2.2 Water

Essential idea: Water is the medium of life.

The cohesive nature of nature gives it surface tension. The surface tension in turn allows organisms such as pond skaters (above) to move across the surface. For pond skaters the surface of water is their habitat. The surface tension transmits vibrations from fallen invertebrates - this allows pond skaters to detect and locate their prey.

By Chris Paine

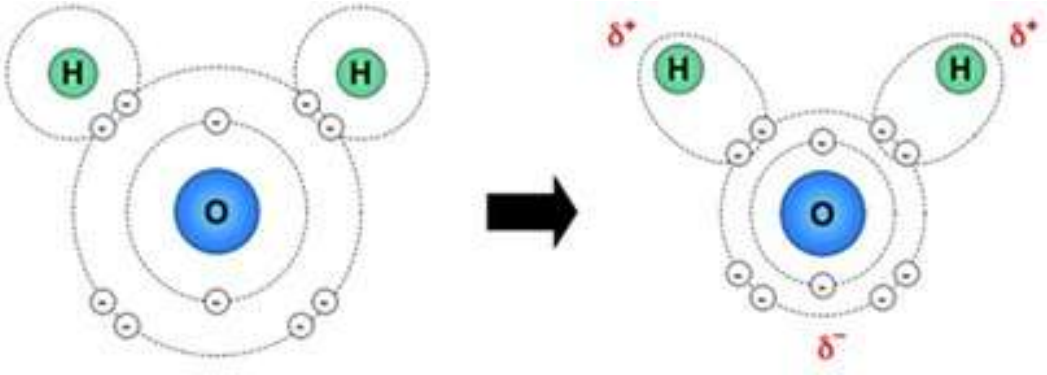
http://www.bioknowledgy.info/

Understandings, Applications and Skills

	Statement	Guidance
2.2.U1	Water molecules are polar and hydrogen bonds form between them.	
2.2.U2	Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water.	Students should know at least one example of a benefit to living organisms of each property of water. Transparency of water and maximum density at 4°C do not need to be included.
2.2.U3	Substances can be hydrophilic or hydrophobic.	
2.2.A1	Comparison of the thermal properties of water with those of methane.	Comparison of the thermal properties of water and methane assists in the understanding of the significance of hydrogen bonding in water.
2.2.A2	Use of water as a coolant in sweat.	
2.2.A3	Modes of transport of glucose, amino acids, cholesterol, fats, oxygen and sodium chloride in blood in relation to their solubility in water.	

Water molecules and their bonds

- Water (H_2O) is made up of two hydrogen atoms covalently bound to an oxygen atom
- While this bonding involves the sharing of electrons, they are not shared equally
- The number of protons in each atom is different; oxygen atoms have 8 whilst hydrogen atoms have just 1
- having more protons the oxygen atoms attract the electrons more strongly
- Thus the oxygen end of the molecule becomes slightly negative and the hydrogen end becomes slightly positive



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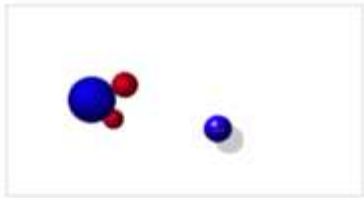
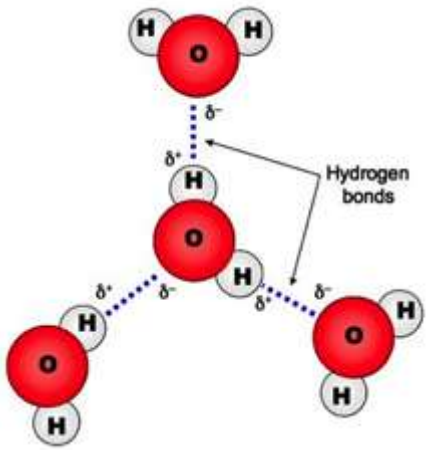
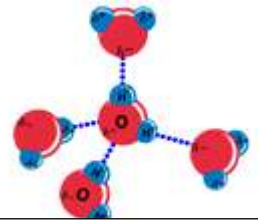


http://www.colorado.edu/physics/2000/applets/h2ob.html



- Covalently bonded molecules that have a slight potential charge are said to be polar
- The slightly charged regions of the water molecule can attract other polar or charged compounds
- Water molecules can associate via weak hydrogen bonds
- Hydrogen bonds are transitory in nature – they constantly form, break and re-form

Animated tutorial on hydrogen bonding



http://programs.northlandcollege.edu/biology/biology1111/animations/hydrogenbonds.html

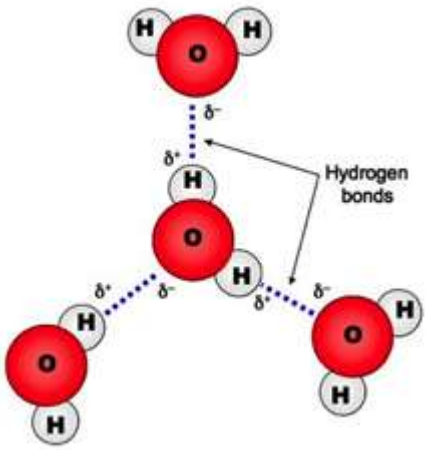
Properties of water molecules

Nature of science: Use theories to explain natural phenomena - the theory that hydrogen bonds form between water molecules explains the properties of water. (2.2)

The observable properties of water are explained by cohesion, adhesion, solvent and thermal properties, which are in turn explained by hydrogen bonding.

Cohesion:

- This property occurs as a result of the polarity of a water molecule and its ability to form hydrogen bonds
- Although hydrogen bonds are weak the large number of bonds present (each water molecule bonds to four others in a tetrahedral arrangement) gives cohesive forces great strength
- Water molecules are strongly cohesive (they tend to stick to one another)



http://ib.bioninja.com.au/standard-level/topic-3-chemicals-of-life/31-chemical-elements-and.html

Water droplets form because the cohesive forces are trying to pull the water into the smallest possible volume, a sphere.

Surface tension is caused by the cohesive hydrogen bonding resisting an object trying to penetrate the surface.

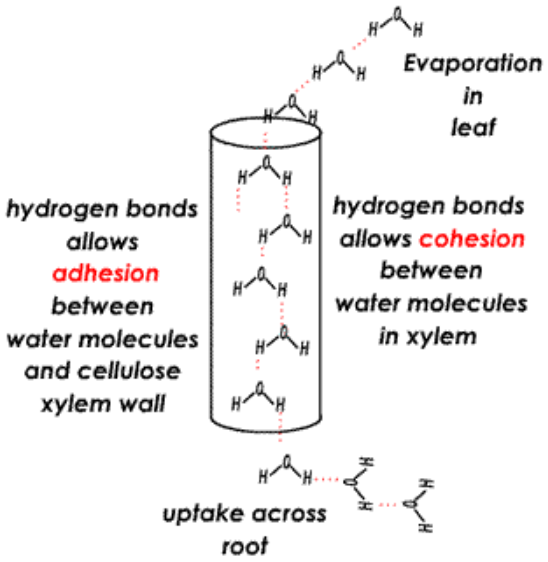
n.b. capillary action involves cohesion and adhesion and so dealt with under adhesion.

Properties of water molecules

Nature of science: Use theories to explain natural phenomena - the theory that hydrogen bonds form between water molecules explains the properties of water. (2.2)

Adhesion:

- This property occurs as a result of the polarity of a water molecule and its ability to form hydrogen bonds
- Water molecules tend to stick to other molecules that are charged or polar for similar reasons that they stick to each other
- Again similarly individual hydrogen bonds are weak, but large number of bonds gives adhesive forces great strength



http://click4biology.info/c4b/9/plant9.2.htm

Water droplets stick to surface and seem to defy gravity because of form because the adhesive forces that bond them to the surface of the grass blade.

Capillary action is caused by the combination of adhesive forces causing water to bond to a surface, e.g. the sides of a xylem vessel and the cohesive forces bonding water molecules together. Capillary action is helpful in the movement of water during transpiration and also when you drink using a straw.

http://commons.wikimedia.org/wiki/File:GemeineFichte.jpg

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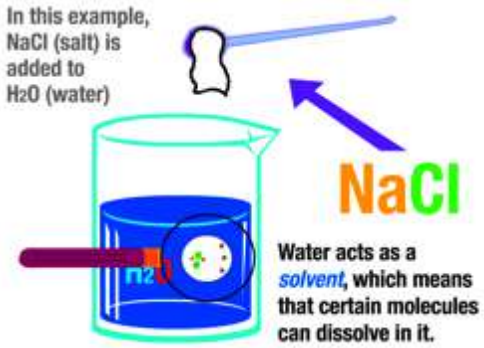
Solvent:

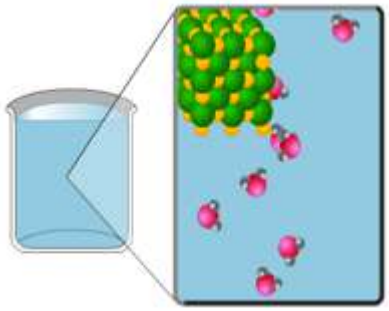
- Water can dissolve many organic and inorganic substances that have charged or polar regions.
- The polar attraction of large quantities of water molecules can interrupt intra-molecular forces (such as ionic bonds) and resulting in the dissociation of the atoms
- Positive atoms, e.g. Na+ end up being surrounded by the negative oxygen regions of water molecules and the Cl- being surrounded by the positive hydrogen region of water molecules
- Because of this water is often (wrongly) referred to as being the 'universal solvent', it is however a very good solvent for many substances.

Metabolic reactions happen most readily in solutions of water – water in cells dissolves the reactants /substrates

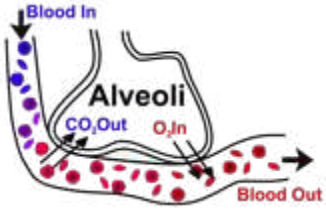
Cells are mostly water therefore diffusion into and out of them happens most easily if the substance concerned is in solution, e.g. before oxygen diffuses from the alveoli to the blood it dissolves into the moist layer lining the alveoli.



http://www.northland.cc.mn.us/biology/Biology1111/animations/dissolve.swf



http://www.sumanasinc.com/webcontent/animations/content/propertiesofwater/water.html



http://upload.wikimedia.org/wikipedia/commons/8/8b/Alveoli.svg

Soluble substances such as sucrose can be easily transported around the plant in the phloem. Once dissolved in the water of the phloem the sucrose can be moved to where it is needed by mass flow.

What kind of bears dissolve in water?

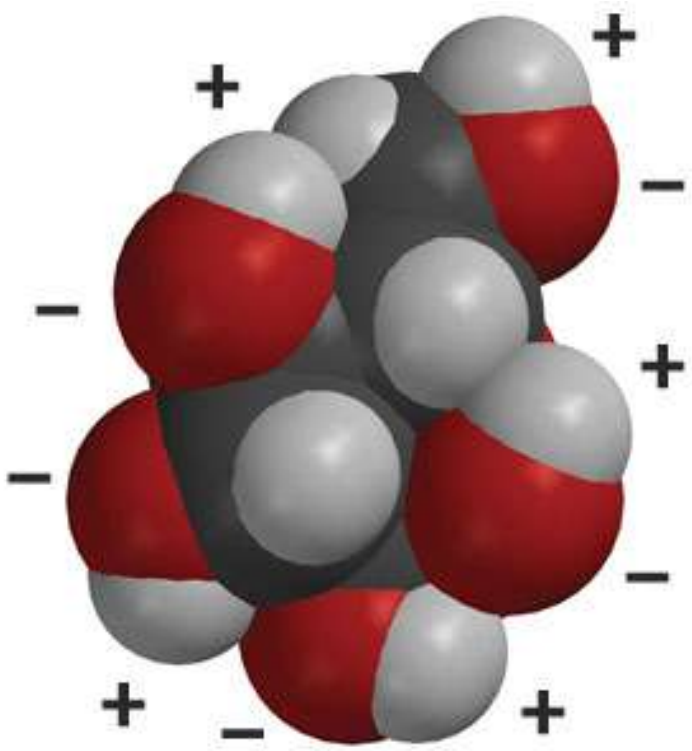
Polar Bears!

https://upload.wikimedia.org/wikipedia/commons/0/09/Polar_

hydrophilic

(water loving)

This term is used to describe substances that are chemically attracted to water.



A space filling molecular diagram of glucose showing the positive and negative charges

- All substances that dissolve in water are hydrophilic, including polar molecules such as glucose, and particles with positive or negative charges such as sodium and chloride ions.
- Substances that water adheres to, cellulose for example, are also hydrophilic.

http://www.middleschoolchemistry.com/img/content/multimedia/chapter_5/lesson_7/glucose.jpg

hydrophobic

(water fearing)

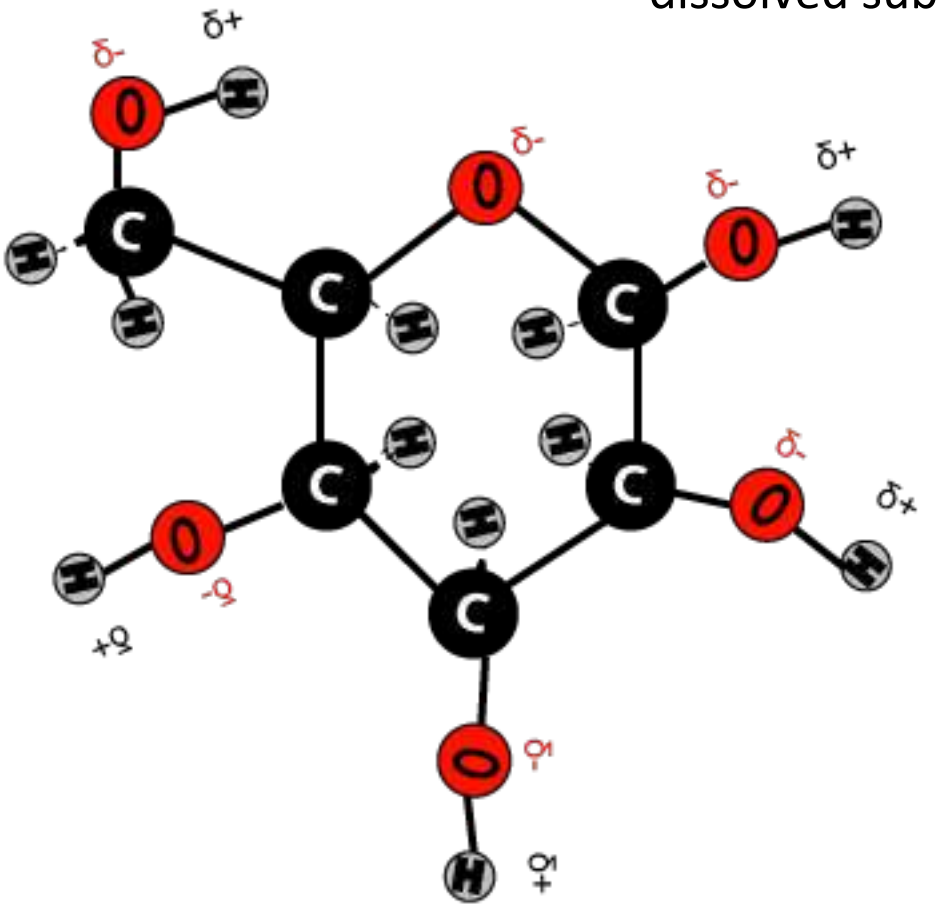
This term is used to describe substances that are insoluble in water

- Molecules are hydrophobic if they do not have negative or positive charges and are nonpolar
- All lipids are hydrophobic, including fats and oils
- Hydrophobic molecules dissolve in other solvents such as propanone (acetone)

http://upload.wikimedia.org/wikipedia/commons/thumb/f/f1/Water_and_oil.jpg/450px-Water_and_oil.jpg

Transport of molecules in the blood

Blood plasma consists of mainly of water (95%) plus dissolved substances which it transports.



Glucose

Glucose

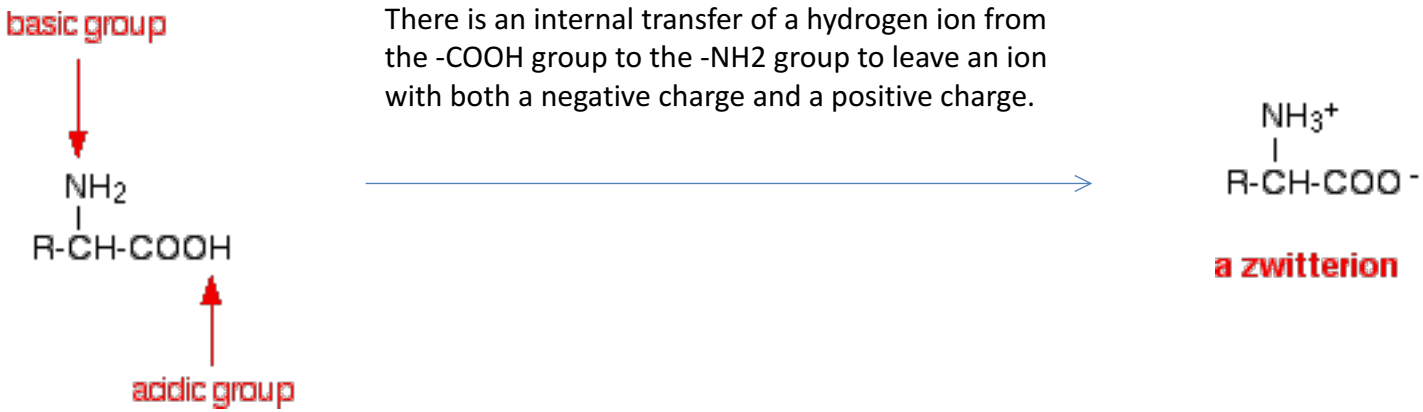
- polar molecule hence freely soluble
- **carried by the blood plasma**

http://4.bp.blogspot.com/-71TuXJIWv8o/UChT59p73fI/AAAAAAAAAFY/B1zkMgT-dlA/s1600/Glucose.png

Transport of molecules in the blood

Amino acids

- Positive and negative charges (due to the amine and acid groups) therefore soluble in water
- R group varies, can be polar, non-polar or charged
- R group determines the degree of solubility
- **carried by the blood plasma**

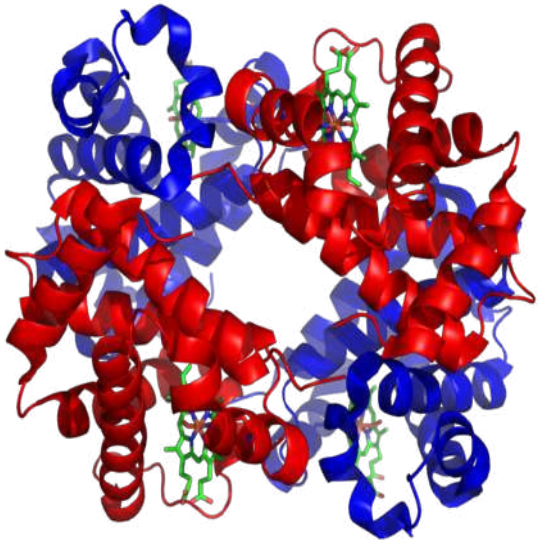


n.b. the bullet points summarise what you need to know. The below chemistry gives a more complete understanding for those who want to know why.

http://chemwiki.ucdavis.edu/Under_Construction/Chemguide_(Jim_Clark)/Properties_of_Organic_Compounds/XIII._Amino_Acids_and_Other_Biochemistry/A._Amino_Acids/2._Acid-Base_Reactions_of_Amino_Acids

Transport of molecules in the blood

O = O



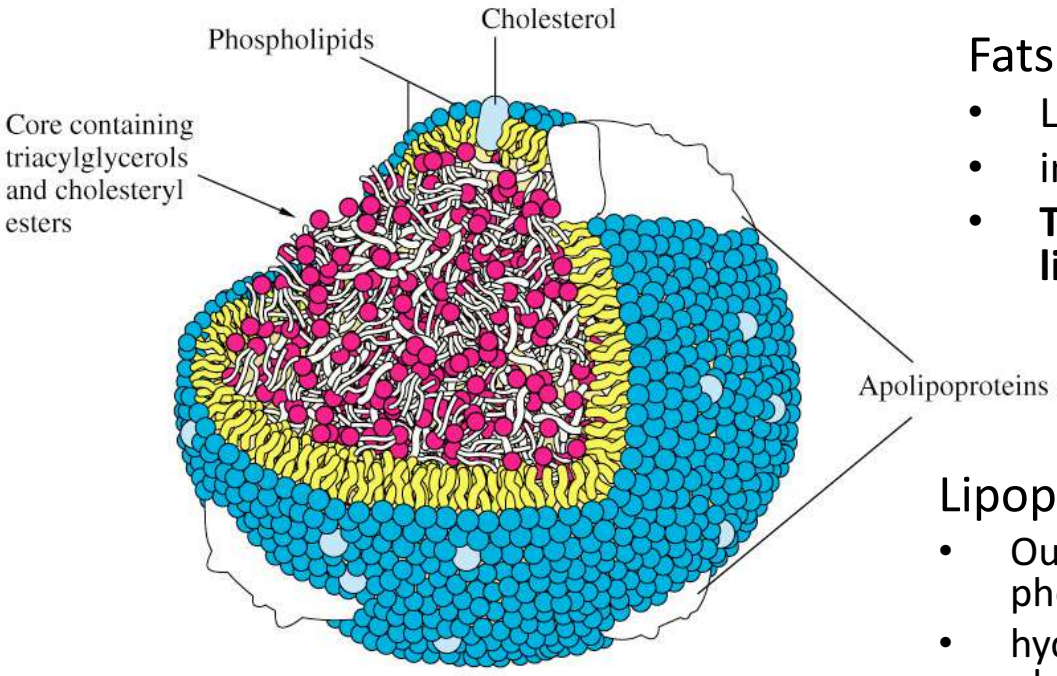
Hemoglobin

Oxygen

- Non-polar molecule
- Due to the small size of an oxygen molecule it is soluble in water, but only just
- water becomes saturated with oxygen at relatively low concentrations
- As temperature increases the solubility of oxygen decreases
- At body temperature (37 °C) very little oxygen can be carried by the plasma, too little to support aerobic respiration
- **hemoglobin in red blood cells carry the majority of oxygen**
- Hemoglobin has (4) binding sites for oxygen

https://upload.wikimedia.org/wikipedia/commons/thumb/3/3d/1GZX_Haemoglobin.png/480px-1GZX_Haemoglobin.png

Transport of molecules in the blood



Fats

- Large, non-polar molecules
- insoluble in water
- **They are carried in blood inside lipoprotein complexes (in the plasma)**

Cholesterol

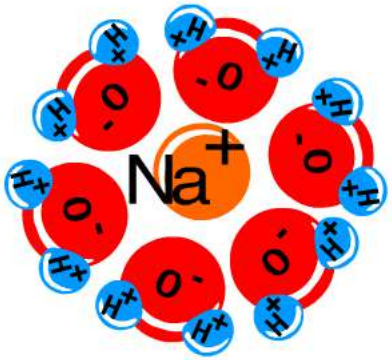
- molecules are hydrophobic, apart
- from a small hydrophilic region at one end
- This is not enough to make cholesterol dissolve in water
- **They are carried in blood in lipoprotein complexes (in the plasma)**

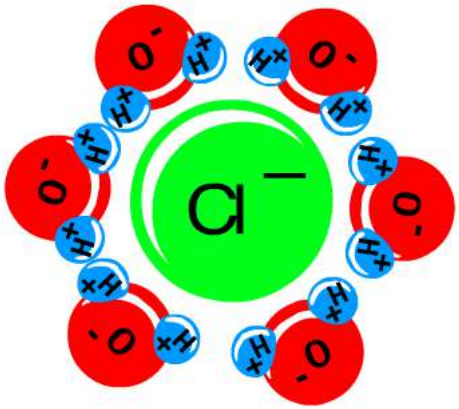
Lipoprotein complex

- Outer layer consists of single layer of phospholipid molecules
- hydrophilic phosphate heads of the phospholipids face outwards and are in contact with water
- The hydrophobic hydrocarbon tails face inwards and are in contact with the fats
- cholesterol molecules are positioned in the phospholipid monolayer - hydrophilic region facing outwards
- Proteins are also embedded in the phospholipid layer (hence the name)

http://chienlab.wikispaces.com/file/view/lipoprotein.jpg/45882185/lipoprotein.jpg

Transport of molecules in the blood





Sodium Chloride

- ionic compound
- freely soluble in water
- dissolving to form sodium ions (Na+) and chloride ions (Cl-)
- **carried in the blood plasma**

http://www.northland.cc.mn.us/biology/Biology1111/animations/dissolve.swf

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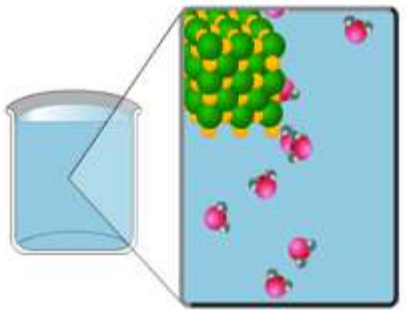
Thermal:

- Water has a high specific heat capacity (4.2 Joules is required to raise the temperature of 1 g of water by 1°C)
- Water has a high heat of vaporisation (amount of energy needed to change from a liquid to a gas or vapour)
- Water has a high heat of fusion (amount of energy needed to be lost to change liquid water to ice)
- These properties are due to many hydrogen bonds that need to be formed or broken to change the temperature or state of water
- Therefore the temperature of water remains relatively stable



http://www.sumanasinc.com/webcontent/animations/content/propertiesofwater/water.html

Water is used by Leaves as a coolant. The heat lost from leaves for evaporation prevents them over-heating. If the leaves get too hot enzymes in their cells will start to denature.

http://www.flickr.com/photos/jaxxon/37559138/

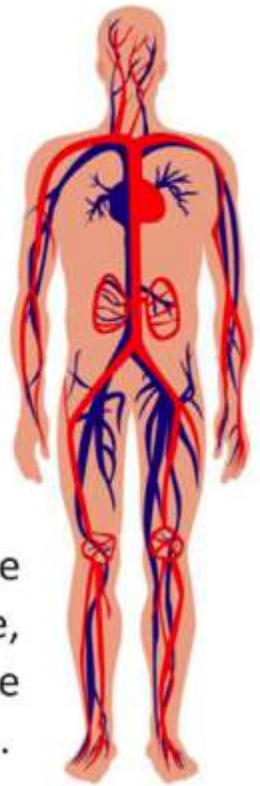
Water as a coolant:

High temperatures damage tissues and denature proteins - causing enzymes to cease to work.

It takes a lot of energy for water to change temperature.
This means that it will heat and cool more slowly than air or land.
This is useful to animals in hot climates - who can use water or mud to cool off in the hot day.

http://image03.webshots.com/3/5/28/47/752847_ph.jpg

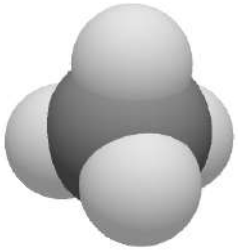
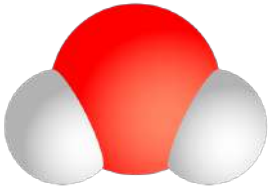
When water evaporates, it removes a lot of energy from the system.
This is felt as a cooling sensation - excess heat energy is removed from the body (latent heat of evaporation). The skin and their blood vessels are cooled.
This also helps aquatic habitats remain at fairly constant temperatures in hot summers.



http://www.telemediamagazine.com/circulation.htm

Water makes up 70% of the body, including the blood. Because it is resistant to temperature change, cooler blood from some parts of the body can be circulated to other parts, cooling them down.

Comparing and contrasting the properties of water and methane

	Methane	Water
		
Formula	CH_4	H_2O
Molecular mass	16	18
Bonding	Single covalent	
Polarity	nonpolar	polar
Density (g cm^{-3})	0.46	1
Specific Heat Capacity (J g^{-1} $^oc^{-1}$)	2.2	4.2
Latent heat of vapourisation (J g^{-1})	760	2257
Melting point (^{o}C)	-182	0
Boiling point (^{o}C)	-160	100

Methane

- waste product of anaerobic respiration in certain prokaryotes living in anaerobic conditions
- Methane can be used as a fuel
- If present in the atmosphere it contributes to the greenhouse effect.

Key chemical property that causes the major differences seen in the physical properties.

Methanogenic prokaryotes

- can be found in swamps, wetlands, the guts of animals (including cattle and sheep)
- can also be found in waste dumps

https://commons.wikimedia.org/wiki/Water_molecule#mediaviewer/File:Water_molecule.svg

https://upload.wikimedia.org/wikipedia/commons/5/55/3D_methane.PNG

Bibliography / Acknowledgments

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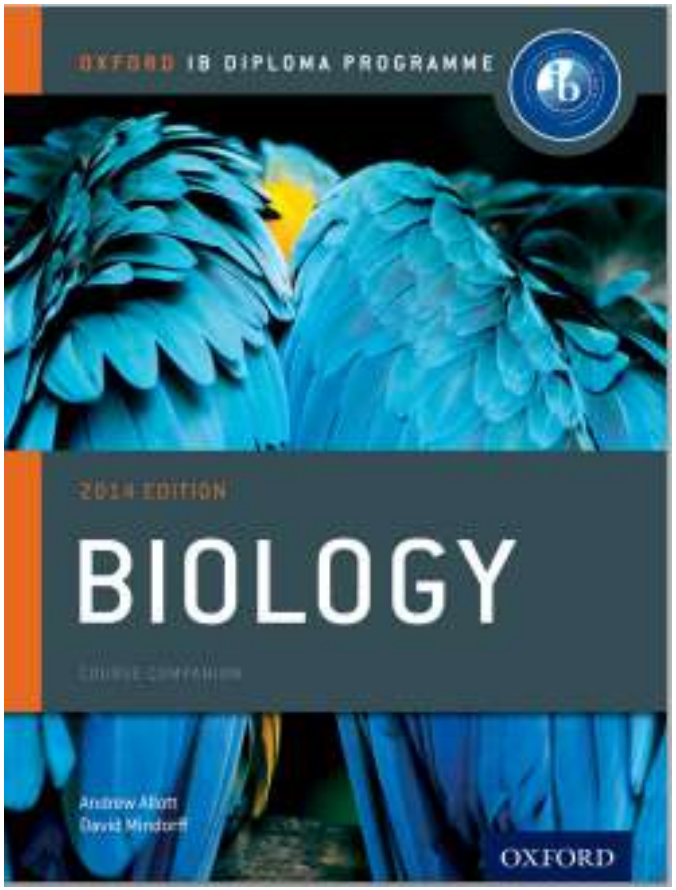

Jason de Nys