Water, carbohydrates and lipids

The importance of water, monosaccharides, disaccharides and polysaccharides, glycosidic bonds, triglycerides, and the core practical on testing for sugars and starch.

Water

A water molecule is **polar**: the oxygen has a slight negative charge ($\delta-$) and each hydrogen a slight positive charge ($\delta+$), giving it a **dipole**. Water molecules are joined by **hydrogen bonds**.

Importance for transport and life:

- A **solvent** for polar and ionic substances. The $\delta+$ and $\delta-$ ends of water attract ions and polar molecules, so they dissolve and can be carried in the blood, in xylem and in the cytoplasm.
- **Cohesion** (hydrogen bonds hold molecules together) allows water to move up the xylem in a column.
- A **high specific heat capacity**, so the temperature of organisms and habitats changes slowly.
- A **high latent heat of vaporisation**, so evaporation (sweating, transpiration) cools effectively.
- Ice is less dense than liquid water, so ice floats and water below stays liquid.

Carbohydrates

Carbohydrates contain carbon, hydrogen and oxygen.

Type	Examples	Notes
Monosaccharide	Glucose, fructose, galactose	Single sugar units, $C_6H_{12}O_6$
Disaccharide	Maltose, sucrose, lactose	Two units joined
Polysaccharide	Glycogen, starch (amylose and amylopectin)	Many glucose units

Glucose exists as α-glucose and β-glucose, which differ in the position of the $-OH$ on carbon 1. (β-glucose and cellulose are covered with plants.)

Condensation and hydrolysis

Two monosaccharides join by a **condensation reaction**, which releases a molecule of water and forms a **glycosidic bond**.

- glucose + glucose → **maltose**
- glucose + fructose → **sucrose**
- glucose + galactose → **lactose**

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Hydrolysis is the reverse: water is added and the glycosidic bond is broken. Enzymes (such as amylase, maltase, sucrase and lactase) catalyse hydrolysis in digestion.

Polysaccharides

	Starch	Glycogen
Found in	Plants	Animals and fungi
Monomer	α-glucose	α-glucose
Structure	**Amylose**: unbranched helix with 1,4 glycosidic bonds. **Amylopectin**: branched, with 1,4 and 1,6 bonds	Highly **branched** with 1,4 and 1,6 bonds
Role	Energy store	Energy store

Structure relates to function:

- They are **compact** (amylose coils into a helix, branched molecules pack closely), so a lot of energy is stored in a small space.
- They are **insoluble**, so they do not affect the water potential of the cell and do not diffuse out.
- **Branching** gives many free ends, so enzymes can hydrolyse glucose rapidly. Glycogen is more branched than amylopectin, since animals have a higher metabolic rate.

> **Glycosidic bonds are formed by condensation and broken by hydrolysis. Say which one in an answer, and mention the molecule of water.**

Lipids

Triglycerides are made of **one glycerol** and **three fatty acids**. Each fatty acid joins to glycerol by a **condensation reaction**, forming an **ester bond** (three molecules of water are released).

	Saturated	Unsaturated
Carbon–carbon bonds in the fatty acid	All single	At least one C=C double bond
Shape	Straight chains	Kinked chains
State at room temperature	Usually solid (animal fats)	Usually liquid (oils)
Health	Linked with raised blood cholesterol	Healthier in moderation

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Triglycerides are good energy stores: they are **insoluble** (hydrocarbon chains are non-polar), have a high ratio of energy to mass, and release **metabolic water** on oxidation. They also insulate and protect organs.

Core Practical 1: sugars and starch

A **semi-quantitative** method estimates concentration from a colour.

- **Reducing sugars** (all monosaccharides, and maltose and lactose): heat with **Benedict's reagent**. The colour goes from blue to green, yellow, orange then brick red as the concentration increases. Sucrose is a **non-reducing** sugar: it gives a result only after hydrolysis with acid and neutralisation.
- **Starch**: add **iodine in potassium iodide**. Yellow-brown goes blue-black.

To estimate concentration:

1. Make **colour standards** from known concentrations (a dilution series).
2. Treat the sample the same way (same volume, same heating time).
3. Compare the sample colour with the standards. A colorimeter and a calibration curve give a more quantitative result.

> **NOTE**
>
> To make a dilution series, use a serial dilution with the same volume of solution at each step, and keep other variables (volume of reagent, temperature, time) the same.

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