# A1.1 Water

Exam preparation notes covering core content plus HL extension: the medium of life, polarity, hydrogen bonding, cohesion, adhesion, solvent properties, aquatic adaptations, the origin of Earth’s water, and the search for extraterrestrial life.

### Why water matters

- Life first evolved in water and most life processes still occur in aqueous environments.
- Water exists on Earth as liquid, vapour and ice, supporting the water cycle and stable habitats.
- About 70% of Earth’s surface is covered by water.

### Chemistry that drives biology

- Polar O-H bonds create partial charges.
- Hydrogen bonds give rise to cohesion, adhesion and surface tension.
- Water is an excellent solvent for many polar and charged solutes.

### What examiners like to test

- Linking structure to property to function.
- Explaining xylem transport using cohesion, adhesion, tension and transpiration.
- Comparing water with air for aquatic animals.

### Core exam chain

Use this sequence in longer answers: polar covalent bonds -> partial charges -> hydrogen bonds -> cohesion / adhesion / solvent action -> transport, metabolism, habitat support and thermal stability.

### Guiding questions

- What physical and chemical properties make water essential for life?
- What opportunities and challenges does water create as a habitat?
- Why does the search for water matter in the search for life elsewhere?

### HL extension

- Extraplanetary origin of water on Earth: focus on asteroid delivery.
- Retention of water: gravity plus temperatures low enough for condensation.
- Goldilocks zone and the search for extraterrestrial life.

# A1.1 at a glance

| Section | Core idea | Key language / examples |
|---|---|---|
| A1.1.1 | Water is the medium in which life began and where most life processes still occur. | Aqueous solution, cytoplasm, tissue fluid, blood, oceans; first cells evolved in water. |
| A1.1.2 | Water molecules are polar because O-H electrons are shared unequally. | Polar covalent bond, $\delta^+$, $\delta^-$, hydrogen bond, bent molecule. |
| A1.1.3 | Cohesion between water molecules produces surface tension and supports xylem transport. | Surface tension, water striders / basilisk, transpiration, tension, water column. |
| A1.1.4 | Adhesion helps water stick to other polar surfaces such as cellulose, glass and soil particles. | Capillary action, xylem walls, root hairs, soil water films. |
| A1.1.5 | Water dissolves many hydrophilic substances and acts as the medium for metabolism and transport. | Hydrophilic, hydrophobic, enzymes, ions, blood plasma, wax cuticle. |
| A1.1.6 | Water's physical properties shape aquatic life. | Buoyancy, viscosity, thermal conductivity, specific heat, loon, ringed seal. |
| A1.1.7 HL | Earth's water may have arrived in hydrated asteroids and was retained because Earth could keep it. | Hydrated minerals, deuterium, gravity, condensation, crust water. |
| A1.1.8 HL | Liquid water is central to the search for life on other planets. | Habitable zone, Goldilocks zone, G / K / M stars, atmosphere, magnetic field. |

## Memory chain

Memorise the logic, not isolated facts. In exam answers, always move from molecular structure to biological consequence.

**Polar O-H bonds** → Unequal electron sharing → **Hydrogen bonds** → Cohesion + adhesion → **Biological functions**

## Must-know definitions

- Aqueous solution: a solution in which water is the solvent.
- Cohesion: attraction between water molecules.
- Adhesion: attraction between water and another polar or charged material.
- Surface tension: strong cohesive effect at the water surface.
- Hydrophilic: dissolves readily in water.

## Must-know processes

- Transpiration: evaporation of water from leaves, mainly through stomata.
- Capillary action: upward movement through narrow spaces because of cohesion plus adhesion.
- Goldilocks zone: orbital region where liquid water can exist.
- Buoyancy: upward force from a fluid on an object placed in it.
- Specific heat: how much heat a substance can gain or lose without changing temperature much.

## A1.1.1 Water as the medium of life

Life first evolved in water, and water remains the medium in which most biochemical processes occur. Early Earth had to cool before liquid water and the water cycle could exist. Once water was present, it provided the solvent needed for the reactions of the first cells.

### Why life began in water

- Biochemical reactions need a solvent so that molecules can move, collide and react.
- Ocean water provided that solvent before terrestrial environments were available.
- The first cells separated their internal water-rich cytoplasm from surrounding ocean water with a membrane.

### Where water is biologically important

- Cytoplasm of every cell.
- Fluid inside organelles.
- Intercellular or tissue fluid between cells.
- Blood and other body fluids.
- Habitats such as oceans, lakes and rivers.

| Aqueous solution | Biological example | Why it matters |
|---|---|---|
| Water as solvent | Cytoplasm | Allows metabolic reactions to occur in solution. |
| Water as solvent | Blood plasma | Transports nutrients, wastes and other dissolved substances. |
| Water as habitat | Oceans, rivers, lakes | Provides a living environment for aquatic organisms. |

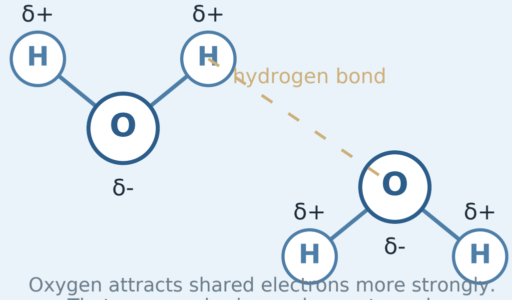
## A1.1.2 Structure and polarity of water molecules

### What gives water polarity?

Each water molecule contains one oxygen atom bonded to two hydrogen atoms by covalent bonds. The electrons are not shared equally: oxygen attracts them more strongly, so the oxygen end becomes partially negative and the hydrogen ends partially positive.

- O-H bonds are polar covalent bonds.
- Water is a polar molecule because opposite charges are separated within its bent shape.
- Hydrogen bonds form between the $\delta^+$ hydrogen of one water molecule and the $\delta^-$ oxygen of another.

### Water molecule and hydrogen bond




Oxygen attracts shared electrons more strongly. That uneven sharing makes water polar.

### Polar vs non-polar covalent bonds

- Non-polar covalent: electrons shared equally; no significant partial charges.
- Polar covalent: electrons shared unequally; creates partial charges and molecular polarity.
- In water, polarity is the starting point for hydrogen bonding and all major biological effects.

### Nature of science note

- Scientific measurements can change with better tools, different methods or natural change over time.
- Example: recorded depths of Challenger Deep and heights of Everest vary slightly between sources.
- The chapter values highlight scale: 10,984 m below sea level versus 8,848 m above, a difference of more than 19 km.

## A1.1.3 Cohesion of water molecules

Cohesion means attraction between molecules of the same substance. In water, cohesion arises because neighbouring water molecules form hydrogen bonds with one another. Even though each bond is weak, the total effect is biologically powerful.

### Consequences of cohesion

- Surface tension: molecules at the surface are pulled sideways and downward more strongly than upward.
- Water surfaces can support small organisms and even brief running movements if the surface is not broken.
- Water forms a connected column inside xylem because molecules remain linked by hydrogen bonding.

### Surface tension as a habitat

- Paperclips can float if placed carefully because the surface behaves like a stretched film.
- Water striders exploit this surface layer.
- Basilisk lizards increase surface area with webbed feet and must keep running to avoid sinking.

### Transport of water under tension in xylem

A transpiring leaf creates a low-pressure region. Because water molecules are cohesive, the whole water column in xylem is pulled upward together.

Soil water → Root hair → **Xylem** → Leaf → **Stoma** → Atmosphere

Transpiration at the stoma lowers pressure in the leaf. Cohesion pulls the water column upward; adhesion helps it cling to xylem walls.

## A1.1.4 Adhesion between water and other polar substances

### Adhesion explained

- Adhesion is attraction between water and a different polar or charged material.
- Examples: cellulose in xylem walls, glass in capillary tubes, polar particles in soil.
- Adhesion helps stop the water column in xylem from sliding back down.

### Capillary action

- In narrow spaces, adhesion pulls water against the surface and cohesion drags more water with it.
- This explains water rising in capillary tubes and through tiny spaces in plant tissues and soil.
- Root hairs can absorb water from thin films held around soil particles.

| Feature | Cohesion | Adhesion |
|---|---|---|
| Definition | Attraction between water molecules. | Attraction between water and another polar / charged surface. |
| Important examples | Surface tension; connected xylem column. | Capillary rise; water clinging to xylem walls or soil particles. |
| Shared cause | Polarity and hydrogen bonding. | Polarity and hydrogen bonding. |

## A1.1.5 The solvent properties of water

Because water is polar, it is a very effective solvent for many charged and polar substances. This makes it the medium for metabolism inside cells and for transport within plants and animals. At the same time, some important biological molecules must remain hydrophobic and insoluble.

| Type of substance | Examples from the chapter | Why it matters biologically |
|---|---|---|
| Hydrophilic (water-loving) | Glucose, ions, amino acids, many proteins, enzyme-rich cytoplasm, plasma solutes | Dissolve readily; support metabolism, diffusion and transport in aqueous solution. |
| Hydrophobic (water-fearing) | Steroid hormones, hydrophobic regions of membrane proteins, wax cuticle on leaves | Help molecules cross membranes, anchor proteins in membranes and reduce water loss. |

### Water as the medium for metabolism

- The cytoplasm and the fluids inside organelles are aqueous solutions.
- Most enzymes catalyse reactions in water-based environments.
- Cells therefore depend on water not only as a reactant sometimes, but as the setting in which reactions can happen efficiently.

### Water as the medium for transport

- Xylem carries dissolved inorganic ions upward from roots to leaves.
- Blood plasma is an aqueous solution carrying a huge range of dissolved substances.
- Diffusion into and out of cells depends on substances moving in watery environments.

### Why hydrophobic molecules still matter

- Steroid hormones can pass through membranes because they are non-polar.
- Membrane proteins often contain both hydrophilic and hydrophobic regions so they can anchor and still interact with cell fluids.
- The wax cuticle of leaves limits evaporation and prevents dehydration.

### High-value exam point

- Do not say ‘everything important dissolves in water’.
- A strong answer explains that water supports most metabolism because many substances are hydrophilic, while some key structures and signals depend on being hydrophobic.

## A1.1.6 Physical properties of water and consequences for aquatic animals

| Property | Water | Air | Biological consequence |
| --- | --- | --- | --- |
| Buoyancy | Large upward force equal to the weight of water displaced. | Very small upward force because air is much less dense. | Aquatic animals are supported more easily and can rest at the surface with less skeletal support. |
| Viscosity | Higher resistance to movement. | Much lower resistance. | Aquatic animals need streamlining, webbed feet, flippers or paddle-like limbs. |
| Thermal conductivity | Transfers heat away relatively quickly. | Transfers heat much more slowly. | Animals in water lose body heat faster and need insulation or waterproofing. |
| Specific heat | Temperature changes slowly because water absorbs and releases large amounts of heat with little temperature change. | Temperature changes quickly. | Aquatic habitats are thermally more stable than surrounding air, especially in cold climates. |

### Black-throated loon (Gavia arctica)

- Uses buoyancy to float at the surface.
- Needs energy to overcome water’s viscosity when diving.
- Webbed feet and a streamlined body reduce drag and improve propulsion.
- Oils spread over feathers waterproof them and help reduce heat loss.

### Ringed seal (Pusa hispida)

- Buoyant enough to keep the snout above water while breathing.
- Streamlined body and paddle-like feet help overcome viscosity.
- Thick blubber insulates the body against high thermal conductivity.
- Benefits from water’s relatively stable temperature in Arctic conditions.

### Opportunities that water creates

- Buoyancy supports bodies.
- Stable temperatures reduce thermal shock.
- Water provides a continuous medium for dissolved nutrients and gases.

### Challenges that water creates

- Higher viscosity makes movement harder.
- High thermal conductivity increases risk of heat loss.
- Surface-living and diving organisms need specialised adaptations.

## HL A1.1.7 Origin of water on Earth

For HL, focus on two ideas: where Earth's water may have come from and why Earth was able to keep it. Early Earth was too hot for stable liquid water. As the planet cooled, water could condense and remain on or near the surface.

### Asteroid delivery hypothesis

- Many asteroids contain hydrated minerals rather than liquid water.
- Repeated impacts on early Earth could have released this water into the crust and surface system.
- The hydrogen : deuterium ratio in ocean water is similar to the ratio in many asteroids, which supports the idea.

### Why Earth retained water

- Earth has enough gravity to keep water on or near the surface.
- Surface temperatures became low enough for water to condense.
- Much of Earth's water remains liquid, while some is trapped in the crust and some cycles as vapour and ice.

### Nature of science: evidence is still developing

- Asteroids are not the only proposed source of Earth's water.
- Other ideas include comets and hydrogen trapped in the original material of the planet.
- The explanation is not fully settled; science refines theories as new evidence appears.

### Useful supporting example

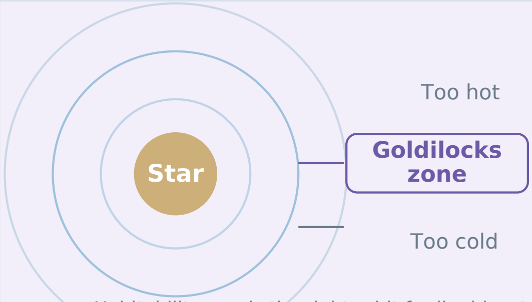
- Some water is almost permanently trapped deep in Earth's crust.
- Geysers release small amounts where underground heat superheats trapped water.
- This illustrates that Earth contains water in more places than the obvious surface reservoirs.

## HL A1.1.8 Search for extraterrestrial life

### Why water guides the search for life

- Life as we know it requires liquid water.
- A planet must lie in a habitable / Goldilocks zone where liquid water can exist.
- Enough gravity is also needed to retain water.
- An atmosphere and magnetic field improve the chances of life by reducing harmful radiation exposure.

### Goldilocks zone




Habitability needs the right orbit for liquid water and enough gravity to retain that water.

### Exam note for HL

- In this topic, limit retention factors to gravity and temperatures low enough for condensation.
- For the origin of Earth's water, focus on asteroids as the syllabus explanation, while still recognising that science considers alternative hypotheses.
- Common names or scientific names of the example organisms are acceptable in exams.

# Rapid synthesis: common comparisons and exam traps

| Compare | High-scoring distinction | Common weak answer |
| --- | --- | --- |
| Polar vs non-polar covalent bond | Polar bonds share electrons unequally and create partial charges; non-polar bonds share equally and do not. | Saying only that one bond is ‘stronger’. |
| Cohesion vs adhesion | Cohesion is water-water attraction; adhesion is water-other polar surface attraction. | Using the two terms as if they mean the same thing. |
| Hydrophilic vs hydrophobic | Hydrophilic substances dissolve in water; hydrophobic substances do not and often help form membranes or water barriers. | Assuming hydrophobic means biologically unimportant. |
| Specific heat vs thermal conductivity | Specific heat is resistance to temperature change; thermal conductivity is rate of heat transfer. | Using both terms simply to mean ‘temperature’. |

## Pathway to write from memory

- Start with water leaving the leaf through a stoma by transpiration.
- This creates tension (low pressure) in the leaf and xylem.
- Cohesion pulls the continuous water column upward.
- Adhesion helps the column remain attached to xylem walls.
- Water taken from the soil through root hairs replaces it.

## Cause-and-effect chain to memorise

- Unequal electron sharing -> partial charges.
- Partial charges -> hydrogen bonding.
- Hydrogen bonding -> cohesion / adhesion / surface tension.
- These properties -> xylem transport, capillary action, aquatic surface habitats and solvent power.

## Nature of science reminders

- Measurements can change because methods improve.
- Competing hypotheses may coexist when evidence is incomplete.
- Science strengthens explanations by refining them over time.

## Revision shortcut

- When stuck, always ask: what property of water is being tested, what causes it, and what is the biological consequence?
- That structure -> property -> function chain rescues many 4- to 10-mark responses.

# Exam toolkit: recall, explain and apply

## High-value practice questions from the chapter

- Q1. Describe how a polar covalent bond differs from a non-polar covalent bond.
- Q2. Describe the pathway and the forces involved in getting water from the soil to a leaf in the upper branches of a tree.
- Q3. State an example of a molecule soluble in the cytoplasm and give its function.
- Q4. State an example of a molecule insoluble in the cytoplasm and give its function.
- Q5. Describe two adaptations of the black-throated loon for overcoming the viscosity of water.
- Q6 (HL). State three conditions needed for a planetary body to be in the Goldilocks zone.

## What strong answers include

- Q1: mention electron sharing plus the presence or absence of partial charges.
- Q2: start at the leaf, include transpiration, tension, cohesion, adhesion, xylem and root hairs.
- Q3: use a real hydrophilic example such as glucose or an ion and link it to respiration, transport or cell chemistry.

## More answer pointers

- Q4: use a real hydrophobic example such as a steroid hormone or leaf cuticle wax and state its role.
- Q5: choose features directly linked to reducing drag or improving propulsion, such as webbed feet or streamlining.
- Q6 HL: mention suitable temperature for liquid water, enough gravity to retain water, and an orbital position in the habitable zone.

## Rapid recall checklist

- I can explain why water is polar.
- I can distinguish cohesion from adhesion.
- I can explain transport in xylem under tension.
- I can compare water with air for buoyancy, viscosity, thermal conductivity and specific heat.
- I can explain why water is central to the search for extraterrestrial life.

## One-sentence final summary

Water is essential for life because its polarity and hydrogen bonding make it an exceptional solvent, a stable transport medium, a supportive habitat and a substance with distinctive physical properties that shape the biology of organisms on Earth - and guide the search for life beyond it.