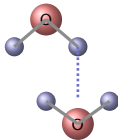


Chemistry of Life

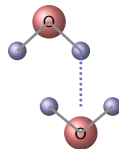
AP Biology ■ Unit 1

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

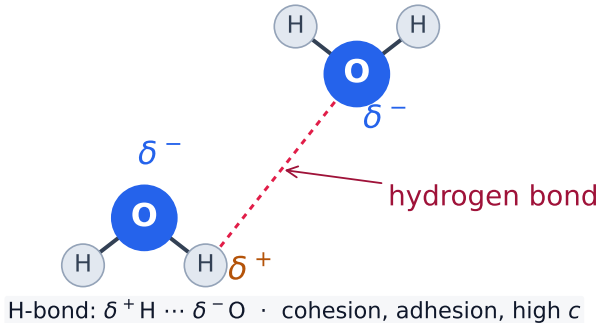
Water is a **polar molecule** 极性分子: oxygen is more **electronegative** 电负性强的, so it is a **dipole** 偶极 (δ^- O, δ^+ H). Neighbours attract by **hydrogen bonds** 氢键.

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



The partial negative O of one molecule attracts the partial positive H of another: this gives water cohesion, a high specific heat and ice that floats.

Every property of water follows from its polarity

property	why, from polarity
polar 极性	O pulls the electrons harder: δ^- on O, δ^+ on H
cohesion 内聚力	water sticks to water: surface tension, the column rising in a plant
adhesion 附着力	water sticks to other polar surfaces: capillary action
high specific heat	H-bonds must break first; high heat of vaporization cools by sweating
ice floats	H-bonds lock an open lattice: less dense , lakes freeze from the top
great solvent 溶剂	dissolves polar and ionic substances: cells are mostly water

Name the **polarity** first, then the property: a list 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.

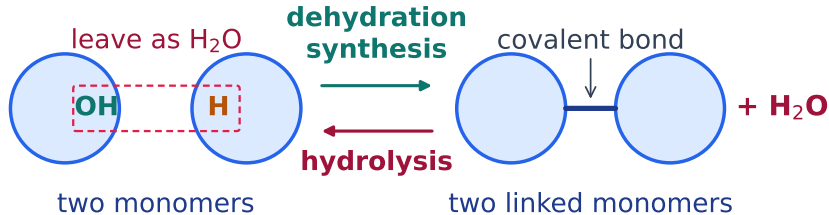
Functional groups 官能团 give a predictable personality; **isomers** 同分异构体 share a formula but differ in shape.

group	formula	behaves as
hydroxyl	–OH	polar
carboxyl	–COOH	acid
amino	–NH ₂	base
phosphate	–PO ₄	energy (ATP)

3

Macromolecules

Building and breaking macromolecules



- **dehydration** 脱水合成 synthesis **joins** monomers, releasing one H₂O per bond
- **hydrolysis** 水解 **breaks** the bond, using one H₂O

N monomers make $N - 1$ bonds and release $N - 1$ waters.

The four macromolecules and their monomers

class	monomer	bond
carbohydrates 碳水化合物	monosaccharides 单糖	glycosidic
lipids 脂质	glycerol + fatty acids (not a true polymer)	ester
proteins 蛋白质	amino acids 氨基酸	peptide bonds 肽键
nucleic acids 核酸	nucleotides 核苷酸	phosphodiester

The same few monomers, joined the **same way**, spell millions of molecules.

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Carbohydrates & lipids

Carbohydrates and lipids

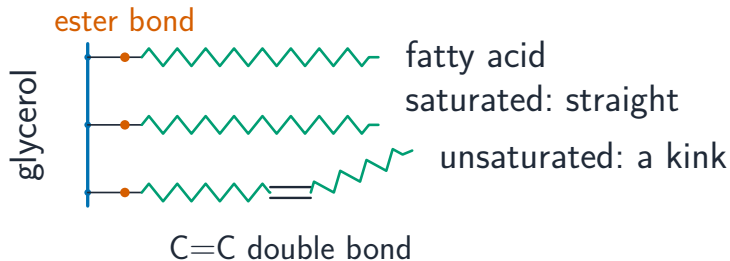
Carbohydrates 碳水化合物: sugars, $(\text{CH}_2\text{O})_n$. **Glucose** 葡萄糖 monomers join by a **glycosidic bond** 糖苷键.

- **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 $\Rightarrow$ the **bilayer** 双分子层 of every membrane.

A triglyceride



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

A triglyceride: glycerol joined to three fatty acids

5

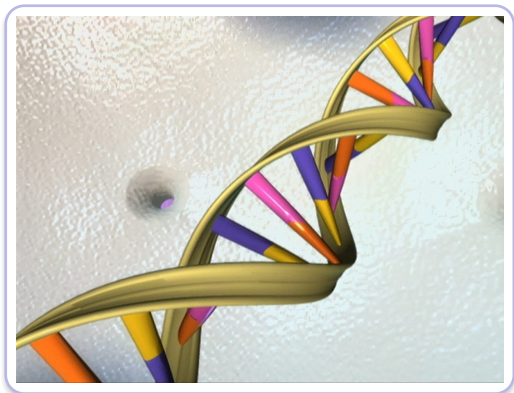
Nucleic acids

Nucleic acids

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

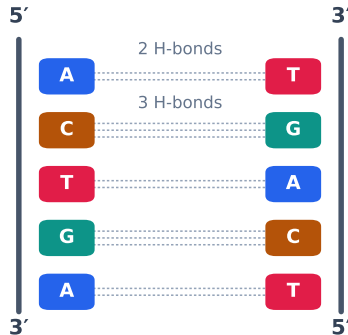
- a **sugar-phosphate backbone** 糖-磷酸骨架, read $5' \rightarrow 3'$
- a **double helix** 双螺旋 of two **antiparallel** 反平行的 strands

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



A pairs with **T** by 2 hydrogen bonds, **G** with **C** by 3; the two strands run **antiparallel** ($5' \rightarrow 3'$ against $3' \rightarrow 5'$).

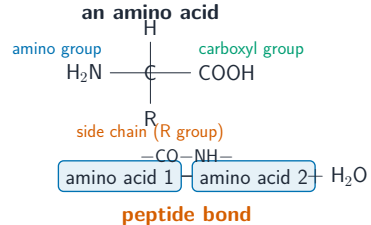
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Proteins

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.



condensation removes one water for each peptide bond

Four levels of protein structure



primary (1°)

order of
amino acids



secondary (2°)

α -helix & β -sheet
(hydrogen bonds)



tertiary (3°)

folded into a
precise 3-D shape

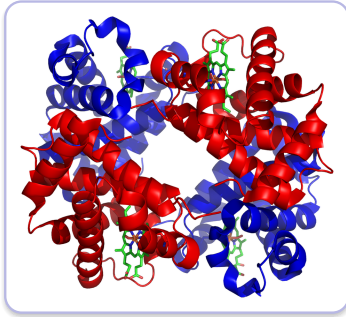


quaternary (4°)

two or more
chains together

1° sequence → 2° α -helix, β -sheet → 3° 3-D fold → 4° several chains.

Quaternary structure: haemoglobin



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

Elements of Life

carbohydrates
and fats
C H O

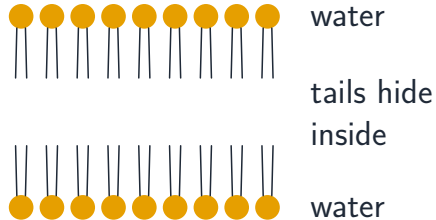
proteins
C H O N

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?

- 10 monomers form 9 bonds; each releases one water: **9 water molecules**
- hydrolysis adds those 9 waters back and splits it 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