

Biological molecules

A-Level Biology 9700 · Topic 2 revision notes

Everything from the 5 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Testing for biological molecules

2. Carbohydrates

3. Lipids

4. Proteins

5. Water

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1 Testing for biological molecules

Syllabus 2.1

Each test pairs a reagent with a colour change. **Benedict's** (heat) goes from blue to a **brick-red precipitate** with reducing sugars, through green, yellow and orange as the sugar concentration rises. A **non-reducing sugar** such as sucrose gives a negative Benedict's until it is **hydrolysed by boiling with dilute acid** and then neutralised. **Iodine** in potassium iodide turns blue-black with starch, the **emulsion test** gives a milky-white emulsion with lipids, and **biuret** turns lilac with proteins. Standardise the Benedict's test and compare with colour standards, and it becomes a way to **estimate concentration**.

Benedict's colour standards (glucose concentration)

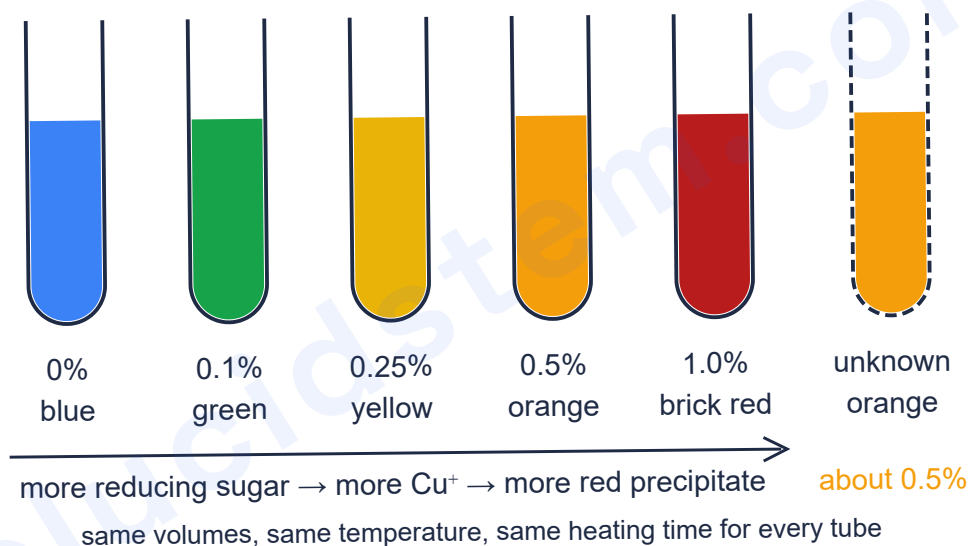


Fig. 1: a set of Benedict's colour standards made from known glucose concentrations, used to estimate the concentration of an unknown

Reagent, method, both colours.

- ✓ **Benedict's:** heat; blue → green, yellow, orange, brick red.
- ✓ **Non-reducing sugar:** negative Benedict's, boil with HCl, neutralise, retest.
- ✓ **Iodine:** orange-brown → blue-black.
Biuret: blue → lilac.
- ✓ **Emulsion:** ethanol, then water; milky white means lipid.

Watch out!

Benedict's must be **in excess** for the semi-quantitative test. If all the Cu^{2+} is used up, every concentration above a certain value gives the same brick red, and the test can no longer tell them apart.

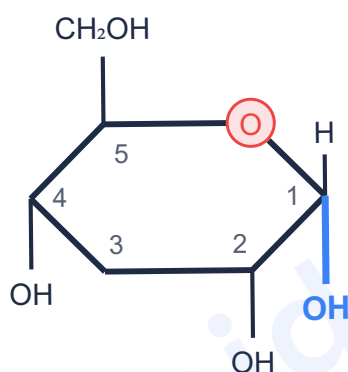
If the first Benedict's test is already positive, a colour after hydrolysis proves nothing on its own: you would need a **deeper** colour (more precipitate) after hydrolysis than before to show a non-reducing sugar was there as well.

2 Carbohydrates

Syllabus 2.2

Carbohydrates are built from **monosaccharides** such as glucose (a hexose) and ribose (a pentose). Glucose exists as **α -glucose** (OH on carbon 1 below the ring) and **β -glucose** (OH on carbon 1 above the ring). Two monosaccharides join by **condensation**, losing water and forming a covalent **glycosidic bond**; **hydrolysis** adds water to break it. Chains of α -glucose coil into **starch** and **glycogen**, compact insoluble energy stores; chains of β -glucose, with alternate units inverted, lie straight and hydrogen-bond into the microfibrils of **cellulose**.

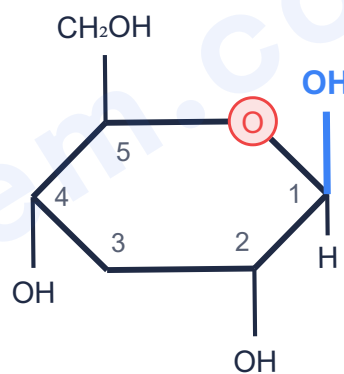
α -glucose



C1 OH below the ring

OH on carbon 3 and most H atoms omitted for clarity

β -glucose



C1 OH above the ring

Fig. 1: ring forms of α -glucose and β -glucose. The only difference is the position of the OH group on carbon 1

Monomer, bond, shape, job.

- ✓ **α -glucose:** C1 OH below the ring. **β :** above.
- ✓ **Condensation** removes water; **hydrolysis** adds it.
- ✓ **Starch and glycogen:** α -glucose, compact, insoluble stores.
- ✓ **Cellulose:** β -glucose, straight chains, H-bonded microfibrils.

Watch out!

Each hydrogen bond in cellulose is weak; the strength comes from the **very large number** of them between many parallel chains. And cellulose is not coiled: only α -glucose chains form helices.

3 Lipids

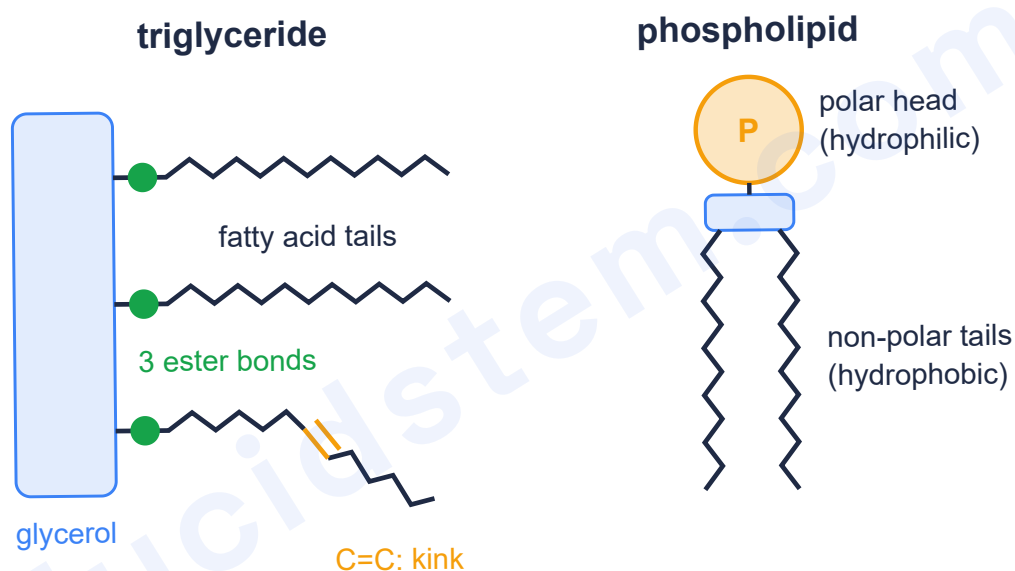
Syllabus 2.2

A **triglyceride** is one **glycerol** joined to three **fatty acids** by three **ester bonds**, each formed by condensation between an OH of glycerol and the COOH of a fatty acid.

Triglycerides are **non-polar and hydrophobic**. **Saturated** fatty acids have no C=C double bonds and straight tails; **unsaturated** ones have at least one C=C, which kinks the tail.

Their many C-H bonds make triglycerides an energy-dense, insoluble store. In a

phospholipid one fatty acid is replaced by a phosphate group, giving a **hydrophilic (polar) head** and two **hydrophobic (non-polar) tails**.



each ester bond forms by condensation, releasing one water molecule

Fig. 1: a triglyceride with one unsaturated fatty acid, and a phospholipid with its phosphate head

Glycerol, three tails, three waters.

- ✓ **Ester bond:** COOH of fatty acid + OH of glycerol, minus H_2O .
- ✓ **Saturated:** no $\text{C}=\text{C}$, straight.
Unsaturated: $\text{C}=\text{C}$, kinked.
- ✓ **Triglyceride:** non-polar, hydrophobic, energy-dense store.
- ✓ **Phospholipid:** hydrophilic phosphate head, hydrophobic tails.

Watch out!

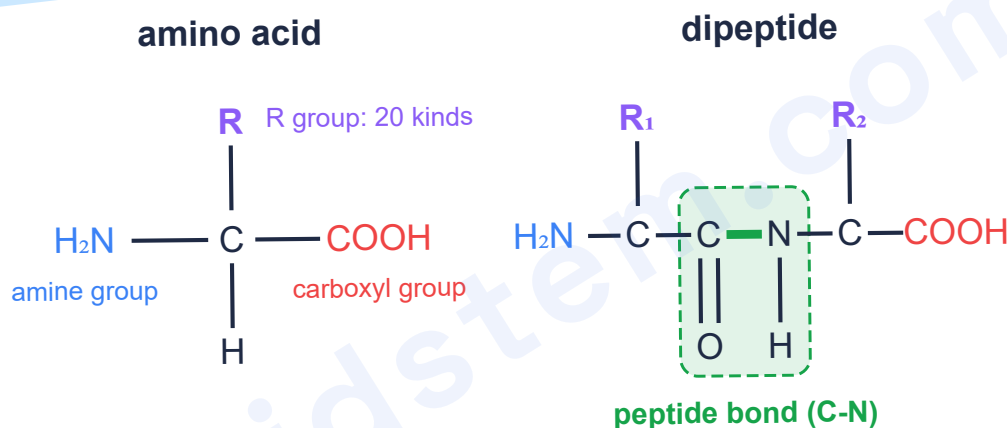
A triglyceride is **not a polymer**: glycerol and fatty acids are different molecules, not a chain of repeating monomers. And do not call the phospholipid head "hydrophobic because it contains phosphorus": it is hydrophilic because the phosphate group is charged.

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4 Proteins

Syllabus 2.3

Every **amino acid** has a central carbon carrying an amine group (NH_2), a carboxyl group (COOH), a hydrogen atom and a variable **R group**. Amino acids join by condensation to form **peptide bonds**. The **primary structure** is the sequence of amino acids; **secondary structure** is the α -helix or β -pleated sheet held by hydrogen bonds in the backbone; **tertiary structure** is the overall 3D folding held by hydrophobic interactions, hydrogen bonds, ionic bonds and disulfide bonds between R groups; **quaternary structure** is two or more polypeptides together. **Globular** proteins such as haemoglobin are soluble with physiological roles; **fibrous** proteins such as collagen are insoluble with structural roles.



condensation: OH from COOH + H from $\text{NH}_2 \rightarrow \text{H}_2\text{O}$ released

hydrolysis: H_2O added to break the peptide bond

Fig. 1: the general structure of an amino acid, and the peptide bond formed when two amino acids condense

Level, then bond.

- ✓ **Primary:** sequence, peptide bonds.
- ✓ **Secondary:** α -helix and β -sheet, backbone hydrogen bonds.
- ✓ **Tertiary:** R-group bonds: hydrophobic, hydrogen, ionic, disulfide.
- ✓ **Globular** soluble and physiological;
fibrous insoluble and structural.

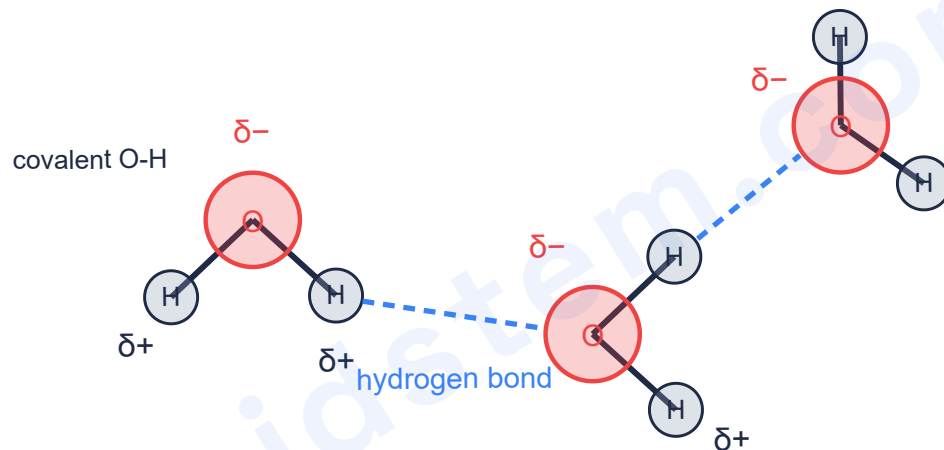
Watch out!

The hydrogen bonds of **secondary** structure are between atoms of the polypeptide **backbone** (C=O and N-H), not between R groups. The hydrogen bonds that help hold **tertiary** structure are between R groups.

5 Water

Syllabus 2.4

Oxygen attracts the shared electrons in each O-H bond more strongly than hydrogen, so a water molecule is **polar**: the O is slightly negative (δ^-) and each H slightly positive (δ^+). A **hydrogen bond** is the attraction between a δ^+ hydrogen of one molecule and a lone pair on the δ^- oxygen of another. Because water is polar it is an excellent **solvent** for ions and polar molecules. Because hydrogen bonds must be broken first, water has a **high specific heat capacity** (its temperature changes slowly) and a **high latent heat of vaporisation** (evaporation removes a lot of heat).



attraction between a δ^+ H and a lone pair on a δ^- O of another molecule
each molecule can form up to four hydrogen bonds

Fig. 1: hydrogen bonds between polar water molecules

Always start from the hydrogen bond.

- ✓ **Polar:** δ^- O, δ^+ H, bent molecule.
- ✓ **Solvent:** ions and polar molecules dissolve; transport and reactions.
- ✓ **Specific heat capacity:** temperature changes slowly.
- ✓ **Latent heat of vaporisation:** evaporation cools.

Watch out!

Do not mix up the two thermal properties. **Specific heat capacity** is about how much energy it takes to **raise the temperature**, so it explains stable temperatures. **Latent heat of vaporisation** is about the energy needed to **evaporate** water, so it explains cooling by sweating and transpiration.