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

1 Water

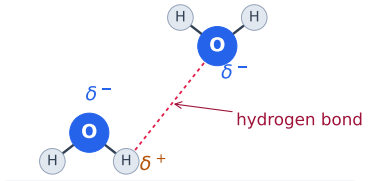
Water and hydrogen bonding

Water is a **polar molecule** 极性分子: oxygen is more **electronegative** 电负性强的, so it is a **dipole** 偶极 (δ^- O, δ^+ H). Neighbours attract by **hydrogen bonds** 氢键.

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

Ice floats – hydrogen bonds hold an open lattice

A hydrogen bond between two polar water molecules



H-bond: δ^+H $\cdots$ δ^-O · cohesion, adhesion, high c

> A hydrogen bond between two polar water molecules

Every property of water follows from its polarity

polar 极性	oxygen pulls the electrons more strongly, leaving a slightly negative O and slightly positive H
cohesion 内聚力	water sticks to water – surface tension, and the column that rises in a plant
adhesion 附着力	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 溶剂	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.

2 Elements

Elements and carbon

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

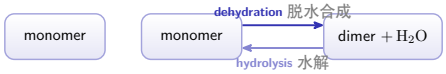
> **Functional groups** 官能团 give a predictable personality; **isomers** 同分异构体 share a formula but differ in shape.

- **hydroxyl** $-\mathrm{OH}$: polar
- **carboxyl** $-\mathrm{COOH}$: acid
- **amino** $-\mathrm{NH_2}$: base
- **phosphate**: energy

3 Macromolecules

Macromolecules

Four classes – all built and broken the same way:



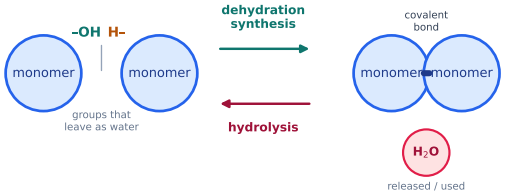
> **Carbohydrates** 碳水化合物, **lipids** 脂质, **nucleic acids** 核酸, **proteins** 蛋白质 – the same alphabet spells millions of molecules.

The four macromolecules and their monomers

carbohydrates	monomer: **monosaccharides** 单糖. Bond: glycosidic
lipids	not true polymers – glycerol plus fatty acids, joined by ester bonds
proteins	monomer: **amino acids** 氨基酸. Bond: **peptide bonds** 肽键
nucleic acids	monomer: **nucleotides** 核苷酸. 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 → polymer + H_2O

> Dehydration synthesis builds polymers and releases water; hydrolysis reverses it

4 Carbohydrates & lipids

Carbohydrates and lipids

Carbohydrates 碳水化合物: sugars, $(CH_2O)_n$. **Glucose** 葡萄糖 monomers join by a **glycosidic bond** 糖苷键.

- **starch** 淀粉 – plant store
- **glycogen** 糖原 – animal store
- **cellulose** 纤维素 – rigid fibre

Lipids 脂质 are nonpolar (not true polymers). A **triglyceride** 甘油三酯 = glycerol + 3 fatty acids.

Phospholipids 磷脂 have a hydrophilic head + hydrophobic tails ⇒ the **bilayer** 双分子层 of every membrane.

A triglyceride

3 ester bonds form → 3 H_2O removed (condensation)

A triglyceride: glycerol joined to three fatty acids

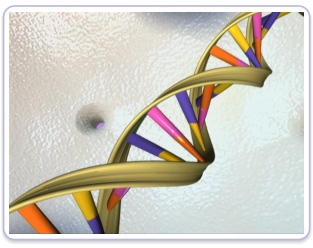
5 Nucleic acids

Nucleic acids

DNA 脱氧核糖核酸 stores information; its monomer is a **nucleotide** 核苷酸 (sugar + phosphate + base).

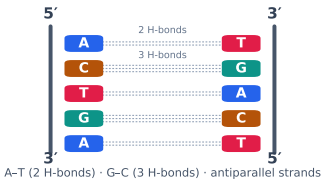
- a **sugar-phosphate backbone** 糖-磷酸骨架, read $5' \to 3'$
- a **double helix** 双螺旋 of two **antiparallel** 反平行的 strands

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



A–T (2 H-bonds) · G–C (3 H-bonds) · antiparallel strands

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

Complementary base pairing holds the two antiparallel strands of DNA together

6 Proteins

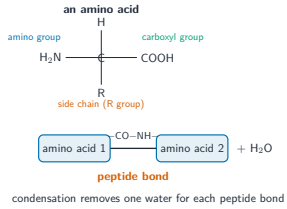
Proteins

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

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

- **1°**: amino-acid sequence
- **2°**: α-helix, β-sheet
- **3°**: full 3-D fold
- **4°**: several chains

An amino acid – one



An amino acid, and the peptide bond formed by condensation

> An amino acid, and the peptide bond formed by condensation

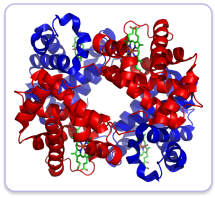
An amino acid – two

primary (1°)	**secondary (2°)**	**tertiary (3°)**	**quaternary (4°)**
order of amino acids	α-helix & β-sheet (hydrogen bonds)	folded into a precise 3-D shape	two or more chains together

The four levels of protein structure

> The four levels of protein structure

Proteins, continued



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

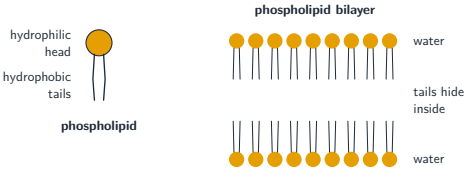
Elements of Life

carbohydrates and fats
C H O

proteins
C H O N

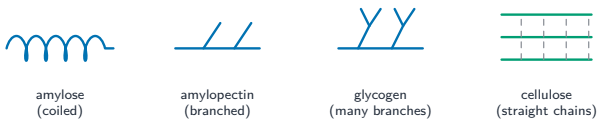
> Carbohydrates and fats contain carbon, hydrogen, and oxygen; proteins also contain nitrogen

Lipids



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

Carbohydrates



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).

7 Recap

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