IB / A Level Biology

A1.1 Water

Exam Preparation Notes (SL + HL extension)

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What this topic is really about (high marks)

- **Polarity** (unequal electron sharing) + **hydrogen bonding** explain most of water's life-supporting properties.
- In answers, write in a chain: **structure** -> **intermolecular forces** -> **property** -> **biological consequence**.
- Use precise terms: *cohesion* vs *adhesion*, *hydrophilic* vs *hydrophobic*, *specific heat capacity* vs *thermal conductivity*.

Syllabus checklist (A1.1)

- Explain why water is essential for life (solvent, transport medium, habitat, temperature stability).
- Draw/annotate a **water molecule** showing polar covalent bonds, bent shape and partial charges ($\delta+$ / $\delta-$).
- Explain **cohesion** and **surface tension** with examples (e.g., water striders).
- Explain **adhesion** and **capillary action** (xylem walls, soil micropores).
- Explain water as a **solvent** in metabolism and transport; contrast hydrophilic vs hydrophobic substances.
- Describe key **physical properties**: buoyancy, viscosity, thermal conductivity, specific heat capacity (and adaptations).
- **HL:** outline ideas for the origin of water on Earth and why Earth retained liquid water.
- Discuss how water guides the search for **extraterrestrial life** (habitable zone, atmosphere, protection).

How to use these notes: revise the boxed definitions, practise the diagram, and do the exam questions at the end using full sentences.

A1.1 Water – Why water makes life possible

Water is essential to life because it is **polar** and forms **hydrogen bonds**. These molecular features give water properties that support metabolism, transport, and stable habitats.

High-yield links to learn

- **Solvent**: dissolves ions/polar molecules -> reactions and transport in cells and body fluids.
- **Medium for metabolism**: enzymes and substrates move and collide in aqueous cytoplasm.
- **Transport**: xylem (plants), blood plasma and tissue fluid (animals).
- **Habitat**: buoyancy supports bodies; high specific heat stabilises temperature; but viscosity increases drag.

Water on Earth

- Present naturally as **solid** (ice), **liquid**, and **gas** (water vapour).
- Moves through the **water cycle** (evaporation, condensation, precipitation, runoff) which redistributes water and influences habitats.
- Most evidence suggests early life evolved in water; all modern organisms still depend on water for biochemical processes.

Key definitions

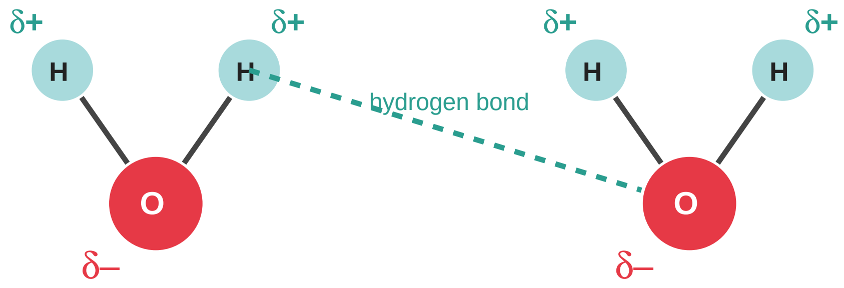
Term	Meaning (exam-ready)
Aqueous solution	A mixture where **water is the solvent** and other substances are dissolved as solutes.
Solvent	The liquid that dissolves other substances (solutes). In biology, this is often water.
Solute	A substance dissolved in a solvent (e.g., ions, glucose).

Exam tip: how to phrase ‘why is water important?’

- Avoid listing properties without links. Always add a biological role.
- Example sentence starter: *Because water is polar, it dissolves ions and polar molecules, allowing...*
- If asked about habitats, compare **water vs air** (density, drag, heat transfer).

A1.1.2 Structure and polarity of water molecules

A water molecule (H_2O) has two **polar covalent** O–H bonds and a **bent** shape. Oxygen attracts shared electrons more strongly (higher electronegativity), creating partial charges: oxygen is δ– and hydrogens are δ+.



Polar covalent bonds + bent shape → net dipole. Hydrogen bonds form between δ+ H and δ– O.

Key terms you must use correctly

- **Electronegativity**: how strongly an atom attracts shared electrons in a covalent bond.
- **Polar covalent bond**: electrons shared unequally -> partial charges form.
- **Dipole**: separation of charge in a molecule (water has a net dipole because it is bent).
- **Hydrogen bond**: weak attraction between δ+ H and δ– O/N in nearby molecules.

How hydrogen bonds explain water’s ‘special’ behaviour

- Hydrogen bonds are individually weak but **numerous** in liquid water, forming a dynamic network (bonds continually break and reform).
- Hydrogen bonding occurs between water molecules (**cohesion**) and between water and other polar substances (**adhesion**).
- Hydrogen bonding helps stabilise biological molecules (e.g., protein structure, DNA base pairing).

Diagram practice (often assessed)

- Draw the bent shape (not linear).
- Show δ– on oxygen and δ+ on both hydrogens.
- Show hydrogen bonds as **dashed lines** between molecules (not within a molecule).
- Label covalent O–H bonds clearly.

A1.1.3 Cohesion of water molecules

Cohesion is the attraction between molecules of the **same** substance. In water, cohesion is caused by hydrogen bonds between δ+ H and δ– O on neighbouring molecules.

Cohesion -> surface tension (link you must explain)

- At the surface, water molecules are pulled **inwards** because there are no molecules above them.
- This creates a 'skin' called **surface tension**.
- Biological examples: water striders/pond skaters and fishing spiders can move on the surface without breaking through.

Cohesion in plants: keeping a continuous water column

- **Xylem** vessels form narrow tubes from roots to leaves.
- **Transpiration** (evaporation of water from stomata) creates a pulling force (lower pressure) at the top of the xylem.
- Because of cohesion, water molecules stay connected as a continuous column, so the pull is transmitted downwards and draws water up from roots.
- Analogy: like drinking through a straw (pressure difference pulls liquid upward).

Common exam mistake

- Don't say 'water is pulled up because it is sticky'. Use **cohesion (water-water)** and **adhesion (water-wall)** and link to hydrogen bonds.

A1.1.4 Adhesion between water and other substances

Adhesion is the attraction between water and **other** polar or charged substances. It happens when water forms hydrogen bonds with those surfaces or molecules (e.g., cellulose in plant cell walls).

Cohesion	Adhesion
Water-to-water attraction (hydrogen bonds).	Water-to-other-substance attraction (hydrogen bonds/charge interactions).
Creates surface tension; helps maintain water column in xylem.	Helps water cling to xylem walls and move through small spaces.

Adhesion + cohesion -> capillary action

- In a narrow tube, water **adheres** to the sides and then **cohesion** pulls more water up behind it.
- In plants, adhesion to xylem walls helps support the water column against gravity.
- In soil, tiny spaces act as natural capillaries; root hairs access water held to mineral surfaces.

A1.1.5 The solvent properties of water

Because water is **polar**, it dissolves many ions and polar molecules. This creates aqueous solutions that support **metabolism** and **transport** in living systems.

Must-know terminology

- **Hydrophilic** (‘water-loving’): polar/charged substances that dissolve in water.
- **Hydrophobic** (‘water-fearing’): non-polar substances that do not dissolve in water.
- **Universal solvent**: a useful phrase in biology, but remember water does **not** dissolve non-polar lipids.

Substance type	Dissolves in water?	Why it matters biologically
Ions (e.g., Na+, K+, nitrate)	Yes (hydration shells form around ions).	Transport in blood/xylem; enzyme function; nerve and muscle activity.
Small polar molecules (e.g., glucose, amino acids)	Yes.	Can move in cytoplasm and body fluids; substrates for respiration and growth.
Non-polar lipids (fats, phospholipid tails)	No.	Form membranes and barriers; reduce water loss (waxy cuticle).

Water as the medium for metabolism

- The **cytoplasm** is an aqueous solution where most enzyme-catalysed reactions occur.
- Water allows molecules to diffuse and collide, increasing reaction chances.
- Many wastes (e.g., urea) are water-soluble, allowing removal in urine and other excretory fluids.

Water as a transport medium

- Plants: xylem carries water + dissolved mineral ions from roots to leaves; phloem transports sucrose in solution.
- Animals: blood plasma and tissue fluid transport nutrients, hormones and dissolved wastes.
- Cell signalling: many hormones/neurotransmitters travel through aqueous environments to reach target cells.

Exam tip: hydrophobic does not mean ‘unimportant’

- Hydrophobic molecules are essential: they form the core of cell membranes and enable compartmentalisation.
- They also create protective waterproof layers (e.g., waxy cuticle on leaves).

A1.1.6 Physical properties of water

Water creates very different living conditions from air. It supports organisms through buoyancy, but it also resists movement and transfers heat efficiently.

Property	What it means	Biological consequence + example
Buoyancy	Upward force exerted by a fluid; water is much denser than air.	Supports body weight so less skeletal support is needed. Example: ducks and seals float and rest with low energy cost.
Viscosity	Resistance of a fluid to flow; water has higher viscosity than air.	More drag when moving -> streamlined bodies and strong propulsion. Example: mackerel streamlined shape; dolphins use powerful tail strokes.
Thermal conductivity	How easily heat is transferred through a material.	Water conducts heat well -> aquatic animals can lose heat quickly -> insulation needed (fur, fat, feathers). Example: sea otter dense fur; penguin insulation.
Specific heat capacity	Energy needed to raise temperature of 1 g of a substance by 1°C.	High in water -> habitats change temperature slowly -> more stable environments (lakes/oceans) compared with air.

Extra high-yield point: why ice floats (often tested)

- In ice, hydrogen bonds form a more ‘open’ lattice -> **lower density** than liquid water.
- Ice floats and insulates water below, helping aquatic life survive in cold climates.

Water as a habitat: benefits and challenges

- **Benefits**: buoyancy reduces need for heavy support structures; high specific heat buffers temperature changes.
- **Challenges**: viscosity increases resistance; thermal conductivity increases heat loss.
- Link adaptations to the challenge: streamlining reduces drag; insulation reduces heat loss.

Markscheme language that scores

- ‘Water has a high **specific heat capacity**, so it requires a lot of energy to change temperature; therefore aquatic environments are stable.’
- ‘Water has a high **thermal conductivity**, so animals lose heat quickly and need insulation.’

A1.1.7 Origin of water on Earth (HL)

Earth is able to support life partly because it has retained abundant water for billions of years. Evidence suggests that some of Earth's water may have been delivered early in the solar system's history.

Possible sources of Earth's water (know the ideas, not exact numbers)

- **Asteroid delivery**: many asteroids contain hydrated minerals; impacts could release water into Earth's developing system.
- **Comets**: icy bodies may also have contributed water, though their isotope ratios are not always a close match to ocean water.
- **Internal sources**: water can be stored in minerals in Earth's crust/mantle and released by geothermal activity in some regions (hot springs/geysers).

Key evidence: hydrogen isotopes

- Hydrogen occurs as **protium** (no neutron) and **deuterium** (one neutron).
- The **deuterium:hydrogen (D/H) ratio** in ocean water can be compared with the D/H ratio in water from asteroids and comets.
- Similar ratios support the idea that some water came from asteroid material (but evidence is still being refined).

Why Earth kept liquid water

- Earth's gravity is strong enough to retain an atmosphere and water vapour (smaller bodies lose gases more easily).
- Earth cooled enough for water vapour to **condense** into liquid, forming oceans; temperatures allow water to exist in all three states.

Nature of science (easy extra credit in essays)

- Measurements and scientific 'facts' can change slightly as tools improve (e.g., mapping depths, analysing isotopes).
- Origin-of-water hypotheses are tested and updated as new missions and observations provide better data.

A1.1.8 The search for extraterrestrial life

A practical starting assumption is that life elsewhere will require **liquid water**, because water supports metabolism, transport and chemical reactions. This guides where scientists look for potentially habitable worlds.

Habitable (Goldilocks) zone – definition

- The range of distances from a star where a planet could have **liquid water** on its surface (not too hot, not too cold).
- Being in the habitable zone is necessary but not sufficient; atmosphere, gravity and protection from radiation also matter.

What else is needed besides the right orbit?

- **Gravity** strong enough to hold an atmosphere and water.
- **Atmosphere** that helps regulate temperature and can protect from radiation.
- **Magnetic field / shielding** can reduce exposure to damaging solar particles and radiation.

Star type matters

- G-type stars (like the Sun) provide relatively stable conditions.
- K-type and M-type stars are more common; their habitable zones are closer to the star and they can show stronger radiation bursts, which may challenge life.
- Even so, because K and M stars are abundant, many exoplanet searches focus on them.

Exam-style evaluation point

- Water is a strong indicator for life-as-we-know-it, but it may not capture all possible biochemistries.
- State clearly that **no confirmed extraterrestrial life** has been found; scientists use indirect evidence (orbit, temperature estimates, atmosphere).

Exam practice (IB / A Level style)

Use full biological chains: **polarity** -> **hydrogen bonding** -> **property** -> **function/adaptation**.
Below are typical questions and what examiners look for.

Typical question	What a top answer includes (markscheme cues)
1. Draw and label a water molecule.	Bent shape; O labelled δ–, H labelled δ+; polar covalent O–H bonds; dashed hydrogen bond between molecules.
2. Explain surface tension in water.	Cohesion via hydrogen bonds; net inward pull at surface; forms ‘skin’; example organism (water strider).
3. Explain how water moves up xylem.	Transpiration lowers pressure; cohesion maintains continuous column; adhesion to walls supports column; capillary action in narrow tubes.
4. Why is water a good solvent?	Polarity; hydration shells; dissolves ions/polar molecules; enables transport and enzyme reactions in cytoplasm/blood.
5. Compare viscosity and buoyancy.	Viscosity = resistance to movement (drag) -> streamlining; buoyancy = upthrust -> support in water.
6. Compare specific heat capacity and thermal conductivity.	Specific heat: resists temperature change -> stable habitats; thermal conductivity: transfers heat quickly -> heat loss/insulation.

Common misconceptions to avoid

- Hydrogen bonds are **between** molecules, not the covalent O–H bonds **within** a water molecule.
- Cohesion is not the same as adhesion. Define both before applying them to xylem/capillaries.
- Specific heat capacity is not the same as thermal conductivity (one is temperature stability; one is heat transfer speed).
- ‘Universal solvent’ does not mean water dissolves lipids.

One-minute summary (use for last-minute recall)

- Water is bent and polar -> hydrogen bonds form.
- Hydrogen bonding -> cohesion (surface tension, continuous xylem column) and adhesion (capillary action).
- Polarity -> solvent for ions and polar molecules -> metabolism and transport.
- Physical properties: buoyancy supports; viscosity adds drag; high thermal conductivity causes heat loss; high specific heat stabilises habitats.
- HL: isotopes and asteroid/comet hypotheses for water origin; liquid water guides the search for life in habitable zones.