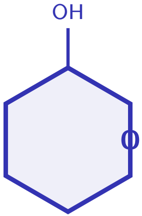
Biological Molecules

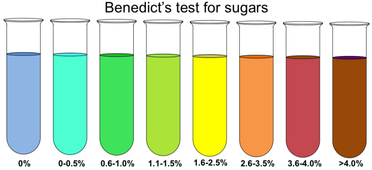
A-Level Biology ▪ Topic 2

A-Level Biology



What we will cover

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



Benedict's colour scale

1 Food tests

Food tests

Benedict's

reducing sugar 还原糖 → brick-red

iodine

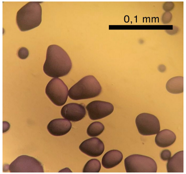
starch 淀粉 → blue-black

emulsion

lipid 脂质 → white emulsion

biuret 双缩脲

protein 蛋白质 → purple



Starch grains

Testing for a non-reducing sugar

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

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

Benedict's: stays **blue** → add acid + heat (hydrolysis) → neutralise with $NaHCO_3$ → Benedict's again: **brick-red**

no reducing sugar yet — non-reducing sugar 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 半定量	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 浓度** rises
more precise	filter off the precipitate and measure the remaining blue with a colorimeter
non-reducing sugar	first boil with **hydrochloric acid 盐酸**, 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.

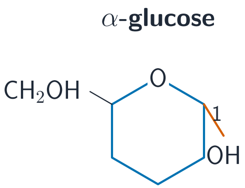
Standardising a colour test

Standardise first	You **standardise** 标准化 the test by running it on solutions of known **concentration** 浓度 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.

2 Carbohydrates

Carbohydrates and the two glucose forms



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

Monosaccharide 单糖 (glucose) $\to$ **disaccharide** 二糖 $\to$ **polysaccharide** 多糖.

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

Monomers, polymers and macromolecules

- a **monomer 单体** is a small molecule that is a single unit.
- a **polymer 聚合物** is a long molecule made of many monomers joined together.
- a **macromolecule 大分子** is any very large molecule.
- a **monosaccharide 单糖** is a single sugar unit, such as **glucose 葡萄糖** and fructose.

Joining and breaking sugars

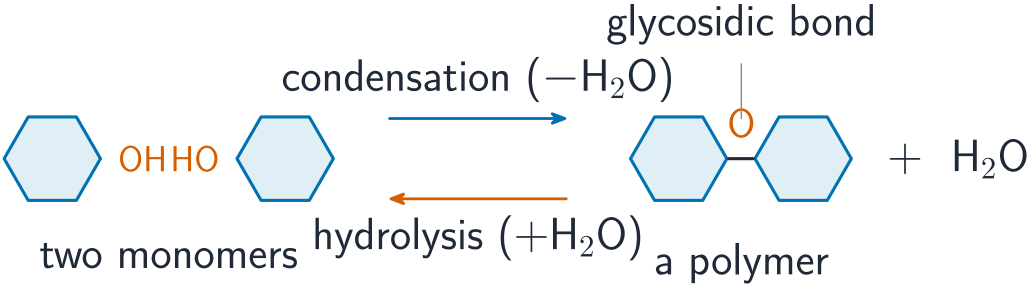
Monomers are joined by strong **covalent bonds 共价键**.

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

Condensation and hydrolysis

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

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



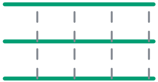
Polysaccharides – shape fits the job

- **starch** 淀粉 (**amylose** 直链淀粉 coil + **amylopectin** 支链淀粉 branched) – plant store
- **glycogen** 糖原 – animal store, more branched
- **cellulose** 纤维素 – 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 不溶** – 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 隔热** and protection
fibrous proteins 纤维状蛋白	long parallel **fibres 纤维**, insoluble, structural – collagen and keratin
globular proteins	folded into a compact ball, soluble, functional – enzymes and haemoglobin
disulfide bonds 二硫键	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** 不溶的 (so they stay in the cell), and they do not change the **water potential** 水势, so they pull no water in by **osmosis** 渗透.
Cellulose	Many straight chains lie side by side, held by hydrogen bonds into strong bundles called **microfibrils** 微纤维.
Disaccharides	A **disaccharide** 二糖 is two units joined – **maltose** 麦芽糖 and **sucrose** 蔗糖.
Haemoglobin	At the centre of each haem group is an **iron** 铁 atom, and that is where one oxygen molecule binds.

The four families are **carbohydrates** 碳水化合物, **lipids** 脂质, **proteins** 蛋白质 and **nucleic acids** 核酸 – and every one is a chain of repeated units.

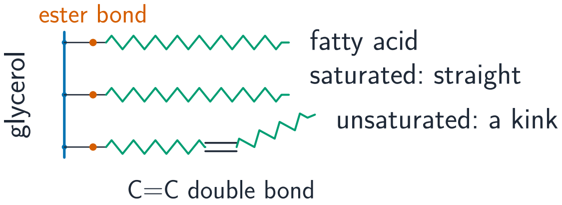
3 Lipids

Triglycerides

A **triglyceride** 甘油三酯: one **glycerol** 甘油 + three **fatty acids** 脂肪酸 by **ester bonds** 酯键.

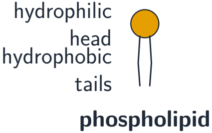
- **saturated** 饱和 – no double bonds (solid)
- **unsaturated** 不饱和 – kinked (liquid)

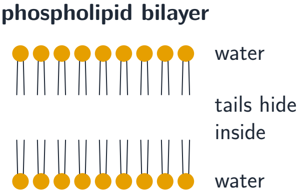
A rich energy store – twice the energy per gram.



3 ester bonds form → 3 H_2O removed (condensation)

Phospholipids



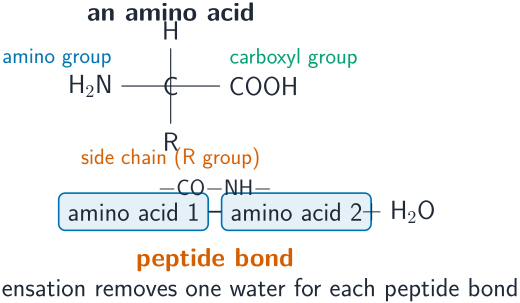


A **phospholipid** 磷脂 has a **hydrophilic** 亲水 **phosphate** 磷酸 head and two **hydrophobic** 疏水 tails.

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

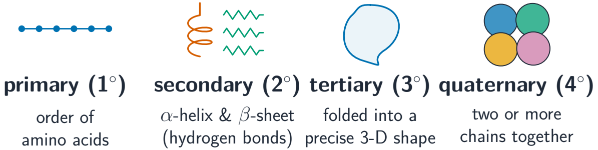
4 Proteins

Amino acids and the peptide bond



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

The four levels of protein structure



- **primary** 一级结构 – the amino-acid order
- **secondary** 二级结构 – α-**helix** 螺旋 & β-**sheet** 折叠片
- **tertiary** 三级结构 – the folded 3-D shape
- **quaternary** 四级结构 – several chains

Globular 球状蛋白质 (haemoglobin) vs **fibrous** 纤维状蛋白质 (collagen).

The four levels, and what holds each

Primary structure	The **primary structure** 一级结构 is the order of amino acids in the chain – and it decides everything that follows.
Secondary structure	The **secondary structure** 二级结构: 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** 四级结构: two or more polypeptide chains joined into one protein – haemoglobin's four.
The amino acid itself	A central carbon with an **amino group** 氨基 ($-NH_2$), a **carboxyl group** 羧基 ($-COOH$), a hydrogen, and a variable **side chain** 侧链.

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

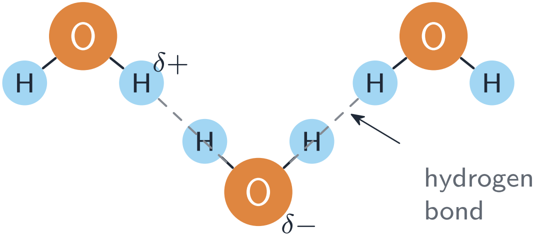
What holds a protein in shape

hydrogen bonds 氢键	many weak bonds between backbone or R groups – individually feeble, collectively decisive
hydrophobic interactions 疏水作用	non-polar R groups cluster inward, away from water
ionic bonds 离子键 & disulfide 二硫键	between charged R groups; the disulfide bridge is a true covalent link

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

5 Water

Water



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

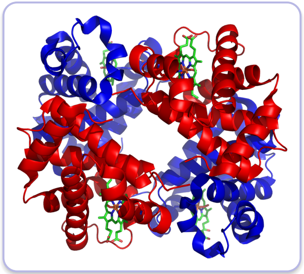
- a good **solvent** 溶剂
- high **specific heat capacity** 比热容 – steady temperature
- high **latent heat** 汽化潜热 – cooling by evaporation

The properties of water that matter to life

solvent 溶剂 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 汽化潜热	a lot of energy is needed to **evaporate 蒸发** 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 $\rightarrow$ brick-red; iodine $\rightarrow$ blue-black; biuret $\rightarrow$ purple; emulsion $\rightarrow$ 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 $\rightarrow$ strong), glycogen/starch (branched/coiled $\rightarrow$ compact store).
- For proteins, name the bond at each level: primary (peptide), secondary (hydrogen), tertiary (R-group interactions), quaternary.

6 Recap

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

Neutralise before the second Benedict's, or the acid stops it working. Blue → 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

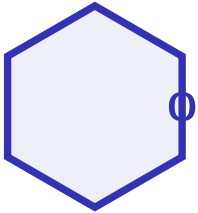
triglycerides store energy; phospholipids form membranes

4 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 $\rightarrow$ purple **2.** a glycosidic bond **3.** β-glucose **4.** the phosphate head