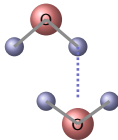


Chemistry of Life

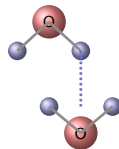
AP Biology ■ Unit 1

AP Biology



What we will cover

- 1 Water and hydrogen bonding
- 2 Elements and carbon
- 3 Macromolecules
- 4 Carbohydrates
- 5 Lipids
- 6 Nucleic acids
- 7 Proteins





Water and hydrogen bonding

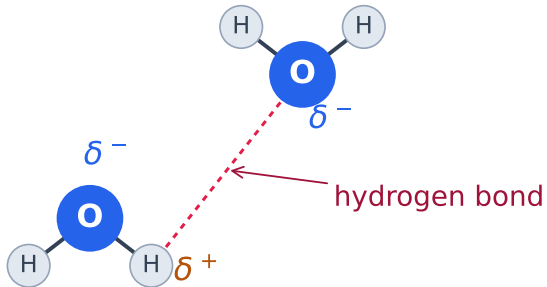
Water is a **polar molecule** : oxygen is more **electronegative** , so it is a **dipole** (δ^- O, δ^+ H). Neighbours attract by **hydrogen bonds** .

Many weak bonds give **emergent properties** : cohesion, high specific heat, ice floats.



Ice floats – hydrogen bonds hold an open lattice

A hydrogen bond between two polar water molecules



H-bond: $\delta^+ \text{H} \cdots \delta^- \text{O}$ · cohesion, adhesion, high c

A hydrogen bond between two polar water molecules

Every property of water follows from its polarity

polar

oxygen pulls the electrons more strongly, leaving a slightly negative O and slightly positive H

cohesion

water sticks to water – surface tension, and the column that rises in a plant

adhesion

water sticks to other polar surfaces – capillary action

high specific heat

and a high **heat of vaporization**, which is what makes evaporative cooling work

ice floats

the solid is **less dense** than the liquid, so lakes freeze from the top down

a great solvent

for polar and ionic substances – which is why cells are mostly water

Name the polarity first, then the property. An answer that lists properties without the cause is a description, not an explanation.



Elements and carbon

Just six elements (**CHNOPS**) are 98% of life. **Carbon** is the backbone – **four bonds** build chains, rings, branches.

Functional groups give a predictable personality; **isomers** share a formula but differ in shape.

hydroxyl –OH: polar

carboxyl –COOH: acid

amino –NH₂: base

phosphate: energy



Macromolecules

Four classes – all built and broken the same way:



Carbohydrates , lipids , nucleic acids , proteins – the same alphabet spells millions of molecules.

The four macromolecules and their monomers

carbohydrates

monomer: **monosaccharides** . Bond: glycosidic

lipids

not true polymers – glycerol plus fatty acids, joined by ester bonds

proteins

monomer: **amino acids** . Bond: **peptide bonds**

nucleic acids

monomer: **nucleotides** . Bond: phosphodiester

building

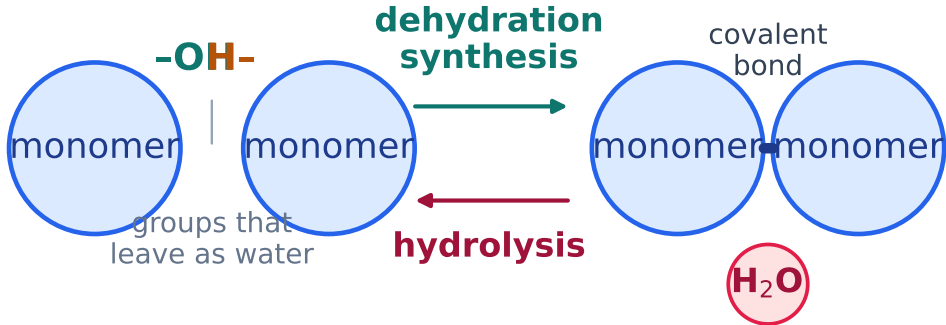
dehydration synthesis joins monomers and **releases** a water molecule per bond

breaking

hydrolysis does the reverse, consuming a water molecule per bond

Ten monomers make **nine** bonds and release **nine** waters – always one fewer than the number of units. That off-by-one is the exam's favourite check.

Introduction to Macromolecules



dehydration synthesis: monomers $\rightarrow$ polymer + H_2O

Dehydration synthesis builds polymers and releases water; hydrolysis reverses it



Carbohydrates and lipids

Carbohydrates : sugars, $(\text{CH}_2\text{O})_n$.

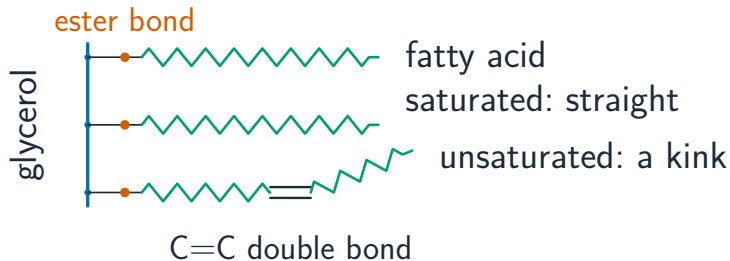
Glucose monomers join by a **glycosidic bond** .

- **starch** – plant store
- **glycogen** – animal store
- **cellulose** – rigid fibre

Lipids are **nonpolar** (not true polymers). A **triglyceride** = glycerol + 3 fatty acids.

Phospholipids have a hydrophilic head + hydrophobic tails $\Rightarrow$ the **bilayer** of every membrane.

A triglyceride



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

A triglyceride: glycerol joined to three fatty acids

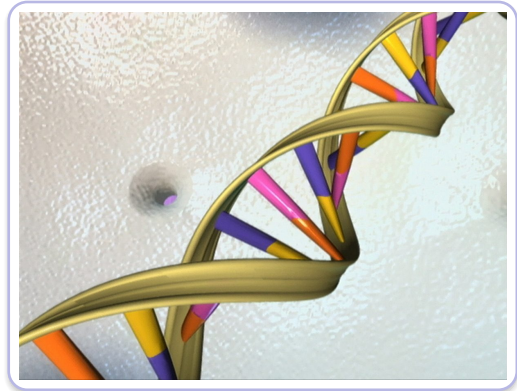


Nucleic acids

DNA stores information; its monomer is a **nucleotide** (sugar + phosphate + base).

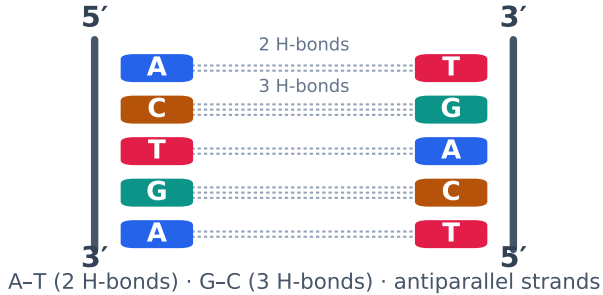
- a **sugar-phosphate backbone** -, read $5' \rightarrow 3'$
- a **double helix** of two **antiparallel** strands

A-T, G-C: each base has one partner, so a strand can template its copy.



Base pairing makes DNA a template for copies

Complementary base pairing holds the two



complementary pairing: A with T, G with C ·
strands run antiparallel (5' ↔ 3')

Complementary base pairing holds the two antiparallel strands of DNA together



Proteins

Proteins do almost everything. The monomer is an **amino acid** (20 of them, each with a variable **R group**), joined by a **peptide bond**.

Shape comes from sequence – so one wrong base can cripple a protein.
Heat or pH can **denature** it.

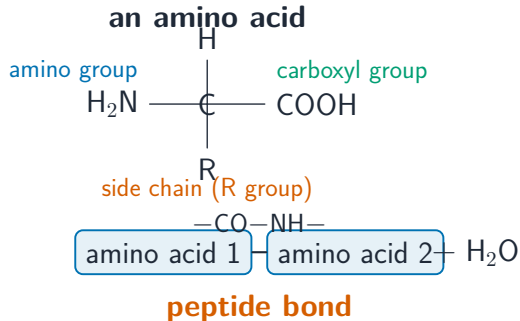
1°: amino-acid sequence

2°: α -helix, β -sheet

3°: full 3-D fold

4°: several chains

An amino acid – one



condensation removes one water for each peptide bond

An amino acid, and the peptide bond formed by condensation

An amino acid – two



primary (1°)

order of
amino acids



secondary (2°)

α -helix & β -sheet
(hydrogen bonds)



tertiary (3°)

folded into a
precise 3-D shape

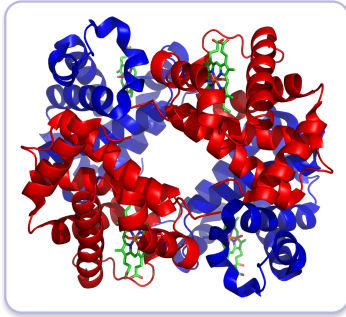


quaternary (4°)

two or more
chains together

The four levels of protein structure

Proteins, continued



Haemoglobin quaternary structure: four folded polypeptide chains, each holding a haem group

Elements of Life

carbohydrates
and fats
C H O

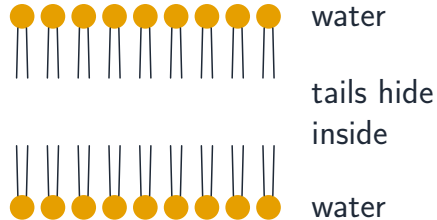
proteins
C H O N

Carbohydrates and fats contain carbon, hydrogen, and oxygen; proteins also contain nitrogen

Lipids



phospholipid bilayer



A phospholipid has a polar head and two nonpolar tails, so phospholipids form a bilayer

Carbohydrates



amylose
(coiled)



amylopectin
(branched)



glycogen
(many branches)



cellulose
(straight chains)

The shapes of storage polysaccharides (starch, glycogen) and structural cellulose

Worked example – counting the waters

Build a polymer from 10 monomers by dehydration synthesis. How many water molecules are released – and what does hydrolysis do?

- Ten monomers form 9 bonds, and each bond releases one water: **9 water molecules**. For N monomers, $N - 1$ waters.
- Hydrolysis reverses it exactly: adding those 9 waters breaks the polymer back into 10 monomers.

Biosynthesis and digestion are chemical opposites – which is why the same enzyme families run in both directions in different compartments.

Exam tips

- Trace every property of water back to its **polarity and hydrogen bonding** (cohesion, high specific heat, solvent power).
- Know the four macromolecule classes and their monomers; polymers are built by **dehydration synthesis** and broken by **hydrolysis**.
- For proteins, **structure (shape) determines function** – heat or a pH change **denatures** them and stops them working.
- In DNA the bases pair A–T and C–G on **antiparallel** strands; RNA is single-stranded and uses U.
- Link each molecule to its role (carbohydrates: energy/structure; lipids: membranes/storage; nucleic acids: information).



Unit 1 – key takeaways

1

Water

polar; hydrogen bonds give life's emergent properties

2

Carbon

four bonds; functional groups; build/break by water

3

Polymers

carbs, lipids, nucleic acids, proteins from monomers

4

Structure

DNA A-T/G-C; protein shape from sequence

Check yourself

- 1 What kind of bond holds two water molecules together?
- 2 How many covalent bonds can one carbon atom form?
- 3 In DNA, what base pairs with guanine?
- 4 What determines a protein's final shape?



Answers 1. a hydrogen bond 2. four 3. cytosine (C) 4. its amino-acid sequence