulose** – straight β chains $\rightarrow$ strong cell wall



amylose
(coiled)



amylopectin
(branched)



glycogen
(many branches)



cellulose
(straight chains)

Why these molecules suit their jobs

three sugar sizes

monosaccharide (one unit), disaccharide (two), polysaccharide (many)

starch and glycogen

compact, **insoluble** – so they do not leave the cell – and they do not change the cell's water potential

triglycerides

release about **twice** the energy per gram of carbohydrate, are insoluble, and give **insulation** and protection

fibrous proteins

long parallel **fibres**, insoluble, structural – collagen and keratin

globular proteins

folded into a compact ball, soluble, functional – enzymes and haemoglobin

disulfide bonds

strong covalent links holding tertiary structure, alongside hydrogen and ionic bonds

Every “why is it suitable” answer pairs a **property** with the **job**. Insoluble because it must stay put; compact because space is limited.

Shape fits job, molecule by molecule

Starch and glycogen Compact, **insoluble** (so they stay in the cell), and they do not change the **water potential**, so they pull no water in by **osmosis**.

Cellulose Many straight chains lie side by side, held by hydrogen bonds into strong bundles called **microfibrils**.

Disaccharides A **disaccharide** is two units joined – **maltose** and **sucrose**.

Haemoglobin At the centre of each haem group is an **iron** atom, and that is where one oxygen molecule binds.

The four families are **carbohydrates**, **lipids**, **proteins** and **nucleic acids** – and every one is a chain of repeated units.

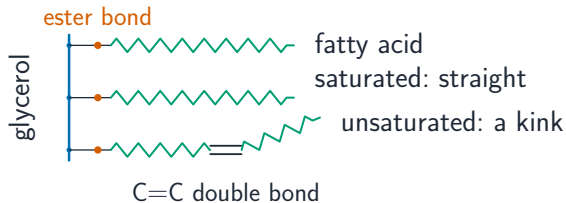


Triglycerides

A **triglyceride** : one **glycerol** + three **fatty acids** by **ester bonds** .

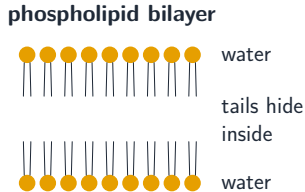
- **saturated** – no double bonds (solid)
- **unsaturated** – kinked (liquid)

A rich energy store – twice the energy per gram.



3 ester bonds form $\rightarrow$ 3 H_2O removed (condensation)

Phospholipids

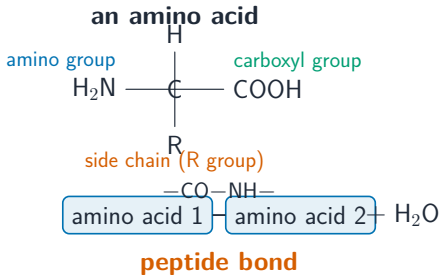


A **phospholipid** has a **hydrophilic phosphate** head and two **hydrophobic** tails.

Heads face the water, tails hide inside – forming the **bi-layer** of every cell membrane.



Amino acids and the peptide bond



condensation removes one water for each peptide bond

Every **amino acid** has an **amino group** , a **carboxyl group** , an H and a variable **R group** . Two join by a **peptide bond** (condensation) into a **polypeptide** .

The four levels of protein structure



- **primary** – the amino-acid order
- **secondary** – α -helix & β -sheet
- **tertiary** – the folded 3-D shape
- **quaternary** – several chains

Globular (haemoglobin) vs **fibrous** (collagen).

The four levels, and what holds each

Primary structure

The **primary structure** is the **order** of amino acids in the chain – and it decides everything that follows.

Secondary structure

The **secondary structure** : local shapes, the α -helix and the β -pleated sheet, held by hydrogen bonds.

Tertiary structure

The whole chain folded into one 3D shape, held by hydrogen bonds, ionic bonds, disulfide bridges and hydrophobic interactions.

Quaternary structure

Quaternary structure : two or more polypeptide chains joined into one protein – haemoglobin's four.

The amino acid itself

A central carbon with an **amino group** ($-\text{NH}_2$), a **carboxyl group** ($-\text{COOH}$), a hydrogen, and a variable **side chain**.

Only the side chains differ, and only the side chains do the bonding – which is why the sequence fixes the shape.

What holds a protein in shape

hydrogen bonds

many weak bonds between backbone or R groups – individually feeble, collectively decisive

hydrophobic interactions

non-polar R groups cluster inward, away from water

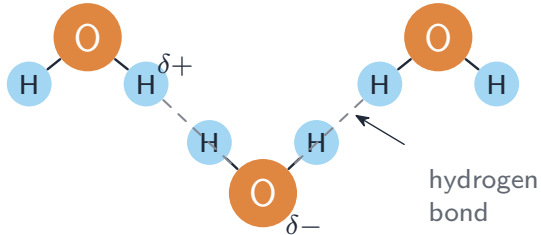
ionic bonds & disulfide

between charged R groups; the disulfide bridge is a true covalent link

Globular proteins fold into a rounded, usually **soluble** shape and *do* jobs – enzymes, haemoglobin. Fibrous ones like **collagen** – three chains wound into a rope – give *structure* to skin, **tendons** and bone.



Water



Water is **polar** , so molecules attract by **hydrogen bonds** . This explains:

- a good **solvent**
- high **specific heat capacity** – steady temperature
- high **latent heat** – cooling by evaporation

The properties of water that matter to life

solvent action

many substances dissolve in it – which lets reactions happen and lets substances be transported

high specific heat capacity

so cells and habitats change temperature slowly

latent heat of vaporisation

a lot of energy is needed to **evaporate** water, so evaporation **cools** effectively – sweating, transpiration

cohesion

water molecules stick together, giving the unbroken column in xylem and surface tension

density of ice

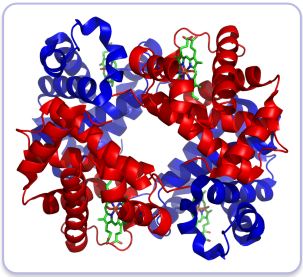
ice is **less dense**, so it floats and insulates the water beneath

a metabolite

water is a **reactant** in hydrolysis and in photosynthesis, not only a medium

Every one of these follows from **hydrogen bonding** between polar molecules. Name the cause before listing the consequences.

Haemoglobin – a globular protein



A real haemoglobin molecule, worked out from X-ray data. Count them: two alpha chains (red), two beta chains (blue), and one green haem group held in each – so four oxygen molecules in total

Exam tips

- Learn each **food test** as reagent + positive result + colour change (Benedict's → brick-red; iodine → blue-black; biuret → purple; emulsion → white).
- Benedict's detects **reducing** sugars; for a non-reducing sugar you must **hydrolyse with acid first**, then re-test.
- Name the bond precisely: **glycosidic** (carbohydrates), **ester** (lipids), **peptide** (proteins) – all made by **condensation** (water removed).
- Link structure to function: cellulose (straight chains, H-bonds → strong), glycogen/starch (branched/coiled → compact store).
- For proteins, name the bond at each level: primary (peptide), secondary (hydrogen), tertiary (R-group interactions), quaternary.



Worked example – identifying a molecule

A sample gives a purple biuret result and stays blue with Benedict's. After boiling with acid it now gives brick-red. Explain.

- Purple biuret $\Rightarrow$ **protein present** (peptide bonds).
- Benedict's blue at first $\Rightarrow$ **no reducing sugar**.
- Boiling with acid **hydrolyses glycosidic bonds**, splitting a non-reducing sugar into its monomers.
- Brick-red after $\Rightarrow$ a **non-reducing sugar** (e.g. sucrose) was there all along.

Neutralise before the second Benedict's, or the acid stops it working.
Blue $\rightarrow$ red only after hydrolysis = **non-reducing sugar**.

Topic 2 – key takeaways

1

Carbohydrates

α vs β glucose; condensation joins them

2

Polysaccharides

starch & glycogen store; cellulose supports

3

Lipids

triglycerides store energy;
phospholipids form membranes

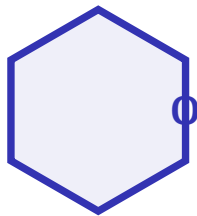
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Proteins

four structure levels; shape fits function

Check yourself

- 1 Which test detects protein, and its colour?
- 2 Which bond joins two monosaccharides?
- 3 Cellulose is made of which glucose form?
- 4 Which part of a phospholipid is hydrophilic?



Answers 1. biuret → purple 2. a glycosidic bond 3. β -glucose 4. the phosphate head