Water

A1.1 · SL and AHL

Why can water support and cool an animal?

One molecule, several biological consequences

A leaf droplet, water rising in a stem and a seal swimming in cold water all depend on water properties.

Connect molecular polarity to interactions, physical properties and biological consequences.

Calculations and experimental data in this unit are invented teaching examples; given physical constants are stated.

Life on land still needs water

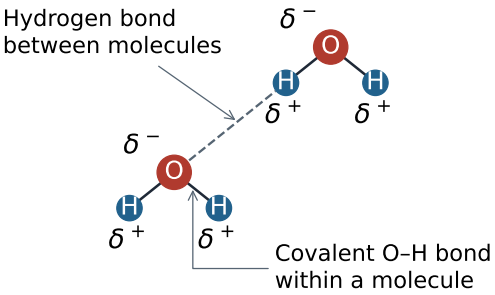
Cells maintain aqueous conditions

The earliest cells arose in water. Most cellular reactions still occur in an aqueous medium where reactants can move and meet enzymes.

Blood plasma transports dissolved glucose; plant transport fluids carry dissolved substances.

Terrestrial organisms maintain internal aqueous environments and replace water losses. Dormancy with reduced activity is not water-independent active metabolism.

Read a water diagram at two scales



Solid covalent bonds are within molecules; a dashed hydrogen bond links different molecules.

Unequal electron sharing produces polarity

Partial charge is not a free ion

Oxygen attracts shared electrons more strongly than hydrogen: O bears δ^- and H bears δ^+.

The bent arrangement means the bond polarities do not cancel. The molecule is polar but has zero net charge.

In a correct diagram, the hydrogen bond connects an appropriate H on one water molecule to O on another, not H to H.

Heating does not normally decompose water

Bond or interaction	What changes?
Covalent O–H	Strong bond within a molecule; survives ordinary boiling
Hydrogen bond	In liquid water: weaker intermolecular attraction that continually forms and breaks
Boiling	Separates intact molecules into vapour; not a supply of hydrogen and oxygen gas

Cohesion links water molecules

Many weak attractions have a large combined effect

Cohesion is attraction between molecules of the same substance. Hydrogen bonding contributes to cohesion in water.

Creating more liquid surface requires energy. Surface tension tends to resist stretching the surface.

The surface remains liquid: it is not a solid skin and cannot support an unlimited load.

A pond skater uses a liquid surface

Support depends on the whole contact arrangement

Water-repellent legs spread the load and deform the surface; surface-tension forces help support the animal.

Mass, leg geometry, wetting and liquid properties matter. Do not generalize the result to every insect or animal.

Detergent changes surface tension and wetting, so detergent concentration is a change to the experimental system.

From leaf evaporation to xylem tension

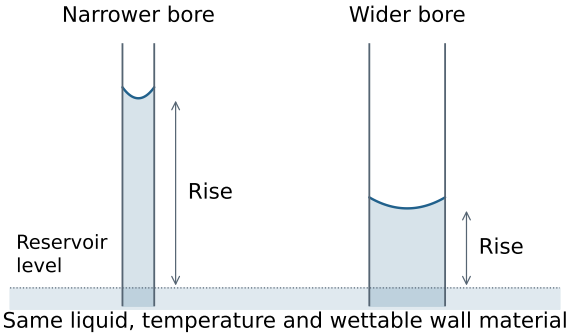
The column transmits a pull

Evaporation from leaves helps generate tension: a pulling stress in the water column.

Cohesion links the column so the pull can be transmitted. Water molecules do not actively crawl upwards.

A gas-filled break can interrupt the column. Cohesion is strong but has limits.

A wettable capillary can raise water



Under matching wettable conditions, the narrower bore supports a greater equilibrium rise.

Adhesion connects water to a different material

The wall chemistry matters

Adhesion acts between water and another material, including polar or charged groups on cell walls and soil particles.

In a wettable narrow space, surface interactions can support water until the raised weight balances the upward force.

A waxy nonpolar surface may resist wetting. Narrow geometry alone does not guarantee a rise.

Capillary action is part of plant water behaviour

A glass tube is not a whole tree

Capillary spaces in soil and cell walls help retain and distribute water.

Long-distance ascent in xylem also depends on transpiration-driven tension in a cohesive water column.

Distinguish the attraction to a wall from attraction between water molecules; do not give capillary rise as the whole tall-tree explanation.

Orient water around an ion

1. **Positive ion.** The oxygen side of water tends to face Na^{+}.
2. **Negative ion.** Hydrogen sides tend to face Cl^{-}.
3. **Interpret.** Water surrounds dissolved ions; the ions do not become water molecules.

Hydrophilic substances can use an aqueous medium

Transport and metabolism depend on suitable solubility

Many ions and small polar molecules interact favourably with water. Dissolved glucose moves in blood plasma; mineral ions move in xylem sap.

Dissolved reactants can diffuse and meet enzymes. Solubility still depends on substance, temperature and concentration.

Dissolving is different from melting or forming a suspension. A clear solution need not be pure water.

Hydrophobic regions are useful too

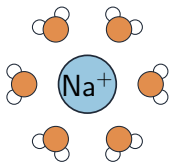
Insolubility helps organize boundaries

Nonpolar regions interact poorly with water and tend to aggregate rather than dissolve.

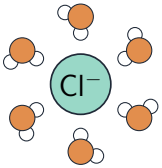
Membrane lipids have water-interacting polar regions and water-avoiding nonpolar regions, helping organize a boundary around an aqueous cell.

Hydrophobic regions also contribute to protein folding. A useful biological solvent does not need to dissolve everything.

Why salt dissolves in water



oxygen (δ^-) sides face the positive ion



hydrogen (δ^+) sides face the negative ion

O of water
H of water

The polar water molecules surround each ion

Match each property with its consequence

Water property versus air	**Biological consequence**
Greater buoyancy at equal displaced volume	Supports body weight; can oppose descent
Higher dynamic viscosity	Contributes to resistance during swimming
Higher thermal conductivity	Can increase heat transfer from a warm body
Higher specific heat capacity per mass	Reduces warming for equal mass and retained energy

A seal and a loon meet different mechanical demands

Support does not remove drag

A ringed seal uses flippers and a streamlined body in water. Buoyancy helps support its weight; propulsion still works against drag.

A black-throated loon uses webbed feet for swimming and wings for aerodynamic forces in flight. Its two media differ in support and resistance.

Viscosity is not density. Drag also depends on shape, size, speed and flow conditions.

Two thermal properties answer different questions

Transfer rate versus temperature change

Thermal conductivity describes heat transfer down a temperature gradient. A warm animal can lose heat quickly to cold water.

Specific heat capacity describes energy needed to change a mass's temperature. A large water body can buffer temperature changes.

These effects coexist: the animal can cool while the surrounding water warms very little.

Insulation changes the rate of heat transfer

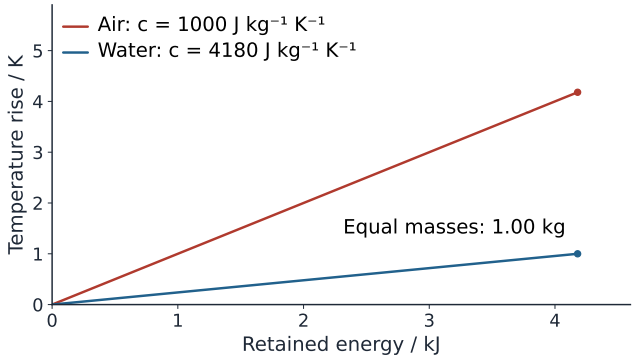
Link a named animal to a mechanism

Ringed-seal blubber slows heat loss to cold water; it does not stop every energy transfer.

Air trapped in suitable dry feathers can insulate a bird. Water movement, body size and temperature difference also affect cooling.

High water heat capacity does not mean every lake or organism stays at constant temperature.

Equal mass and energy give unequal warming



For the same mass and retained energy, water's higher specific heat capacity gives a smaller temperature rise.

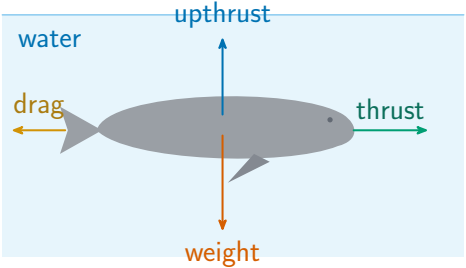
Calculate the equal-mass comparison

1. **Model.** $\Delta T = Q/(mc)$, with no losses or phase change.
2. **Water.** $Q = 4180$ J, $m = 1.00$ kg, $c = 4180$ J kg^{-1} K^{-1}: $\Delta T = 1.00$ K.
3. **Air.** For $c = 1000$ J kg^{-1} K^{-1}: $\Delta T = 4.18$ K.

Decision

Equal volume is a different comparison. This is not a calculation of a seal's cooling rate.

Forces on a swimming seal



upthrust supports weight,
but does not remove drag

streamlined shape and
flippers: less drag, more thrust

Water's density gives large upthrust and drag

Design a fair spreading comparison

Measure an outcome before naming its cause

Place equal-volume drops on clean surfaces at the same temperature; define contact angle from a side photograph.

Control preparation, drop volume, time after placement and camera geometry. Repeat trials and report scatter.

Contact angle measures wetting under stated conditions, not cohesion alone. Contamination or unequal volume can change the result.

A fair test of a water property



surface A



surface B

change: the surface
measure: contact angle θ
hold: drop volume, temperature, cleaning, time, camera angle
repeat and report the scatter

> Only the surface should differ

AHL: distinguish a source from retention

An asteroid hypothesis needs separate retention conditions

Water-bearing asteroidal material is a proposed early source. This does not identify one asteroid as the source of all oceans.

Gravity helps Earth retain material; sufficiently cool conditions allow water vapour to condense.

Neither gravity nor temperature alone guarantees lasting liquid water. Persistent water gave biological evolution a medium.

AHL: a habitable zone is a search guide

Potential liquid water does not detect life

The Goldilocks or habitable zone is a stellar region where surface liquid water could be possible on a suitable planet.

Its position depends on the star; actual conditions also depend on atmosphere, pressure and planetary properties.

Water is a useful target for known-life chemistry, not proof of life. A moon outside the zone may retain subsurface liquid water.

Try an energy and wetting comparison

Work before revealing the answer

Find the retained energy when 0.200 kg water warms by 5.0 K, using $c = 4180$ J kg^{-1} K^{-1}.

Contact angles on A are 68°, 71°, 69°; on B, 108°, 112°, 110°. Find each mean and identify the more readily wetted surface.

Then explain a control, a limitation and the difference between thermal conductivity and heat capacity.

Reveal: connect numerical results to their limits

1. **Energy.** $Q = mc\Delta T = 0.200(4180)(5.0) = 4180$ J, about 4.2 kJ to two significant figures.
2. **Mean angles.** A: $(68 + 71 + 69)/3 = 69.3°$; B: $(108 + 112 + 110)/3 = 110°$. A is more readily wetted.
3. **Boundary.** The energy model omits container heating and losses; contact angle does not measure **cohesion** alone.

Check yourself

Molecule → property → organism

Distinguish partial charges, covalent bonds and hydrogen bonds. Ordinary boiling does not break O–H bonds.

Name the relevant property: cohesion or adhesion; viscosity or density; conductivity or heat capacity.

State comparison conditions, keep calculation units explicit and match an experimental conclusion to its measured outcome.