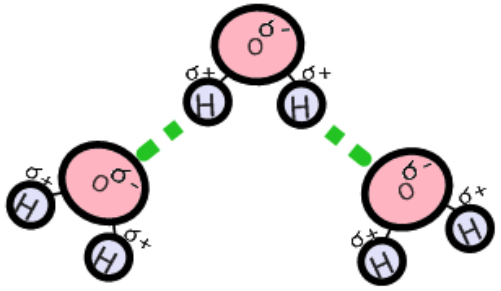


Chemical Elements and Water

Stephen Taylor
Bandung International School

Many elements occur frequently in living organisms or are of use in metabolic processes:

The most commonly occuring elements in living organisms are:

C 6 carbon

H 1 hydrogen

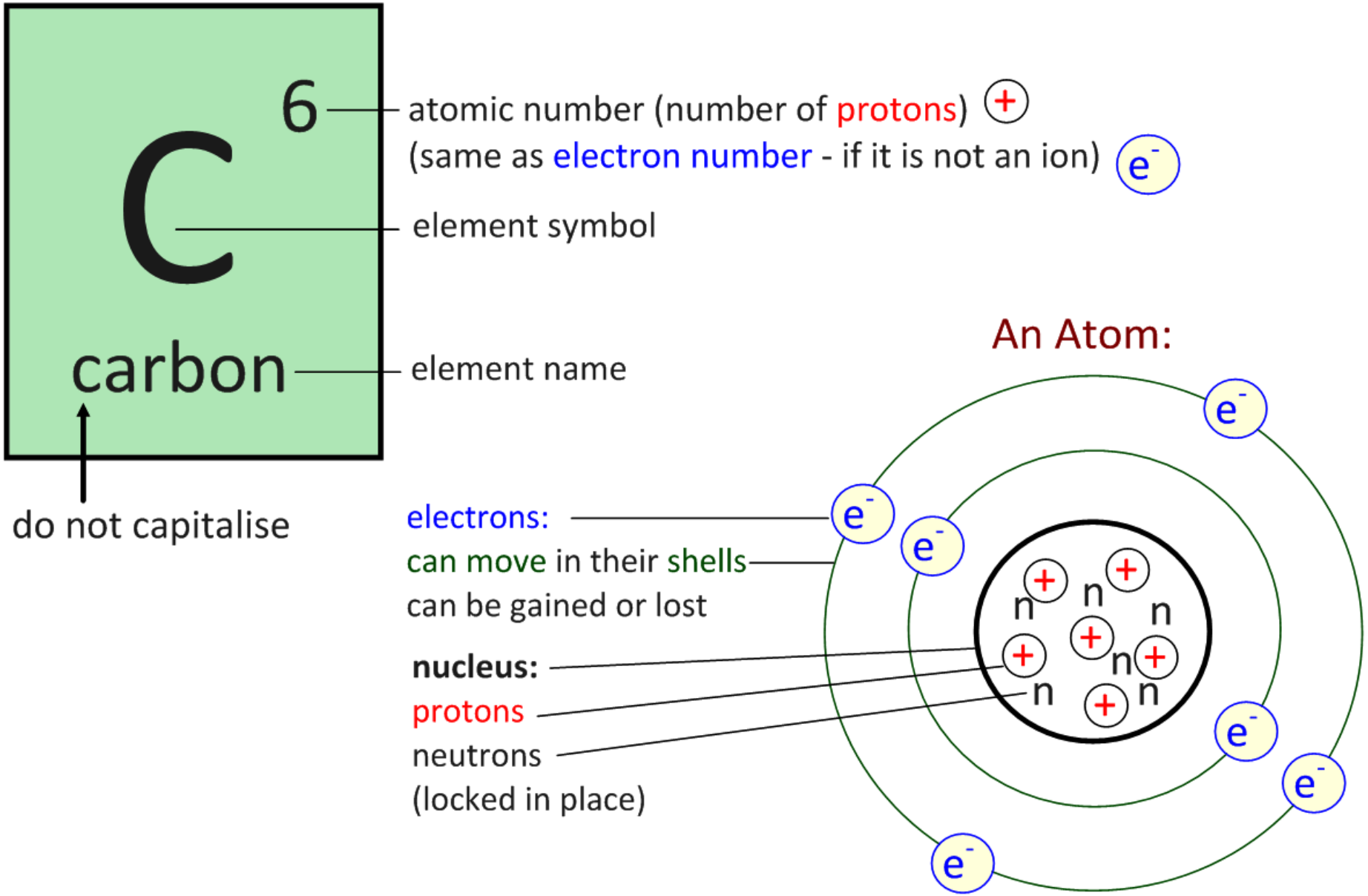
O 8 oxygen

N 7 nitrogen

Other common elements are shaded in green.

	I	II									III	IV	V	VI	VII	VIII
1	1 H hydrogen															2 He
2	3 Li	4 Be									5 B	6 C carbon	7 N nitrogen	8 O oxygen	9 F	10 Ne
3	11 Na sodium	12 Mg magnesium									113 Al	14 Si	15 P phosphorous	16 S sulphur	17 Cl chlorine	18 Ar
4	19 K calcium	20 Ca potassium	21 Sc	22 Ti	23 V	24 Cr	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I iodine	54 Xe
6	55 Cs	56 Ba	57 La	58 Hf	59 Ta	60 W	61 Re	62 Os	63 Ir	64 Pt	65 Au	66 Hg	67 Tl	68 Pb	69 Bi	70 Po	71 At	72 Rn
7	73 Fr	74 Ra	75 Ac	76 Ku	77 Ha													

Elements in the Periodic Table:

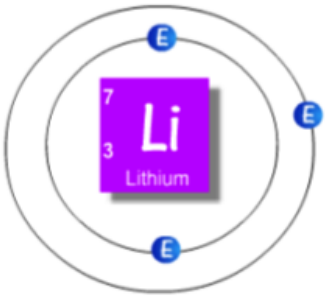


Ions

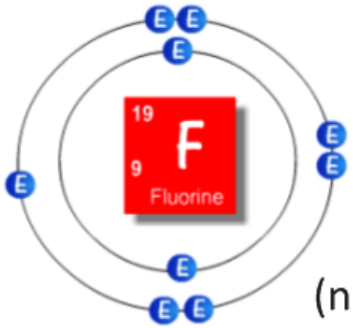
An unreactive (stable) atom has a full outer electron shell.
The inner shell is 'full' with two electrons.
Subsequent shells are 'full' with eight electrons.

inner shell = 2
(full)

outer shell = 1
(not full - lose one!)



Lithium



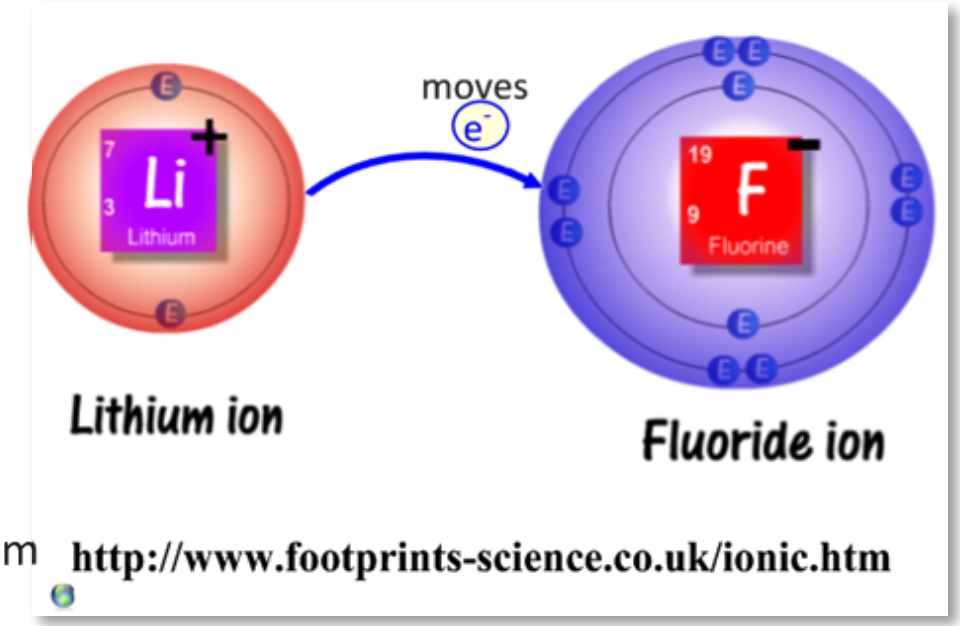
Fluorine

inner shell = 2
(full)

outer shell = 7
(not full - gain one!)

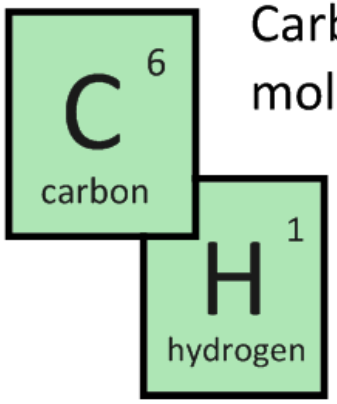
As electrons can be gained or lost, they may move from one atom to another, in order to complete the outer shell of both:

Now:
more protons
than electrons
so
postive CATION

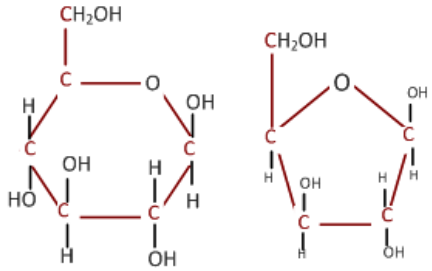


images from

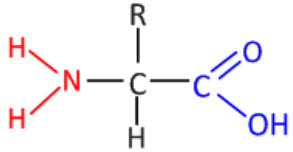
Now:
more electrons
than protons
so
negative ANION
"a negative ion"



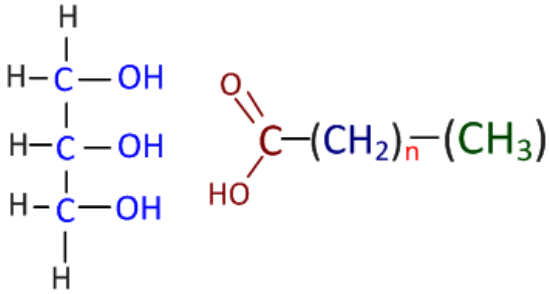
Carbon and hydrogen are the foundation of organic molecules: molecules found in living things:



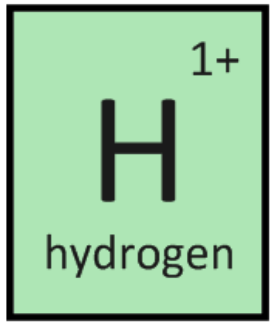
sugars & carbohydrates



amino acids & proteins

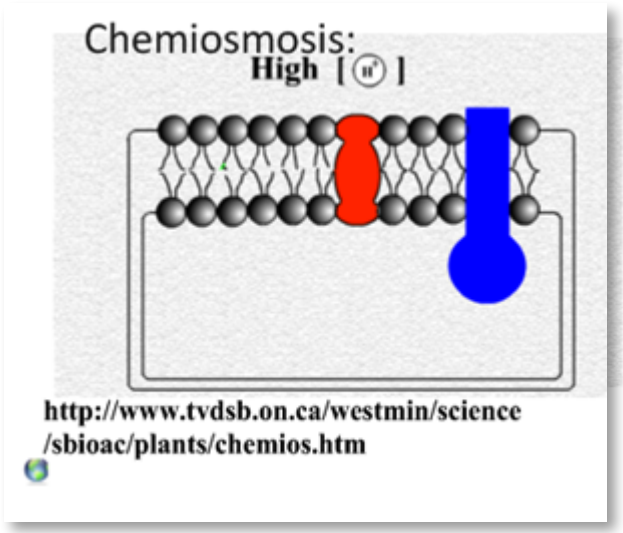


lipids: fats & oils



Hydrogen ions are used in active transport, photosynthesis, cell respiration (through chemiosmosis).

The pH of a solution is a measure of the activity of dissolved H^+ ions.
A low pH (1-6) signifies a high concentration of H^+ ions (high $[H^+]$).
A high pH (8-14) signifies low $[H^+]$.



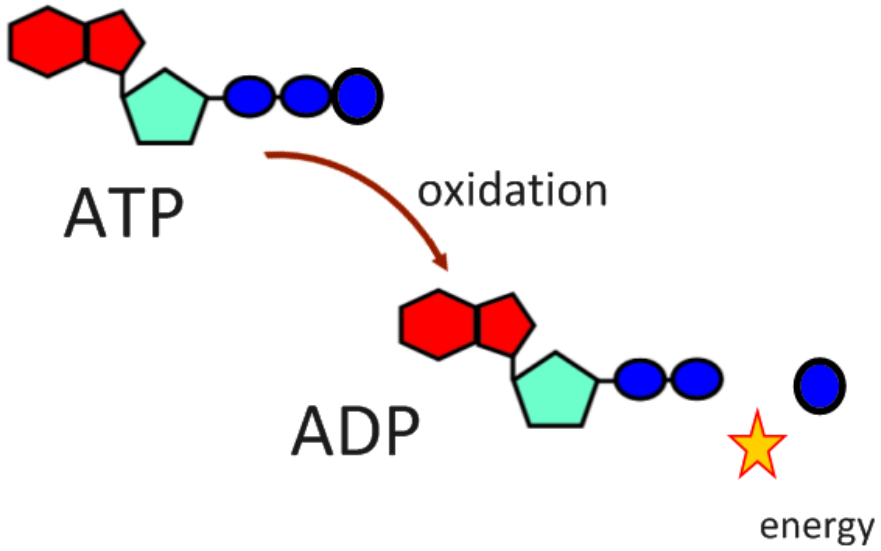
8
O
oxygen

The main role of oxygen is in aerobic respiration.

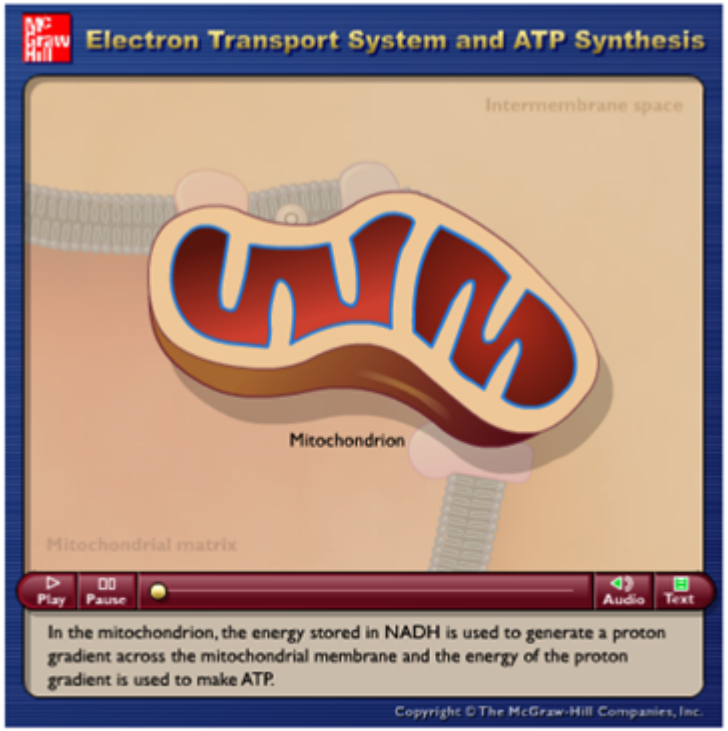
This is in the last stage of cell respiration in the miochondrion: oxidative phosporylation. Oxygen is used to accept electrons following the production of ATP - keeping the whole system flowing.

Oxygen is also used in oxidation reactions: oxygen is put in.

e.g. breaking phosphate from ATP to release energy in tissues.



Oxygen in respiration:



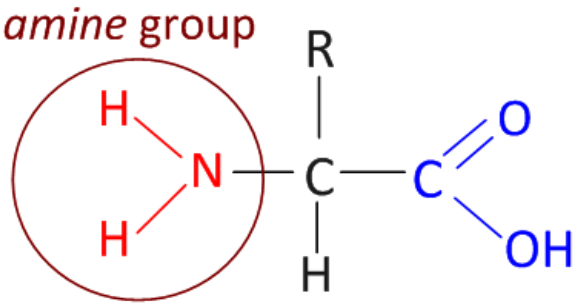
http://highered.mcgraw-hill.com/olc/dl/120071/bio11.swf

7
N
nitrogen

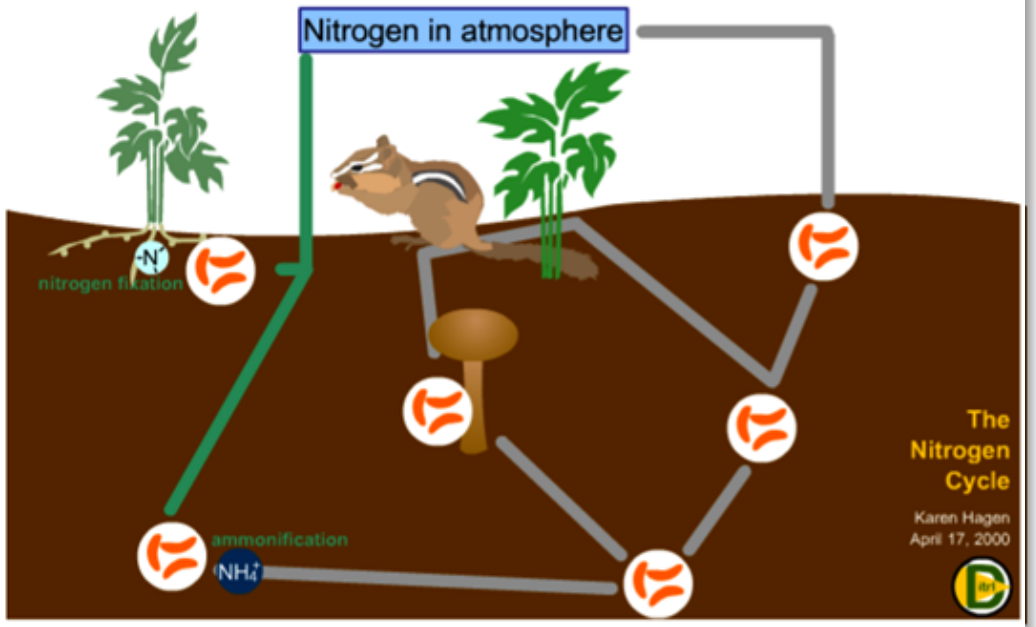
The main use of nitrogen is in the production of amino acids.

Amino acids are polymerised into proteins.

Nitrogen is also used in chlorophyll.



Nitrogen takes many forms in nature:



http://www.biology.ualberta.ca/facilities/multimedia/uploads/ecology/ncycle.swf

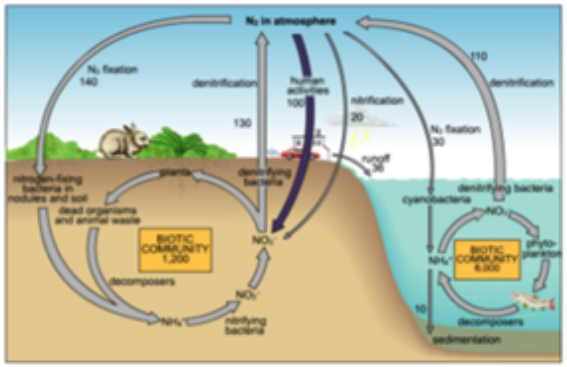
Nitrogen N_2

Ammonium NH_4^+

Nitrates NO_3^-

Nitrites NO_2^-

urea $(NH_2)_2CO$



http://www.mhhe.com/biosci/genbio/tlw3/eBridge/Chp29/animations/ch29/1_nitrogen_cycle.swf

26

Fe

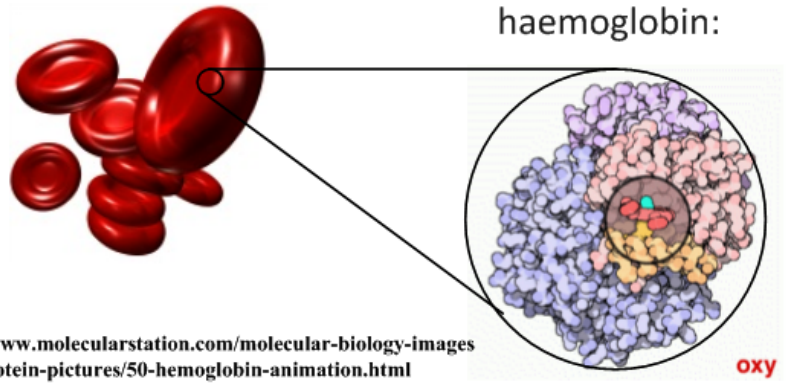
iron

Iron is an important micronutrient in living things.

In animals, it is the oxygen-binding component of haemoglobin.
In plants, it is used to make chlorophyll and takes part in photosynthesis (as ferredoxin).

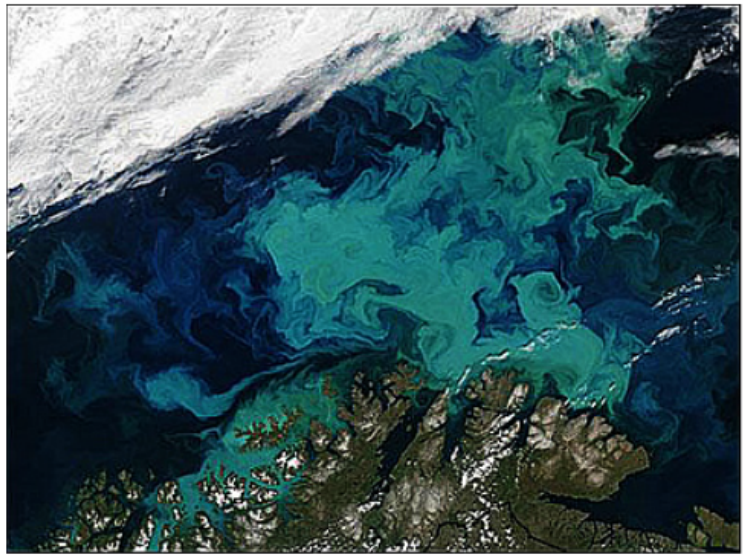
Iron binds well with oxygen for transport. It also faciltates the movement of electrons in cells, including bacteria.

haemoglobin:



http://www.molecularstation.com/molecular-biology-images/505-protein-pictures/50-hemoglobin-animation.html

Iron is often a limiting factor in plant productivity. Experiments of iron seeding can have dramatic effects, such as this phytoplankton bloom:



http://www.fas.org/irp/imint/docs/rst/Sect14/Norway.jpg

20

Ca

calcium

Calcium is an essential mineral in many species.

It is used in the structure of bones and teeth in animals, as well as in blood clotting.

exoskeletons!

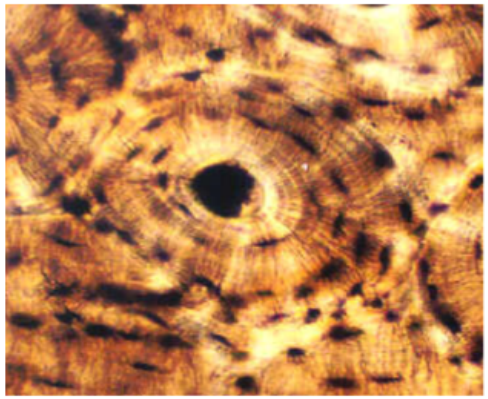
Calcium carbonate ($CaCO_3$)is used in the production of exoskeletons in animals and unicellular organisms.

Calcium ions (Ca^{2+}) are essential in synaptic transmission - the propagation of an electrical signal along nerves (nerve impulses) and muscle contraction.

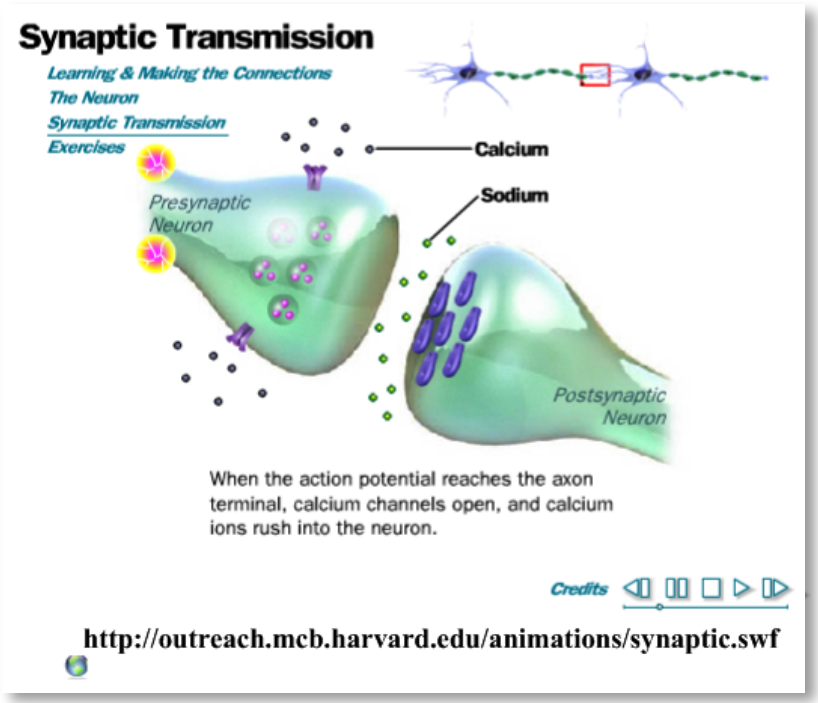
E. huxleyi makes a calcium carbonate shell

http://www.cascadecreativeservices.com/GH/Ehux.htm

Calcium forms the extra-cellular matrix of bone



http://www.usm.maine.edu/bio/courses/bio205/bio205_17_terrestrial_loco.html



http://outreach.mcb.harvard.edu/animations/synaptic.swf

15

P

phosphorous

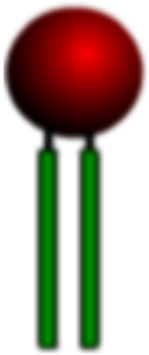
Phosphorous is essential in the formation of the phospholipid bilayer:

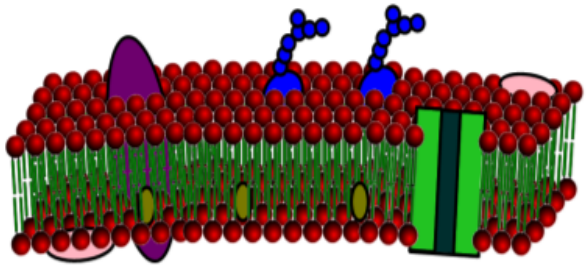
hydrophilic phosphate heads

water attracted

hydrophobic hydrocarbon tails

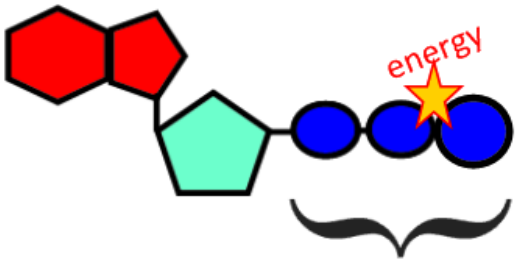
water repelled



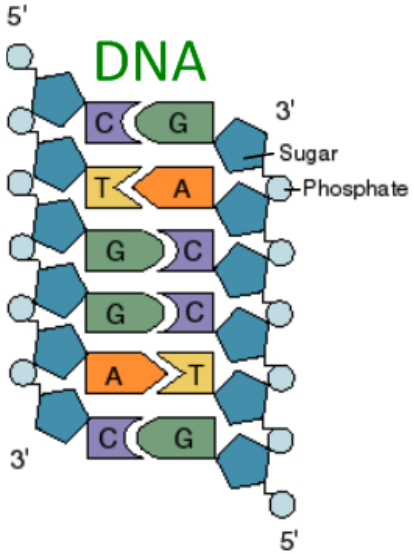


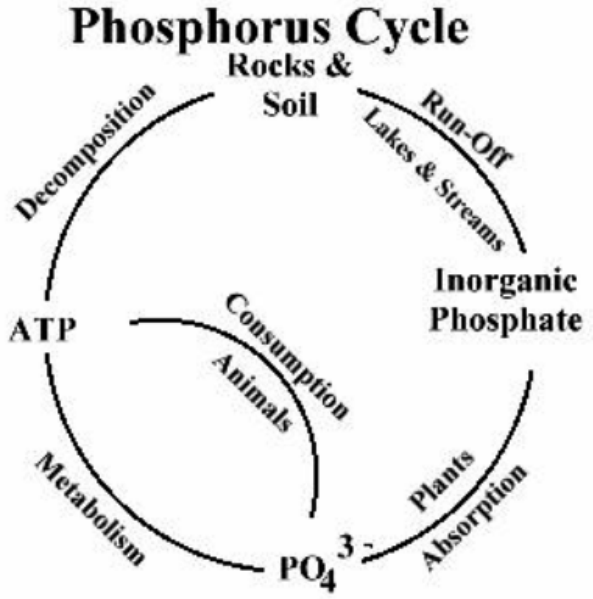
Phosphates are also the active component in ATP molecules and make up part of the 'backbone' of DNA:

ATP



phosphates





http://www.starsandseas.com/SAS%20Ecology/SAS%20chemcycles/cycle_phosphorus.htm

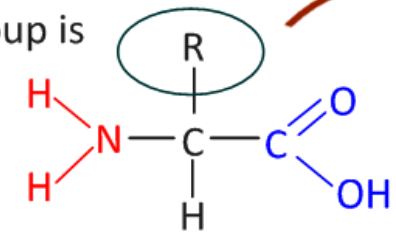
16

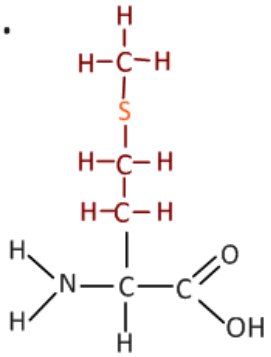
S

sulphur

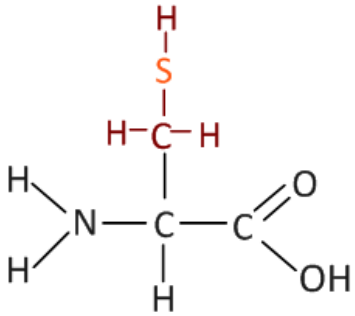
Sulphur is found in some amino acids.

The 'R' group is variable.



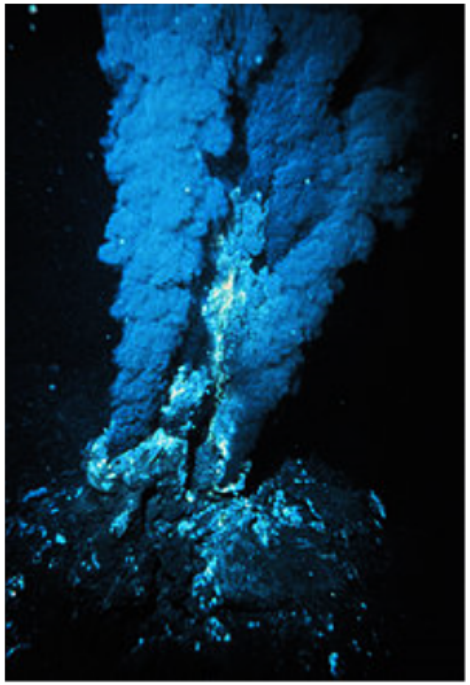


methionine



cysteine

black smoker hydrothermal vent



http://en.wikipedia.org/wiki/Hydrothermal_vent

It is also a reactant for chemosynthetic bacteria (chemoautotrophs) - found in deep-sea vents.

Chemosynthetic bacteria produce organic molecules from hydrogen sulphide, carbon dioxide and oxygen:

$$4H_2S + CO_2 + O_2 \longrightarrow CH_2O + 4S + 3H_2O$$

hydrogen sulphide

formaldehyde

Where do the CO_2 and O_2 come from?

Even though light is not directly part of the process, does chemosynthesis still rely on sunlight to an extent?

http://www.newscientist.com/article/mg17423405.700-life-needs-light.html

11
Na
sodium

19
K
potassium

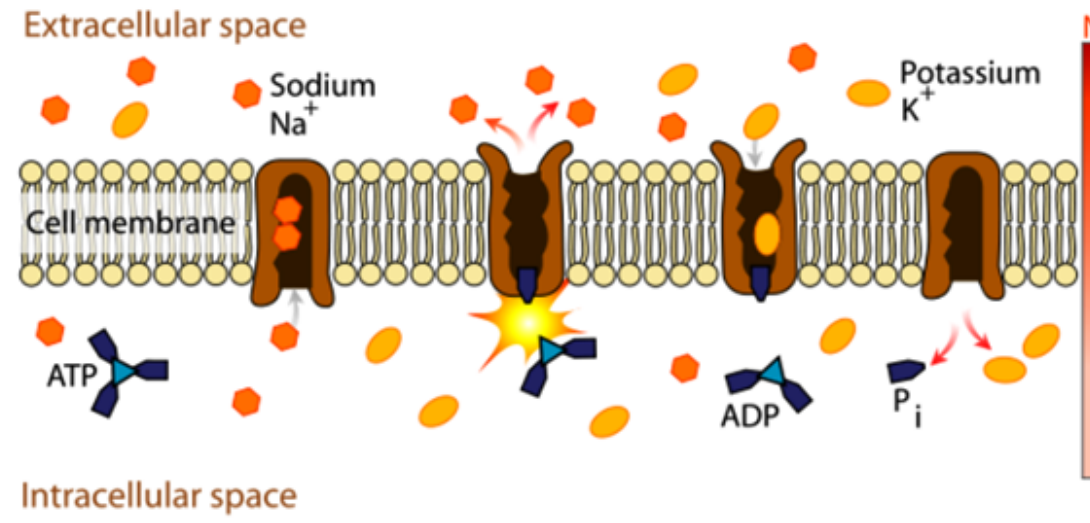
Sodium (Na^+)is essential in generating an action potential for nerve impulses. Sodium chloride (NaCl), or salt, is a main source of these ions.
Sodium is main cation in blood plasma.

Potassium also plays a role in nerve impulses and has a strong influence in osmosis. *Potassium is the main cation in cell cytoplasm.*

Potassium ions are larger than sodium ions.

The sodium-potassium pump:

This is an example of active transport.



blood plasma

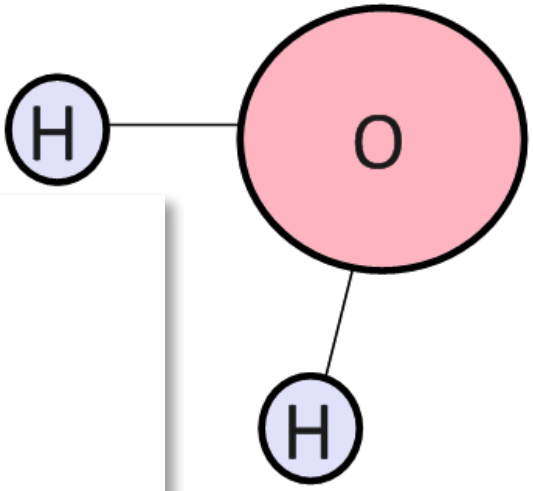
It is responsible for resetting nerve impulses and maintains the volume of cells through its influence on omosis.

cell cytoplasm

http://chaitanya1.wordpress.com/2007/11/15/listening-to-the-body/sp-pump/

Water

Begin with this tutorial:

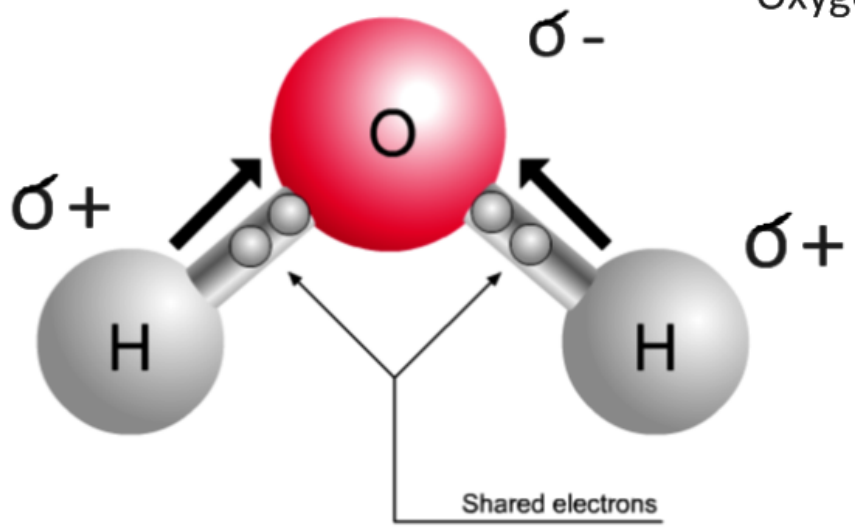


Properties of Water

Go to animation

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

Water is a polar molecule:



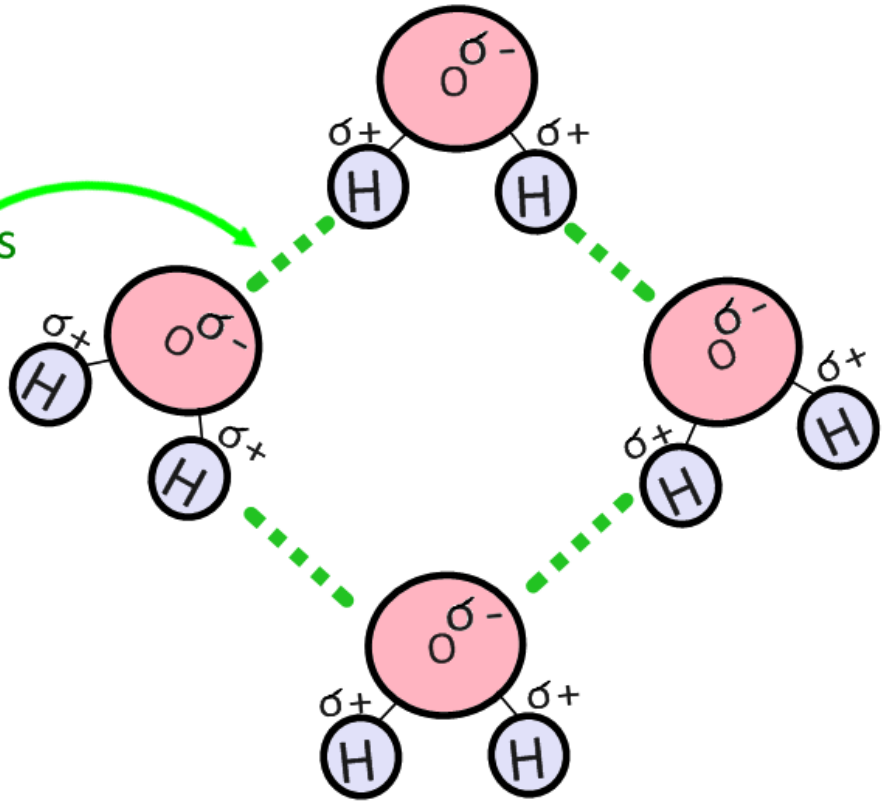
http://www.sumanasinc.com/webcontent/animations/content/propertiesofwater/water.swf

Oxygen exerts a greater pull over the shared electrons. They move a little closer to the oxygen.

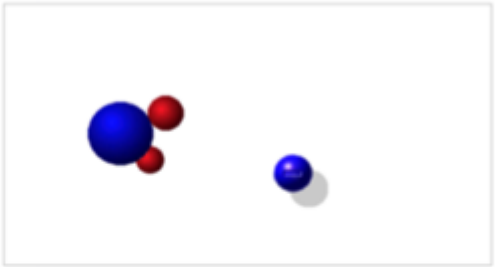
That means the 'oxygen end' is overall *slightly negative*: σ - .

The 'hydrogen end' is overall *slightly positive*: σ+.

Hydrogen bonds are the attractions between polar molecules.



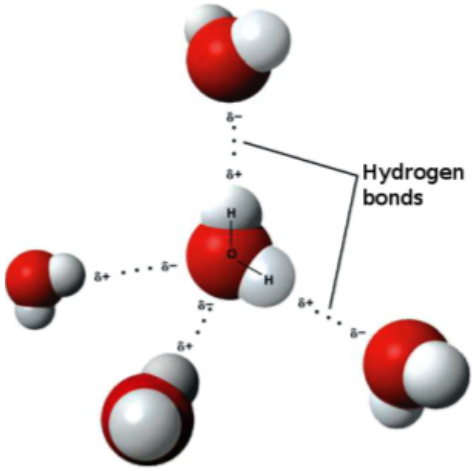
Try this:



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

Cohesive properties of water

A single hydrogen bond is not very strong. A large number of hydrogen bonds is very strong. Each water molecule bonds with four others in a tetrahedral arrangement:



http://en.wikipedia.org/wiki/Water

Because of these hydrogen bonds, water is cohesive: molecules of water stick to each other.
Water is also adhesive - it will stick to other surfaces.

These properties lead to:

Capillary Action - water will move up xylem against gravity

Surface tension - the surface of water is strong enough to support insects and causes drops to form

pondskaters walk on water:

http://focusonnature.be/keywords/insects?page=6

cohesion forms droplets
surface tension keeps them spherical
adhesion sticks them to the leaf

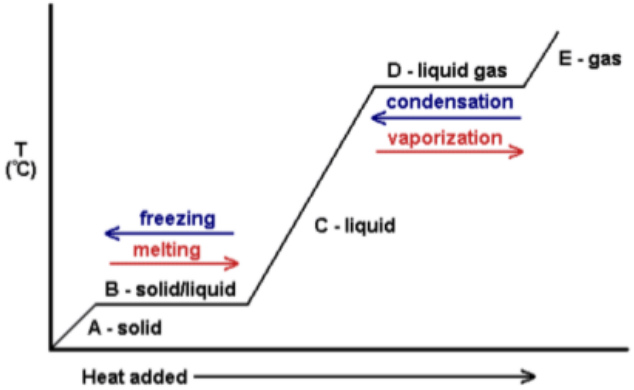
http://en.wikipedia.org/wiki/Adhesion

Thermal properties of water

Water has a high specific heat capacity.
This means it takes a lot of energy for the temperature of water to change.
This is because there are so many H-bonds.

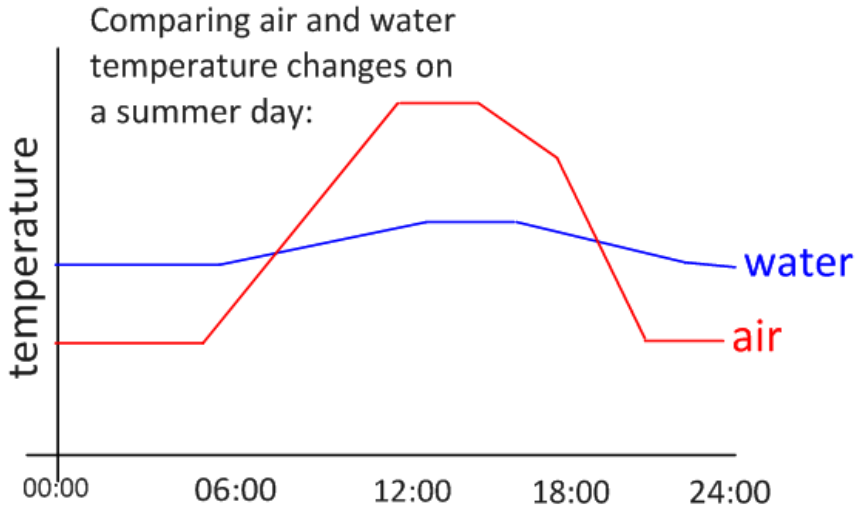
This all means that the temperature of water remains relatively stable

A lot of energy needs to be put in to change state:



http://www.kentchemistry.com/images/links/matter/HeatCool.gif

Most organisms are adapted to a narrow range of conditions. The slow heating and cooling of water are ideal for these organisms - there is less risk of extreme changes.



Because it takes a lot of energy to make water evaporate, it is a good coolant - evaporating water removes a lot of heat energy from the organism.

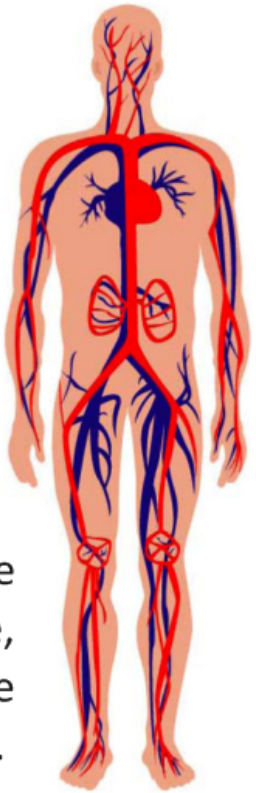
Water as a coolant:

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

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

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.

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.

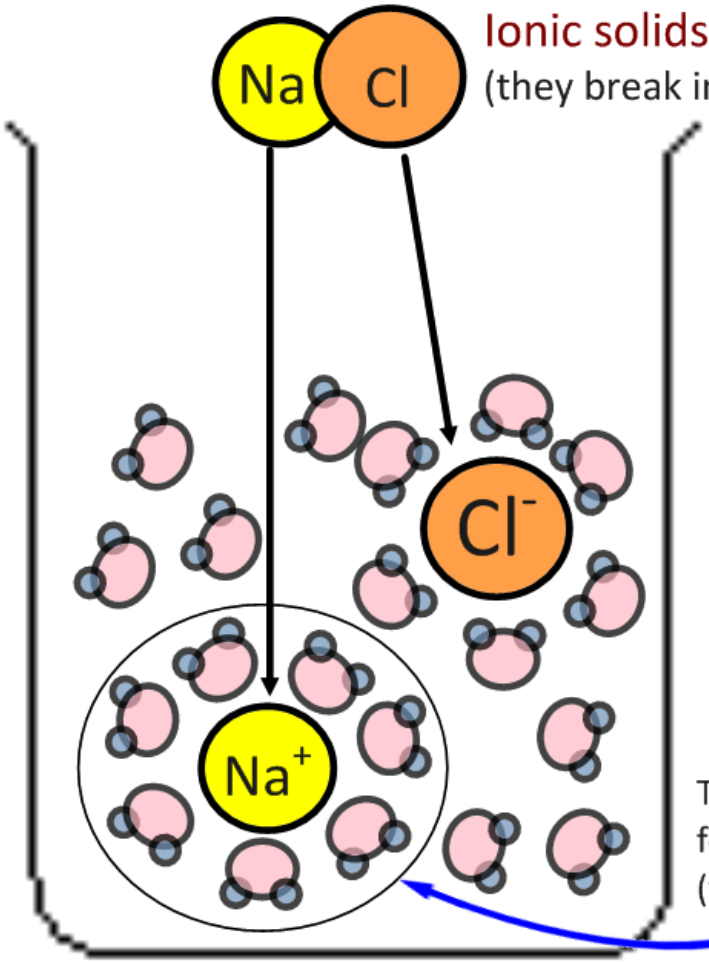


http://www.telemediamagazine.com/circulation.htm

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.

Solvent properties of water

Water is a good solvent because it is a polar molecule.
It will dissolve polar solutes easily.

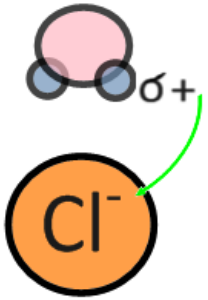


Ionic solids dissociate in water.
(they break into their ions)

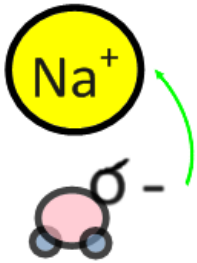
a quick look at
how ionic compounds
dissolve

start movie

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



Polar attractions cause water molecules to surrond and isolate the solute molecules.

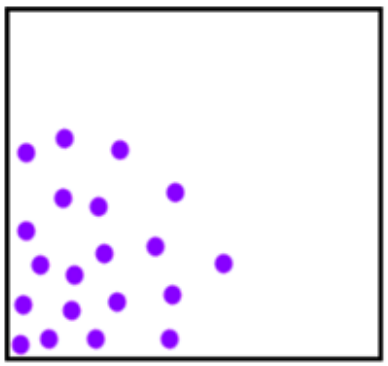


The more soluble a solute is, the easier it is for the ions to be isolated from each other (they will end up in thicker water 'shells'.

another animation:
http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/molvie1.swf

Water as a medium for metabolic reactions:

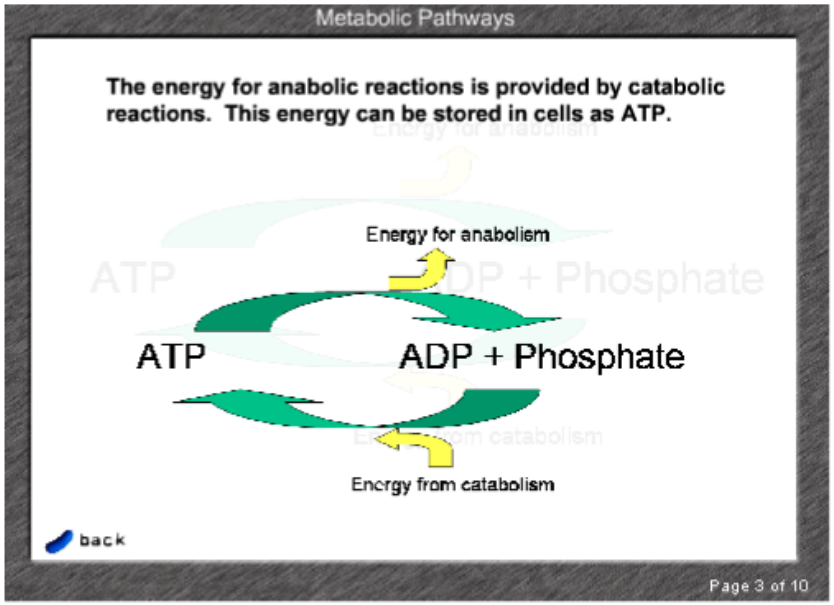
Water is a good solvent.
Dissolved particles are able to move around - and diffuse.
Moving particles are likely to collide with one another, leading to a reaction.



http://iweb.tntech.edu/mcaprio/diffusion-animated.gif

All metabolic reactions (reactions in living things) occur in solution - the reactants are dissolved.

What is a metabolic reaction?

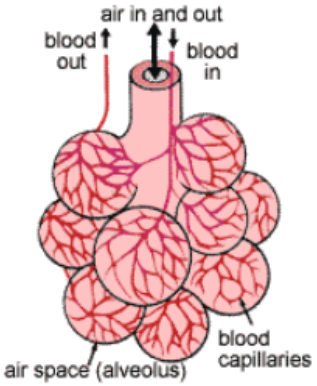


http://www.wisc-online.com/objects/MBY2604/MBY2604.swf

Membranes and biological surfaces are wet.

This allows molecules to dissolve, including gases, so they can diffuse through more easily.

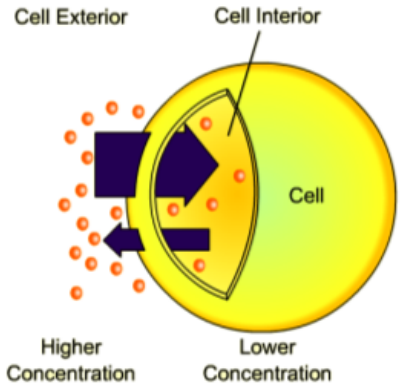
e.g. in the alveoli, oxygen is dissolved on the membrane and can then diffuse into the the blood.



http://resources.schoolscience.co.uk/abpi/asthma/images/5c2AlvBrjpg.gif

Water as a transport medium:

Water is a good solvent: it dissolves nutrients, gases and waste products. These can be carried in the circulatory system of animals, through xylem and phloem in vascular plants or through the water in soil or aquatic habitats.



http://www.wiley.com/legacy/college/boyer/0470003790/animations/membrane_transport/membrane_transport.swf

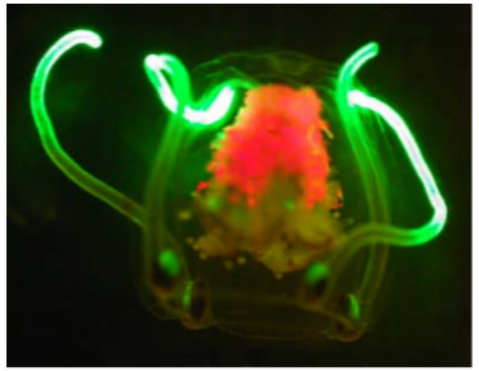
Water can transport molecules across membranes in diffusion, as well as within the cell or interstitial (between-cell) fluid.

http://ocean-spirits.blogspot.com/2007/10/sighting-of-rare-whale.html

Water is dense.
This means it can support the mass of large and small organisms - they can float or swim in water.

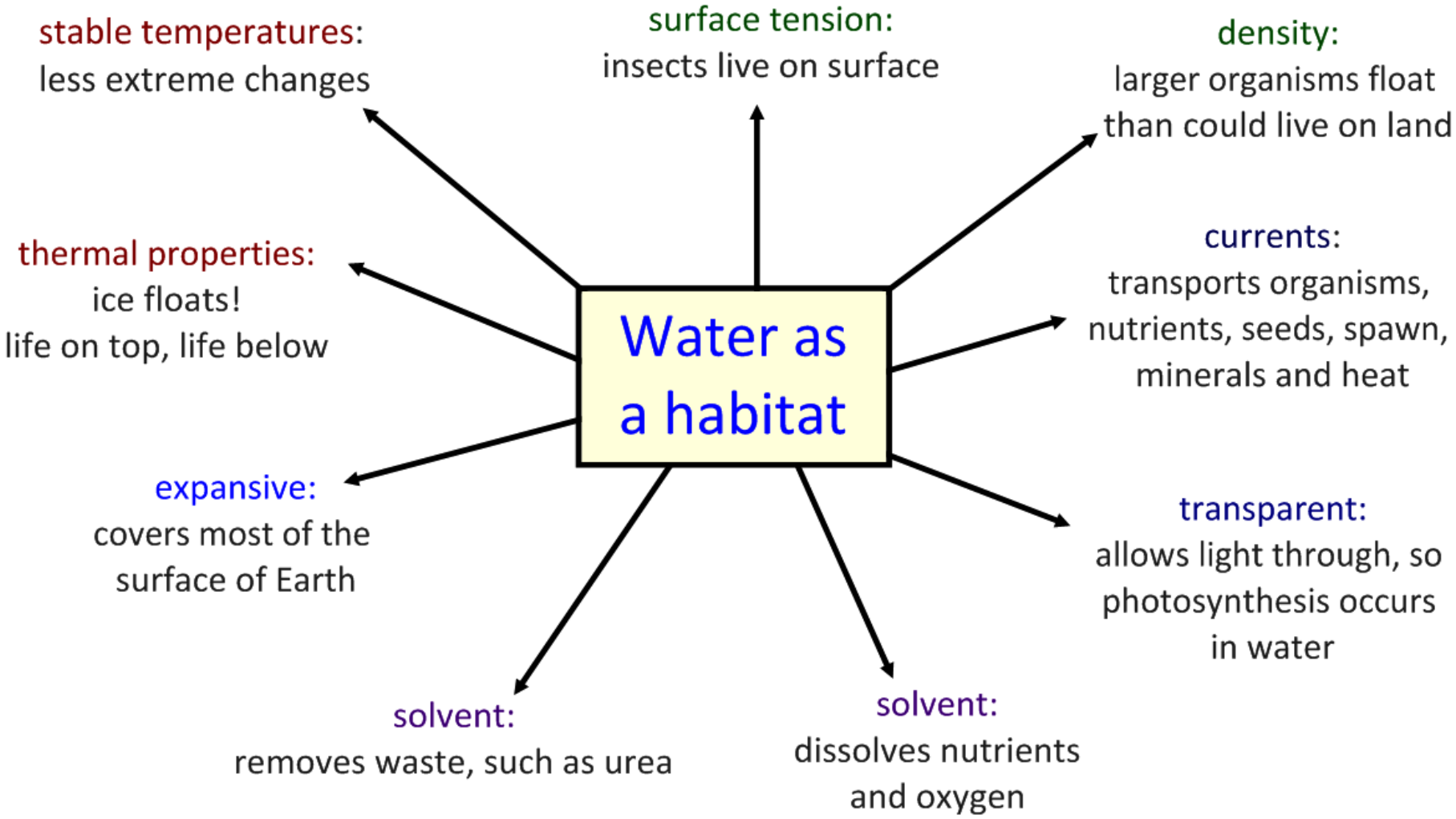
Aquatic systems are rarely still:
they have flows and currents that can carry planktonic organisms, spores, seedsand nutrients over a large area.

Planktonic organisms rely on water movement for their own transport:
Small fluorescent jellyfish



http://oceanexplorer.noaa.gov/explorations/05deepscope/background/fluorescence/media/jellyfish.html

Can you add any more advantages of water as a habitat?

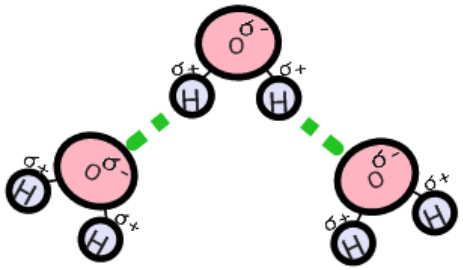


Oxygizer Water: read the article and answer the questions below the text.

http://www.guardian.co.uk/education/2004/jan/22/research.badscience

What is PSEUDOSCIENCE?

http://www.youtube.com/watch?v=Z6G4s8-upGk



For more help and animations visit:

http://sciencevideos.wordpress.com