Chemistry of Life

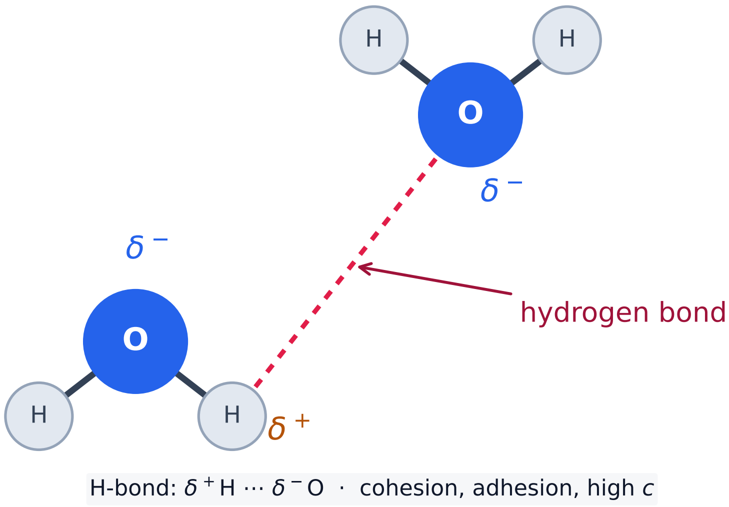
AP Biology

Structure of Water and Hydrogen Bonding

Ice floats on water because hydrogen bonding makes solid water less dense than liquid water

Water is **polar** 极性: its oxygen pulls electrons more strongly than its hydrogens, giving a slightly negative O and slightly positive H. This lets water molecules form **hydrogen bonds** 氢键 with each other, which explains water's life-supporting properties:

- **Cohesion** 内聚力 and **adhesion** 附着力 (surface tension, capillary action, water rising in plants),
- high **specific heat** 比热容 (resists temperature change, stabilizing organisms),
- high heat of vaporization (evaporative cooling),
- ice floating (less dense solid), and being a great **solvent** for polar and ionic substances.



A hydrogen bond between two polar water molecules

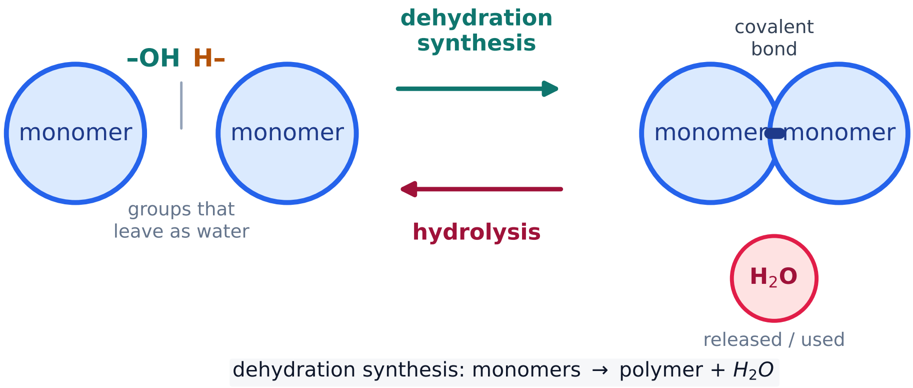
Elements of Life

Living matter is built mostly from a few elements – carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. **Carbon** 碳 is central because it forms four stable covalent bonds, building long chains, branches, and rings – the skeletons of all biological molecules.

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

Introduction to Macromolecules

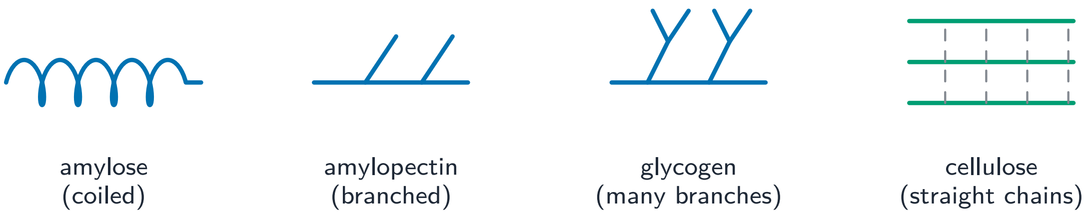
Large biological molecules – **macromolecules** 大分子 – are **polymers** 聚合物 built from repeating **monomers** 单体. Cells join monomers by **dehydration synthesis** 脱水缩合 (removing water to form a bond) and break polymers by **hydrolysis** 水解 (adding water). Four classes: carbohydrates, lipids, nucleic acids, and proteins.



Dehydration synthesis builds polymers and releases water; hydrolysis reverses it

Carbohydrates

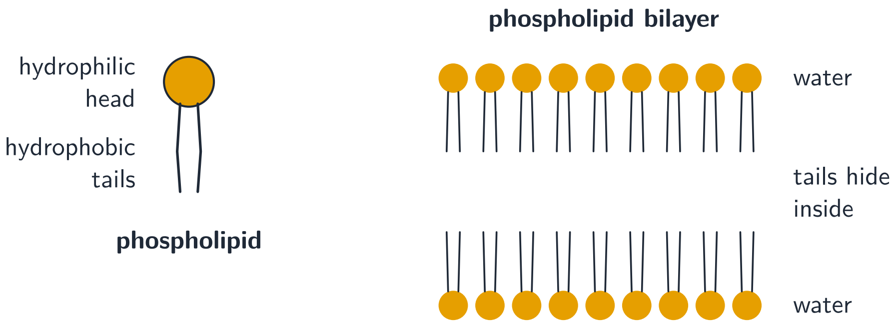
Carbohydrates 碳水化合物 are made of sugar monomers (**monosaccharides** 单糖 like glucose). They store energy (starch, glycogen) and provide structure (**cellulose** 纤维素 in plant walls). Their many hydroxyl groups make them polar and water-soluble.



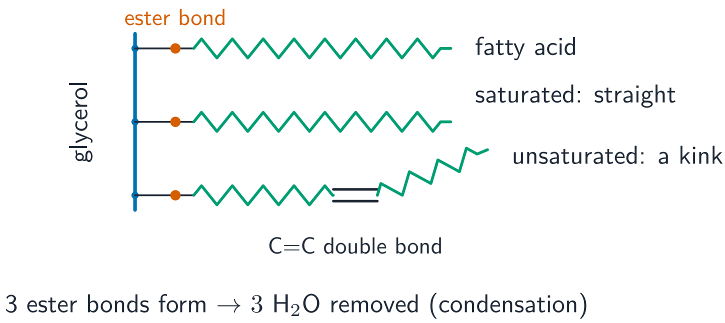
The shapes of storage polysaccharides (starch, glycogen) and structural cellulose

Lipids

Lipids 脂质 are **nonpolar** and do not mix with water (**hydrophobic** 疏水). They include fats (long-term energy storage), **phospholipids** 磷脂 (which build membranes), and steroids. A phospholipid has a polar "head" and nonpolar "tails," the key to the cell membrane.

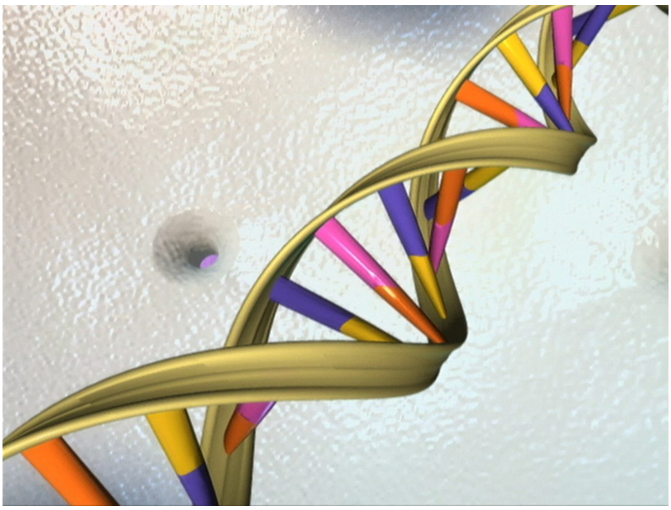


A phospholipid has a polar head and two nonpolar tails, so phospholipids form a bilayer



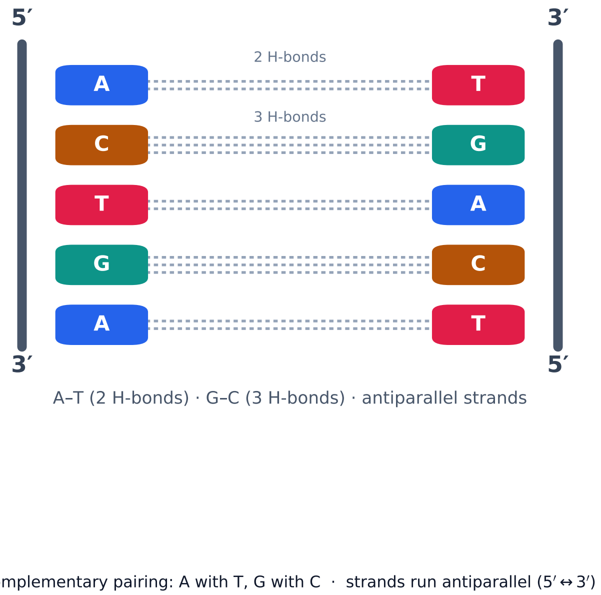
A triglyceride: glycerol joined to three fatty acids

Nucleic Acids



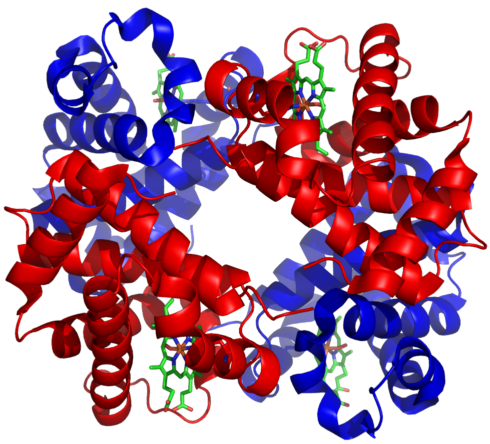
Space-filling model of the DNA double helix (NHGRI)

Nucleic acids 核酸 (DNA and RNA) store and carry genetic information. Their monomers are **nucleotides** 核苷酸, each a sugar, a phosphate, and a nitrogen base. The base sequence encodes instructions; DNA is double-stranded, RNA single-stranded.



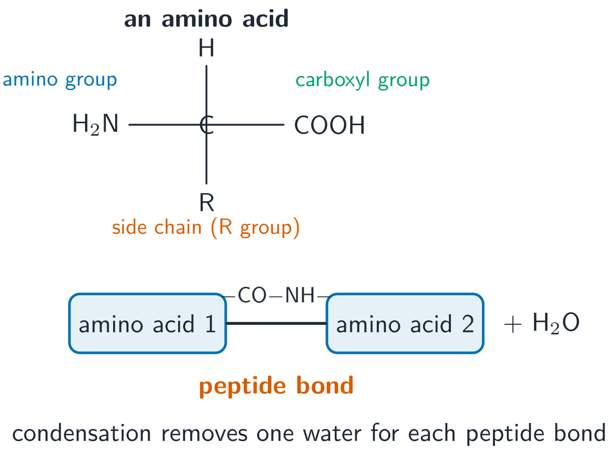
Complementary base pairing holds the two antiparallel strands of DNA together

Proteins

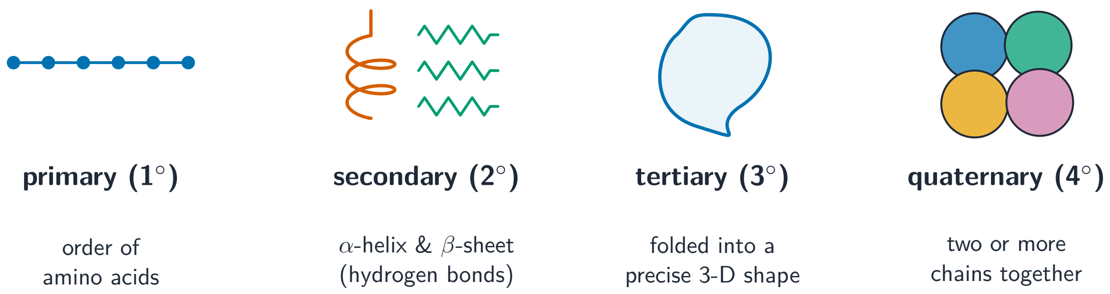


Haemoglobin quaternary structure: four folded polypeptide chains, each holding a haem group

Proteins 蛋白质 are polymers of **amino acids** 氨基酸 joined by **peptide bonds** 肽键. Their sequence folds into a specific 3-D shape at four levels (primary, secondary, tertiary, quaternary), and **shape determines function** – as enzymes, transporters, receptors, and structural parts. Changing the environment (heat, pH) can **denature** 变性 a protein, unfolding it and stopping its function.



An amino acid, and the peptide bond formed by condensation



The four levels of protein structure

Worked example. Building a polymer from **10 monomers** by dehydration synthesis forms 9 bonds and releases **9 water molecules** — one per bond, so N monomers release $N - 1$ waters. Hydrolysis reverses this exactly: adding those 9 waters breaks the polymer back into 10 monomers. This is why biosynthesis (dehydration) and digestion (hydrolysis) are chemical opposites.

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).