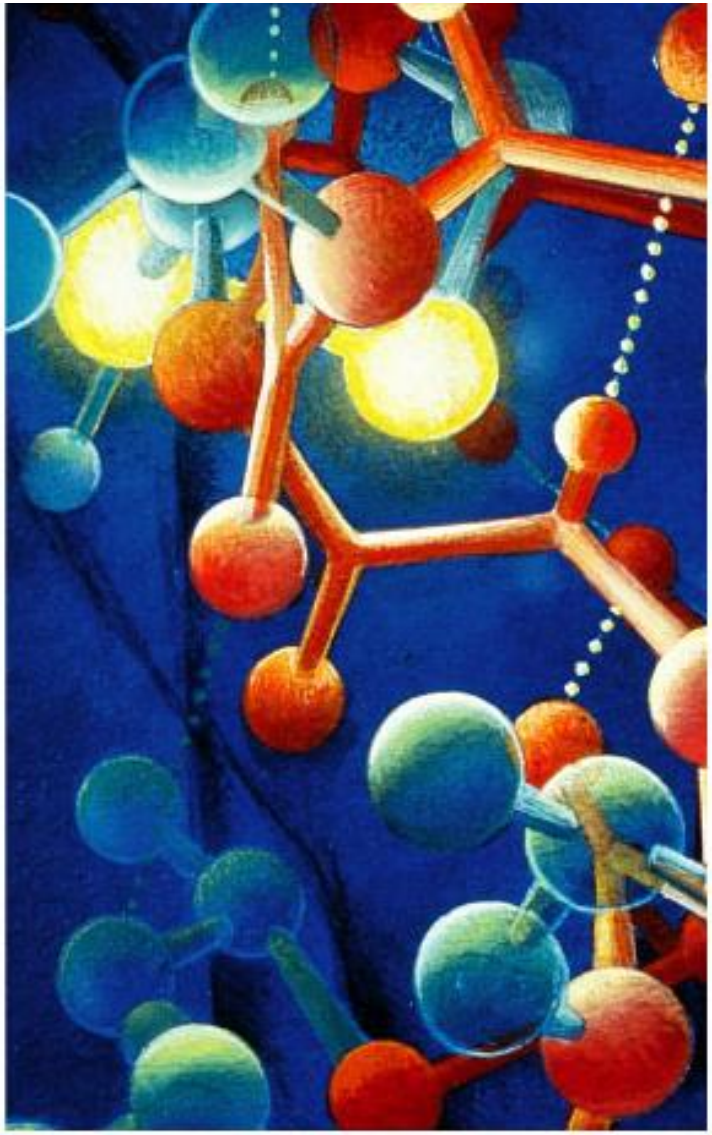
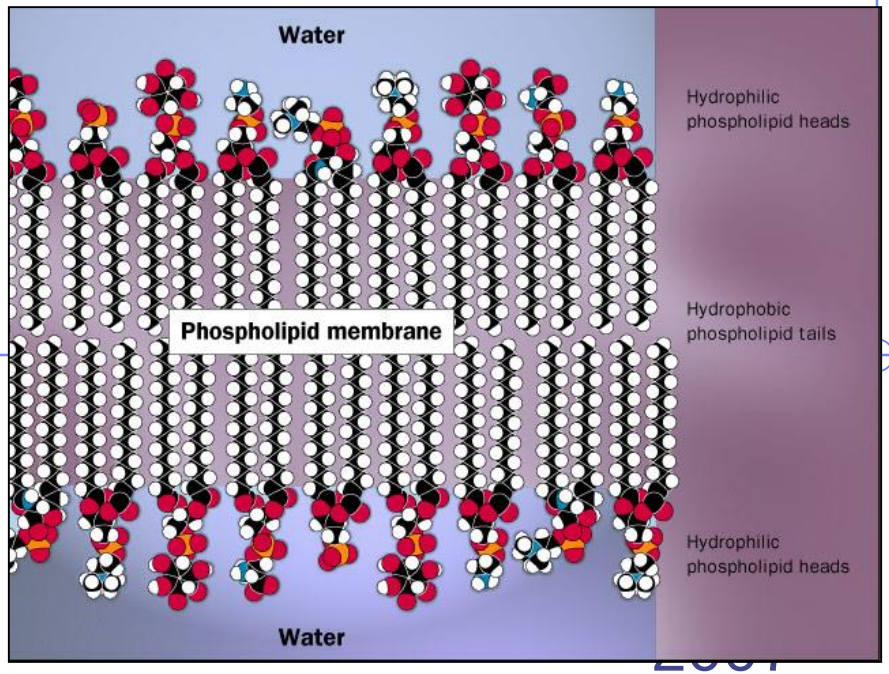
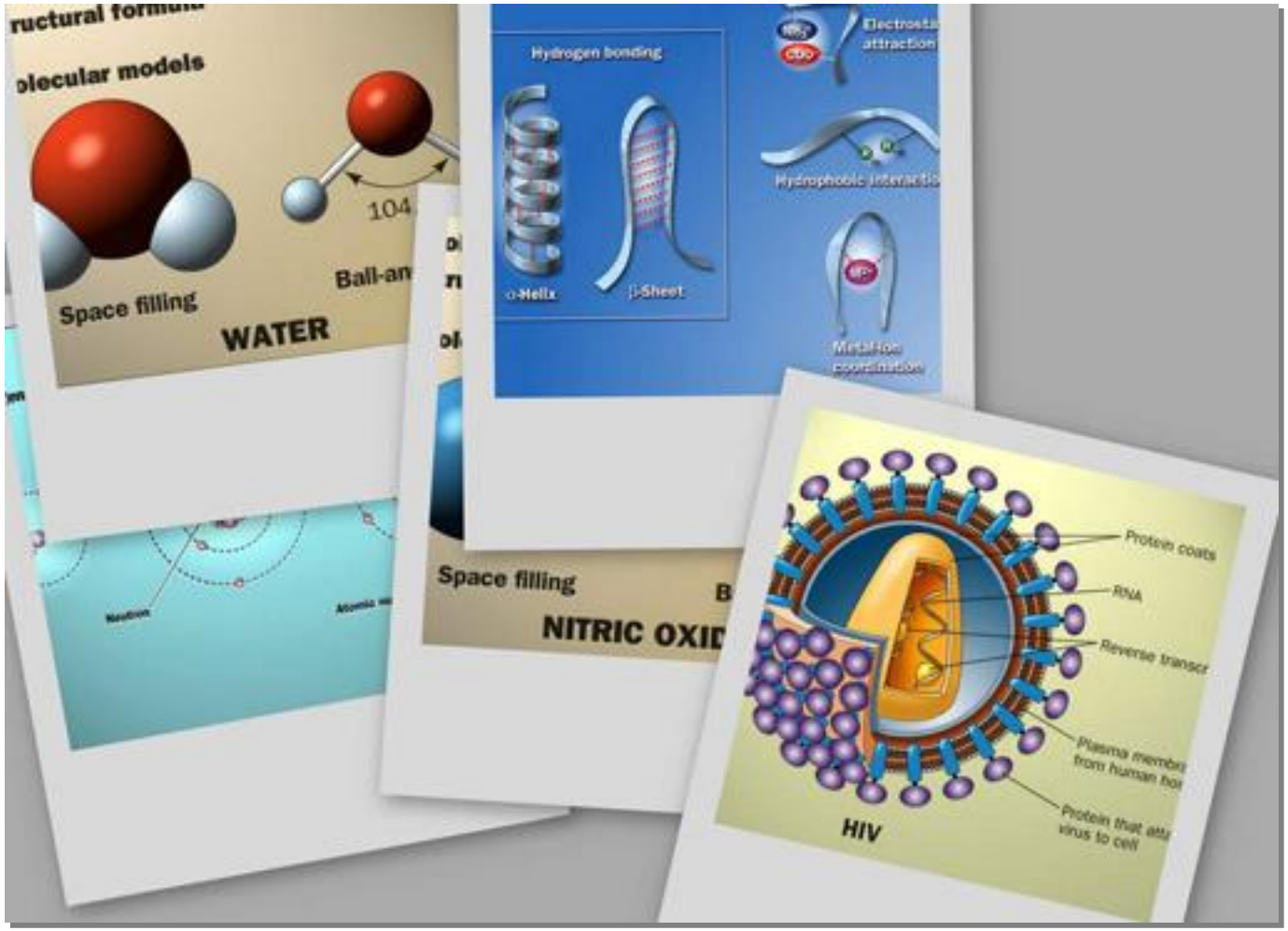


The Chemistry of Life

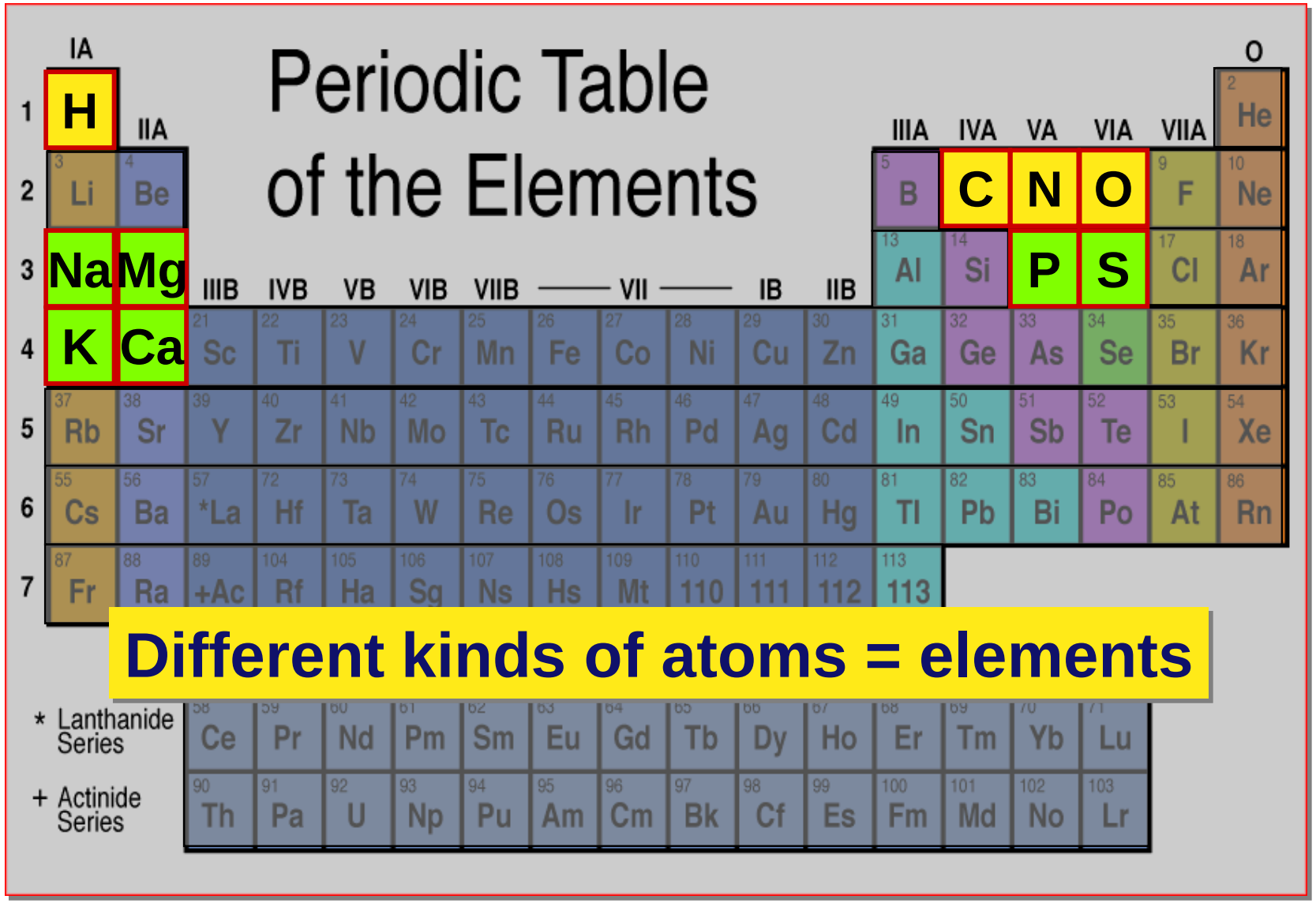


Why are we studying chemistry?

Chemistry is the foundation of Biology



The World of Elements

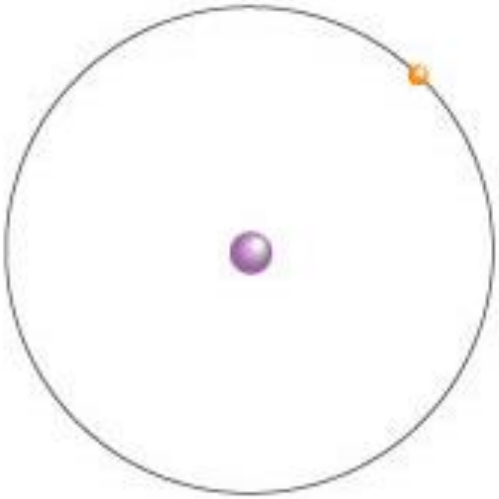


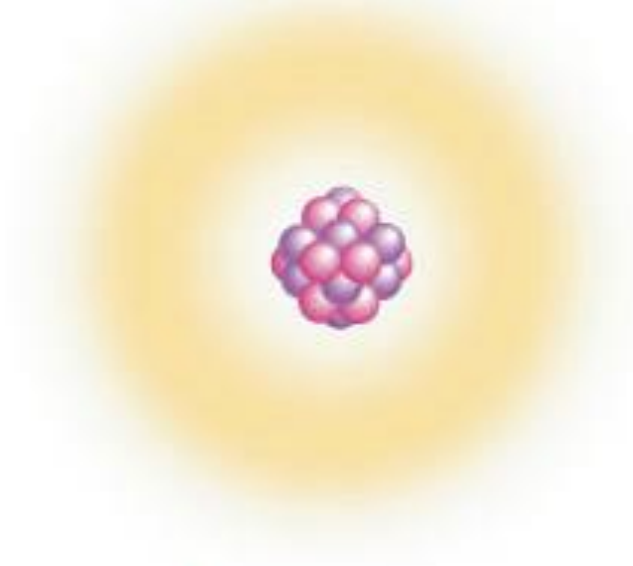
Life requires ~25 chemical elements

- About 25 elements are essential for life
  - Four elements make up 96% of living matter:
    - carbon (C)
    - hydrogen (H)
    - oxygen (O)
    - nitrogen (N)
  - Four elements make up most of remaining 4%:
    - phosphorus (P)
    - calcium (Ca)
    - sulfur (S)
    - potassium (K)

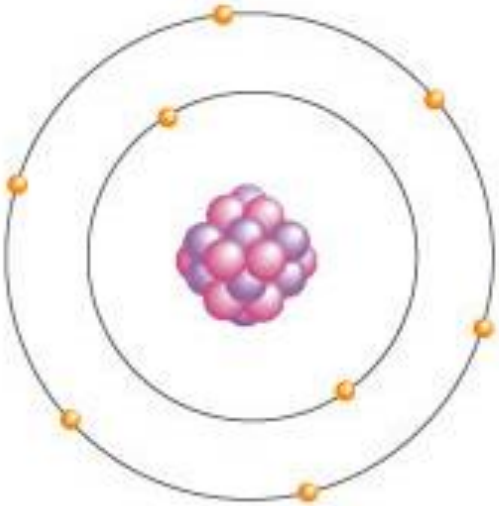
- **Everything is made of matter**
- **Matter is made of atoms**

Hydrogen
1 proton
1 electron





Oxygen
8 protons
8 neutrons
8 electrons



Proton + Neutron 0 Electron –

Differences in Elements

- Atoms of each element
  - Are distinguished by a specific number of protons

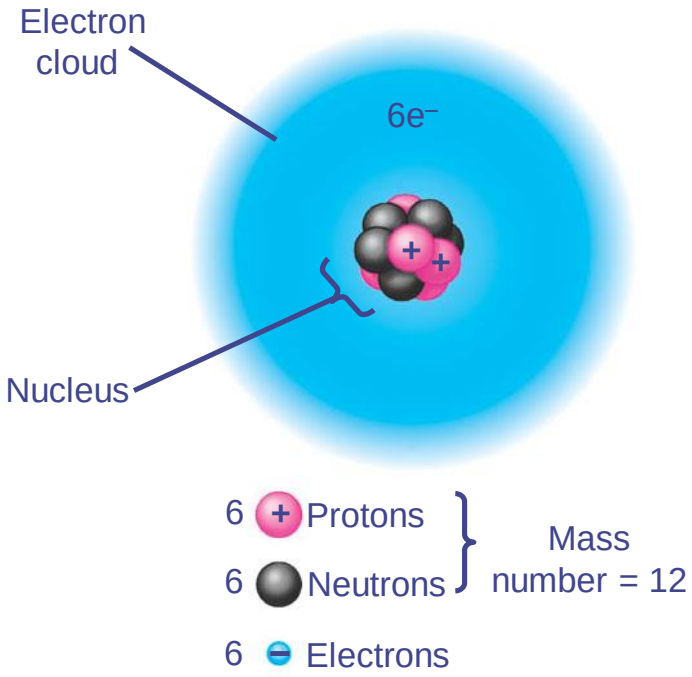


Figure 2.4B

Atoms

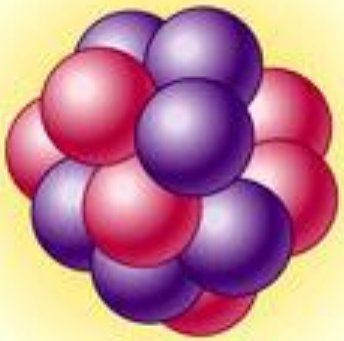
- Atomic number = number of protons
  - determines what element it is
- Atomic mass/weight = average number of protons and neutrons

Isotopes = atoms with unusual numbers of neutrons

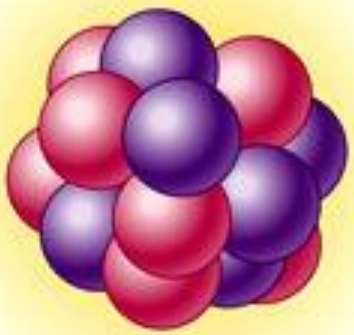
- There are always a certain percent of atoms that are isotopes

- Radioactive isotopes are unstable and release energy when they breakdown ”decay”

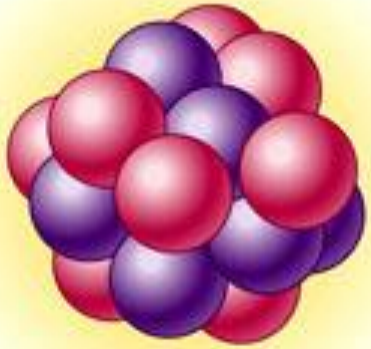
Carbon Isotopes



Carbon – 12
6 Protons
6 Neutrons
6 Electrons



Carbon – 13
6 Protons
7 Neutrons
6 Electrons



Carbon–14
6 Protons
8 Neutrons
6 Electrons

Radioactive isotopes can help us

- **Useful as tracers**
  - **Our body treats isotopes like any other atom**
  - **Can monitor where atoms go in living organisms**

Medical Diagnosis

- **Radioactive tracers often used for diagnosis**

Figure 2.5A

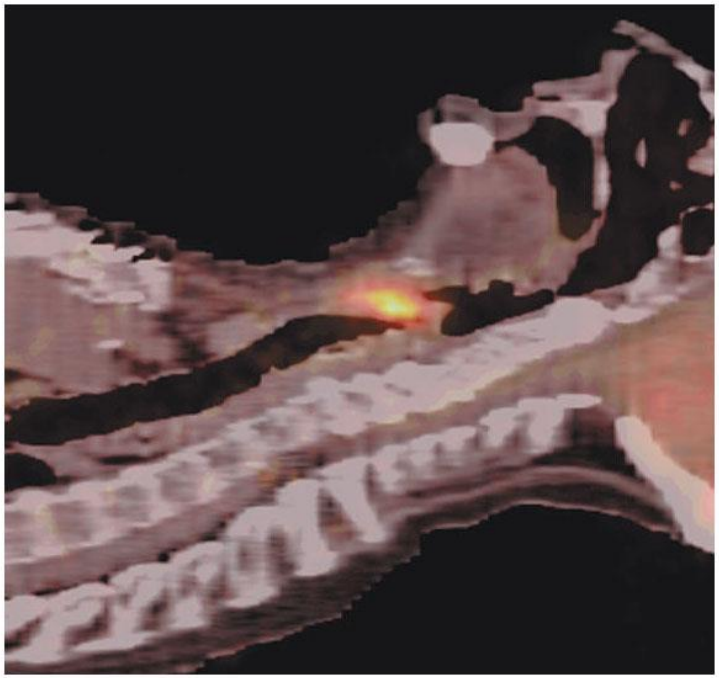


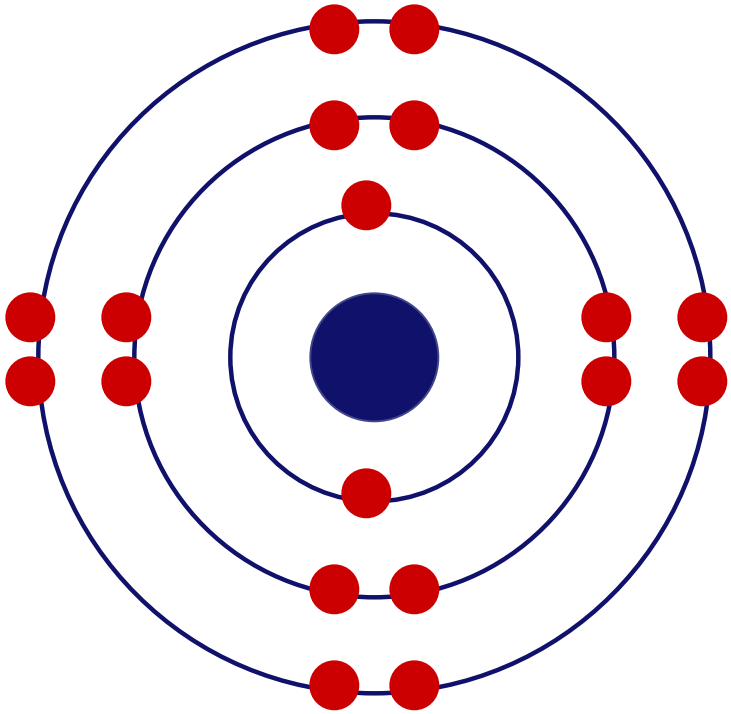
Figure 2.5B

Dangers

- **The energy released can damage cells' DNA**
  - **In Radiation sickness cells die due to DNA damage**
  - **Cancer is caused by damage to DNA that controls cell division**

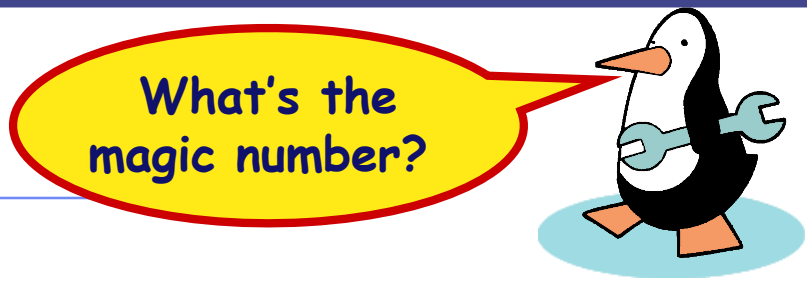
Bonding properties

- **Effect of electrons**
  - **electrons determine chemical behavior of atom**
  - **depends on number of electrons in atom's outermost shell**
    - **valence shell**

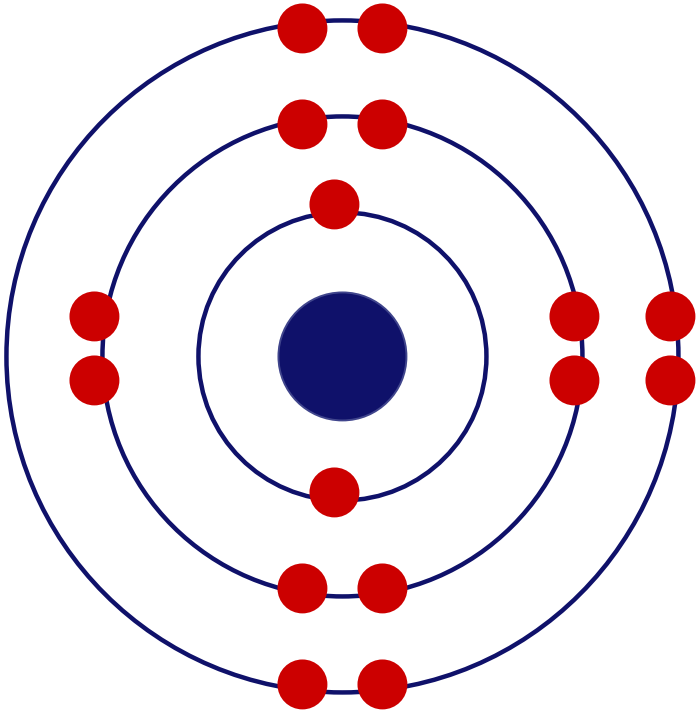


How does this atom behave?

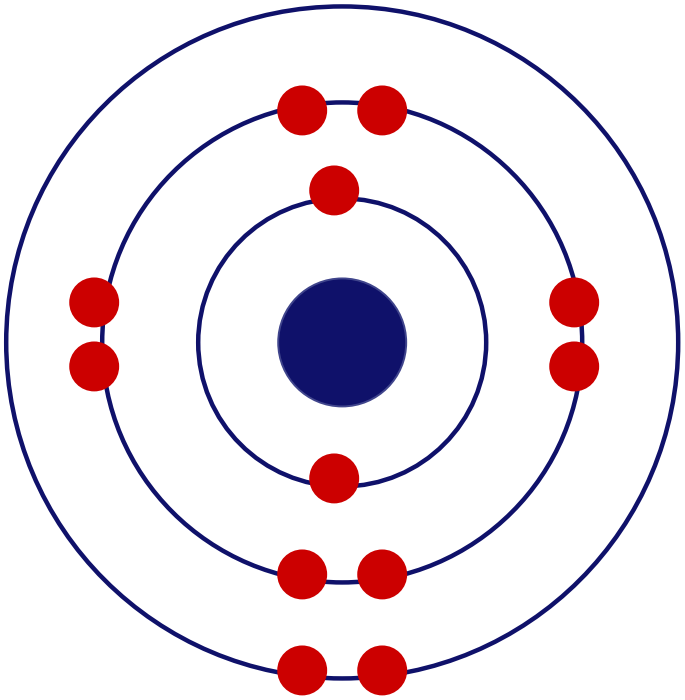
Bonding properties



- Effect of electrons
  - chemical behavior of an atom depends on number of electrons in its valence shell

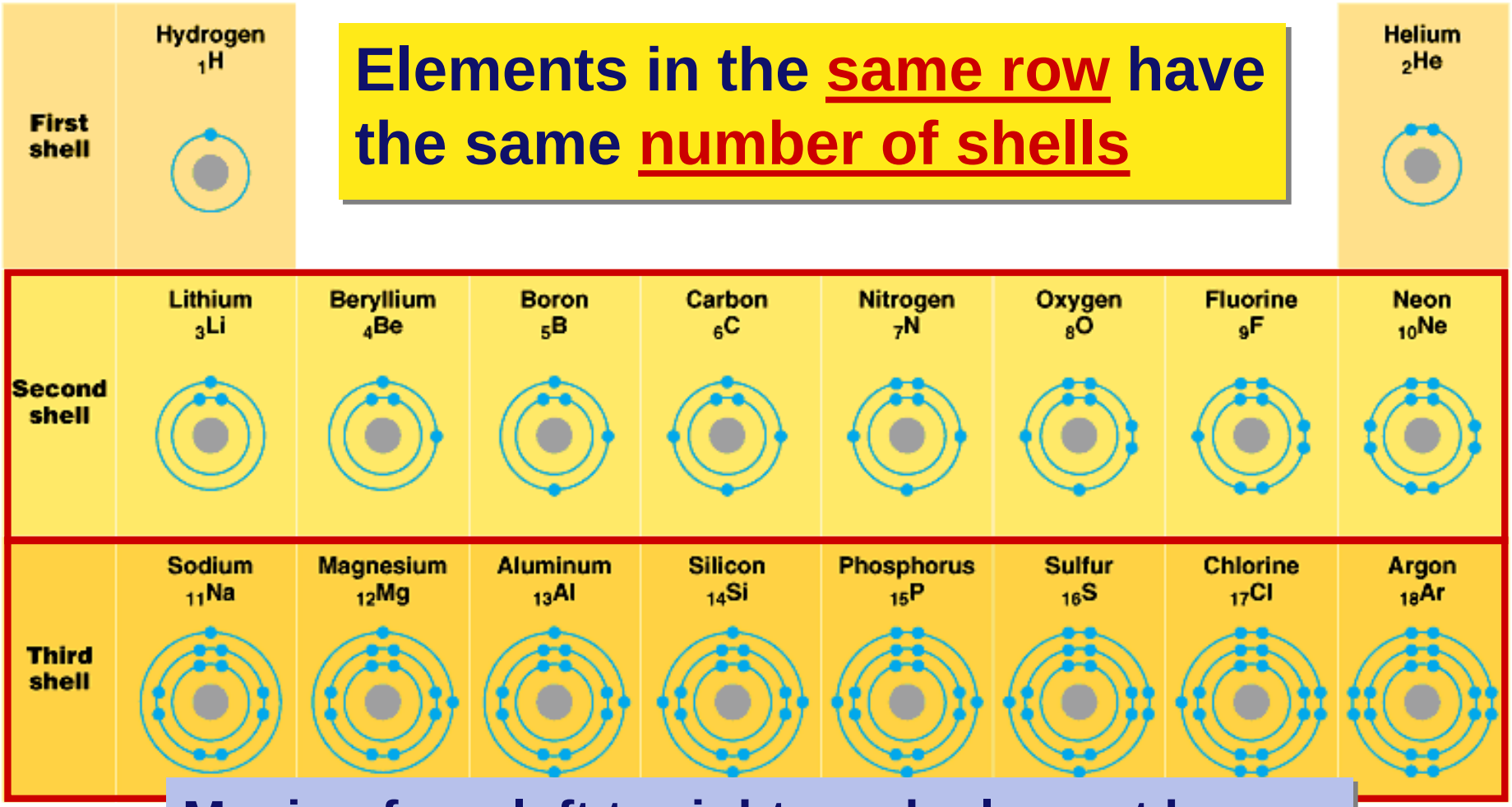


How does this atom behave?



How does this atom behave?

Elements & their valence shells

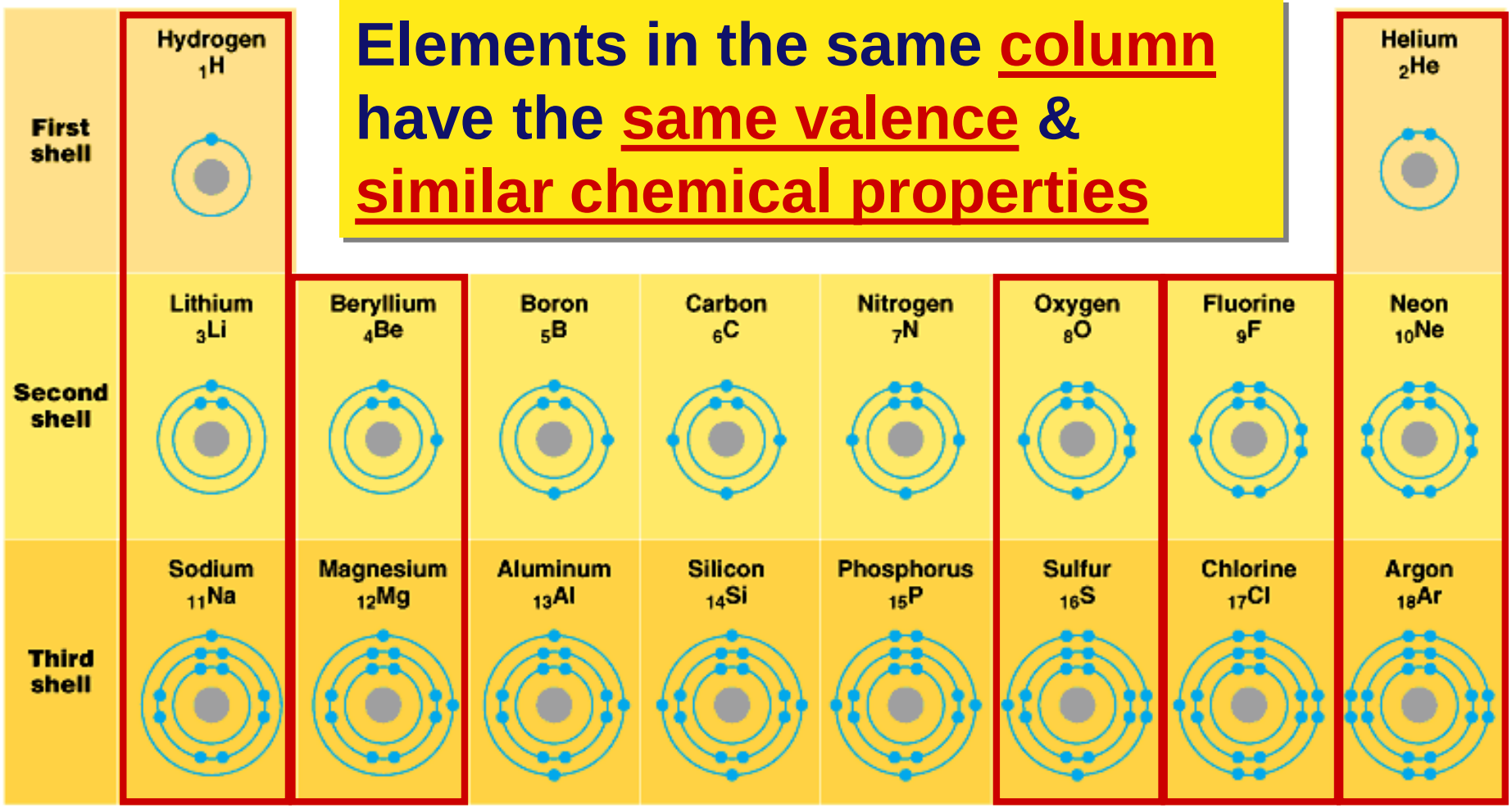


Elements in the same row have the same number of shells

Moving from left to right, each element has a sequential addition of electrons (& protons)

Elements & their valence shells

Elements in the same column have the same valence & similar chemical properties



Chemical reactivity

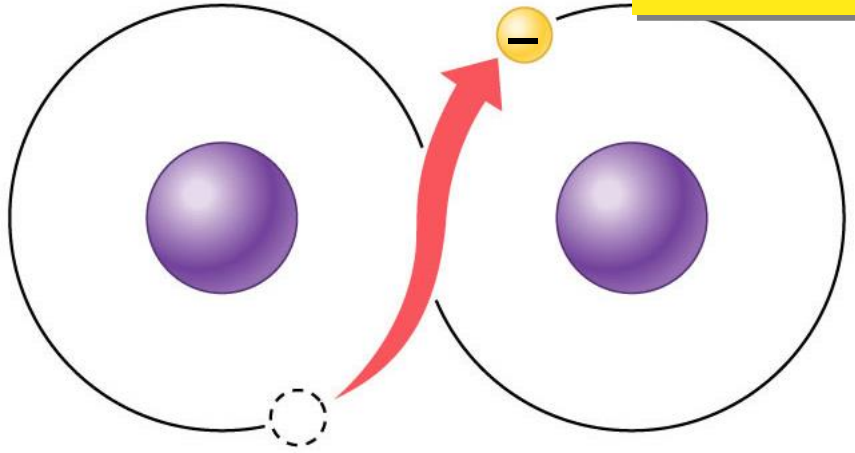
- Atoms tend to
  - complete a partially filled valence shell

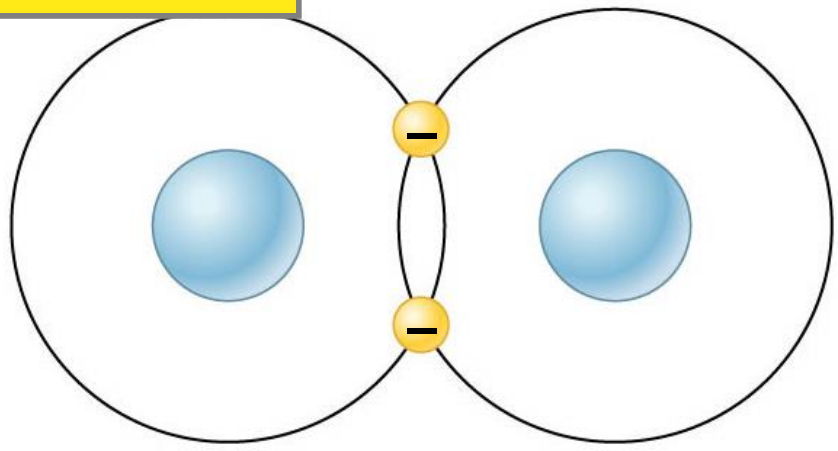
or

  - empty a partially filled valence shell

This tendency drives chemical reactions…

and creates bonds

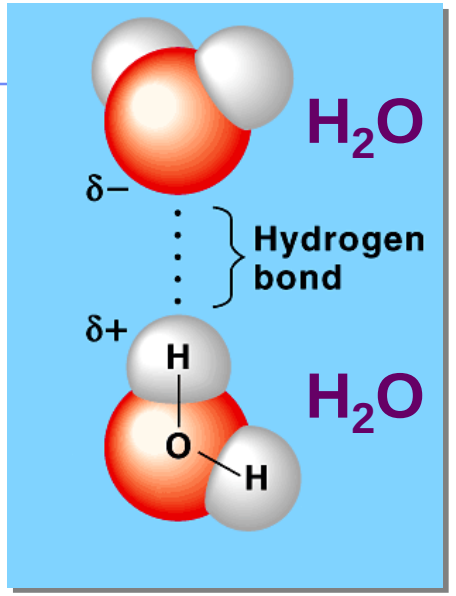




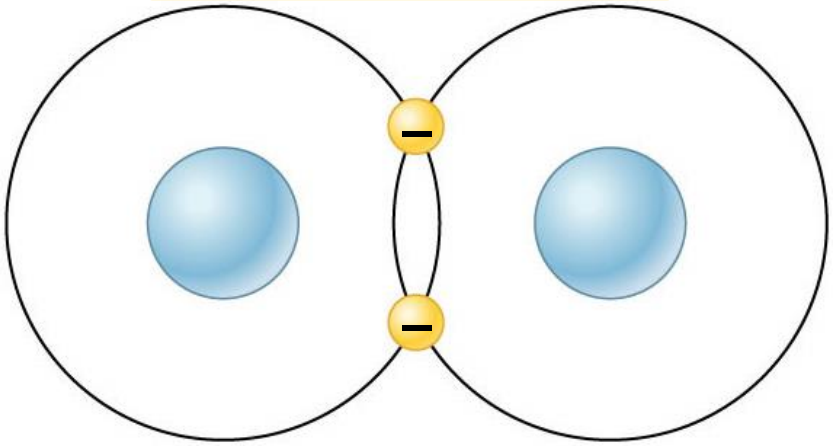
Bonds in Biology

- **Weak bonds**
  - **Ionic**
  - **hydrogen bonds**
    - attraction between + and –
  - **hydrophobic & hydrophilic interactions**
    - interaction with H_2O
- **Strong bonds**
  - **covalent bonds**

Hydrogen bond



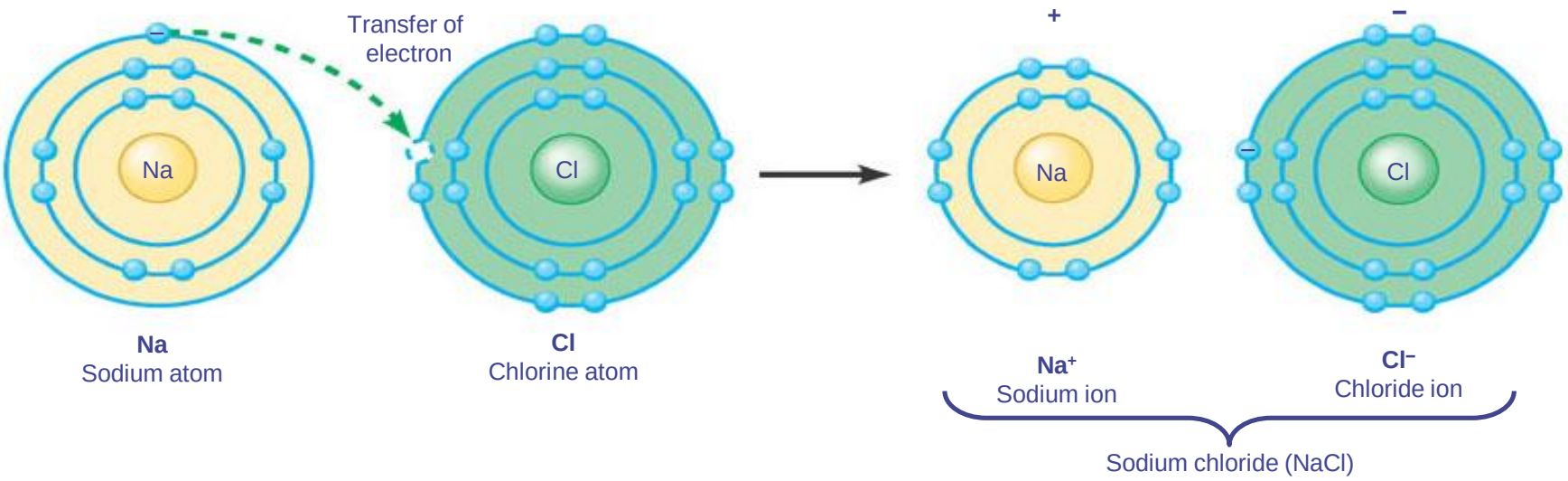
Covalent bond



H_2 (hydrogen gas)

Ionic Bonding

- Electron transferred from one atom to the other
- Electronegativities very different (opposite sides of periodic table)
  - Very different attraction to valance electrons

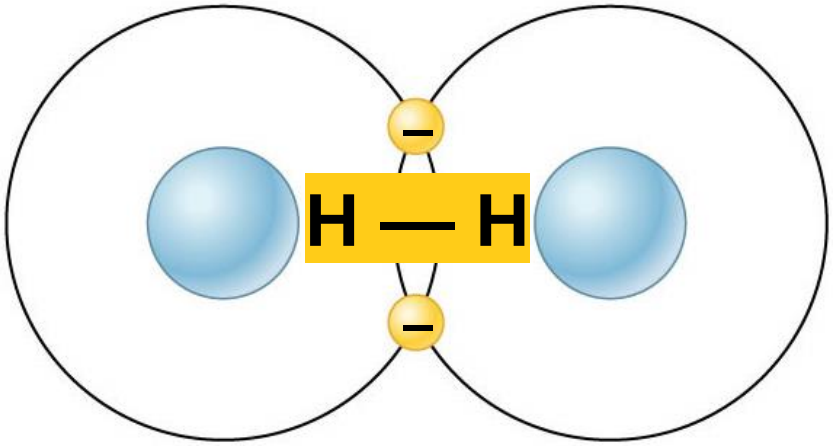


Ionic Bonding

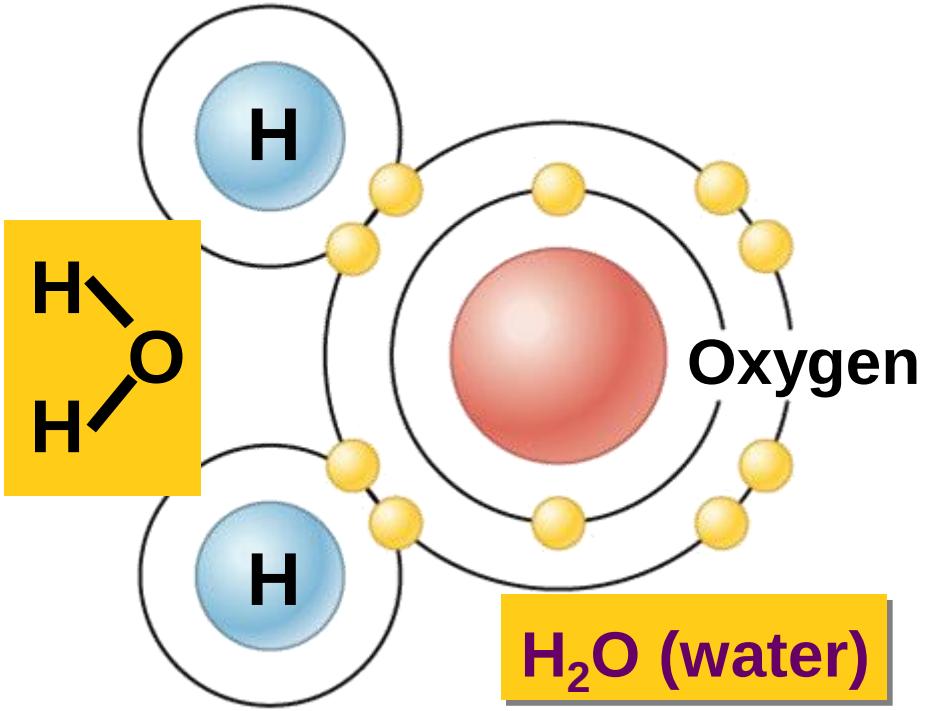
- Atoms gain or lose e- to create IONS
- The opposite charges cause ions to stick together
- Results in an ionic bond held together by charge
- Not a very strong bond

Covalent bonds

- **Why are covalent bonds strong bonds?**
  - two atoms share a pair of electrons
  - both atoms holding onto the electrons
  - very stable
- **Forms molecules**



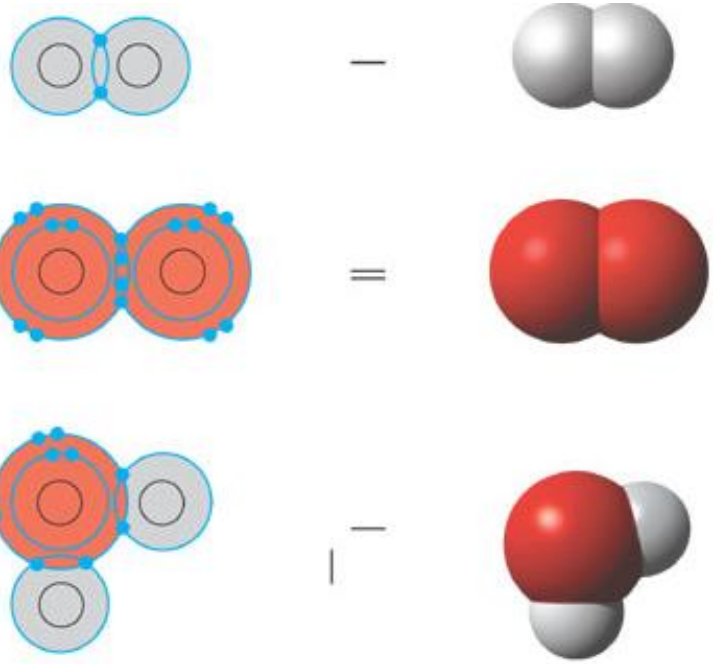
H_2 (hydrogen gas)

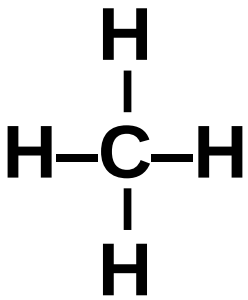


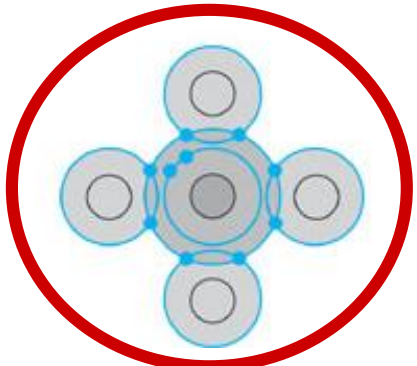
H_2O (water)

Multiple covalent bonds

- 2 atoms can share >1 pair of electrons
  - double bonds
    - 2 pairs of electrons
  - triple bonds
    - 3 pairs of electrons
- **Very strong bonds**





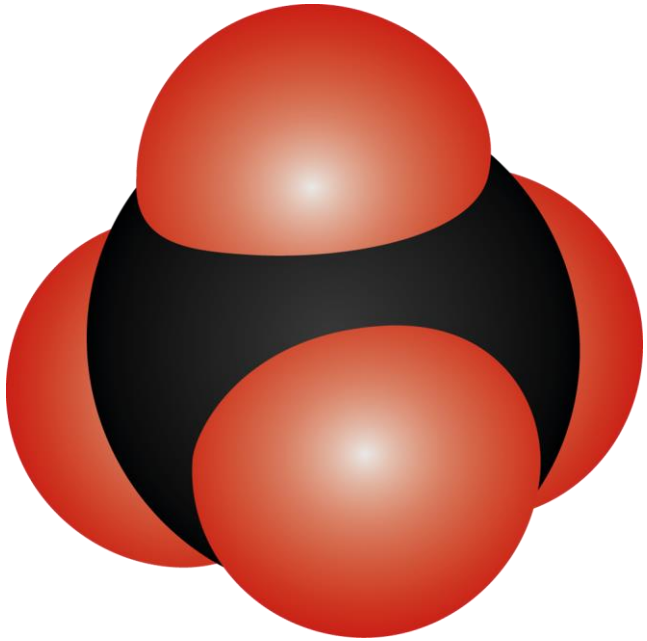


Nonpolar covalent bond

- Pair of electrons **shared equally** by 2 atoms
  - **example**: hydrocarbons = C_xH_x
    - methane (CH_4)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

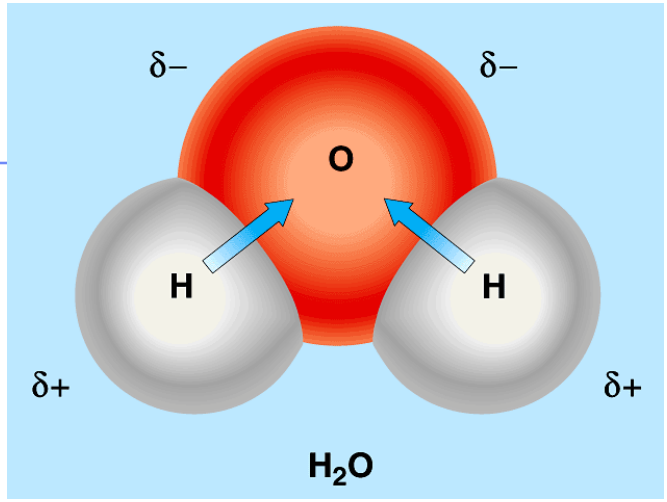
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

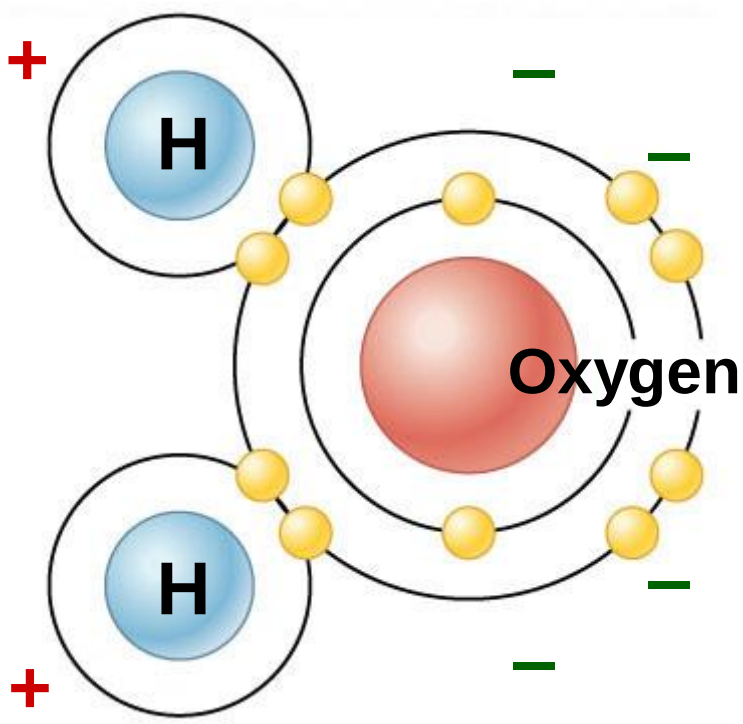


balanced, stable, good building block

Polar covalent bonds

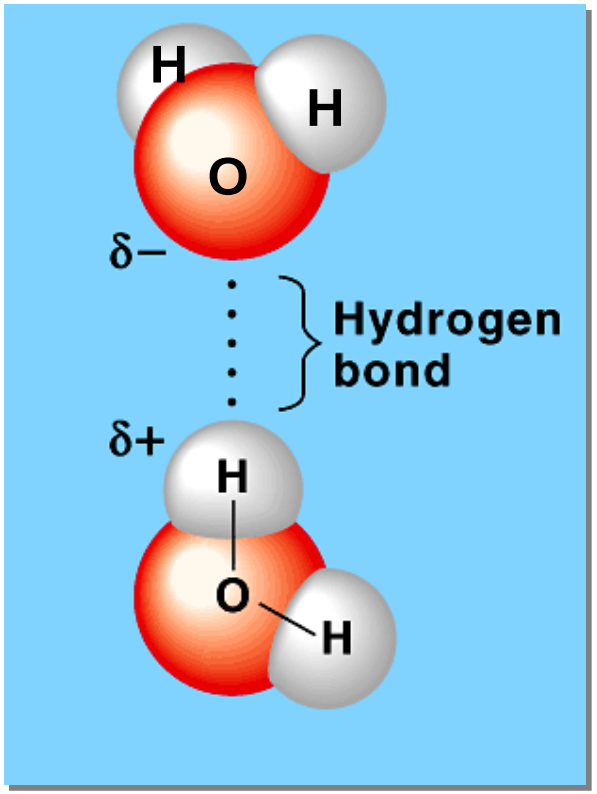
- Pair of electrons **shared unequally** by 2 atoms
  - **example**: water = H_2O
    - oxygen has stronger "**attraction**" for the electrons than hydrogen
    - oxygen has higher **electronegativity**
    - water is a **polar molecule**
      - + vs – poles
      - leads to many interesting properties of water…





Hydrogen bonding

- Polar water creates molecular attractions
  - attraction between positive H in one H_2O molecule to negative O in another H_2O
  - also can occur wherever an -OH exists in a larger molecule
- Weak bond



Chemistry of Life

Properties of Water

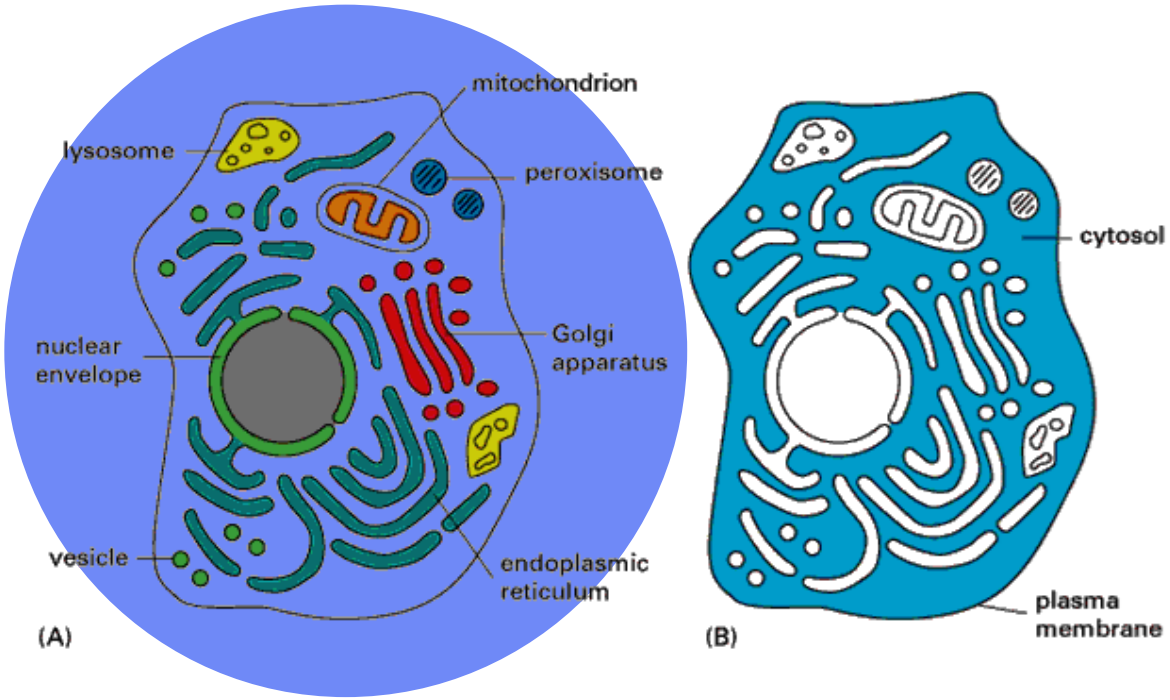
2007-2008

More about Water

Why are we studying water?

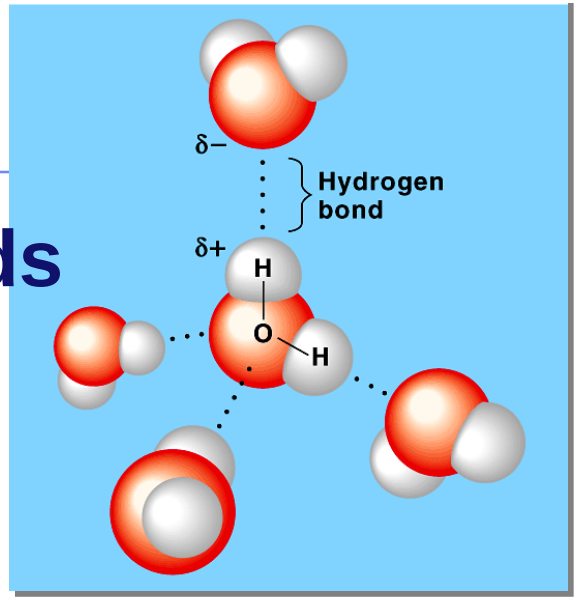
All life occurs in water

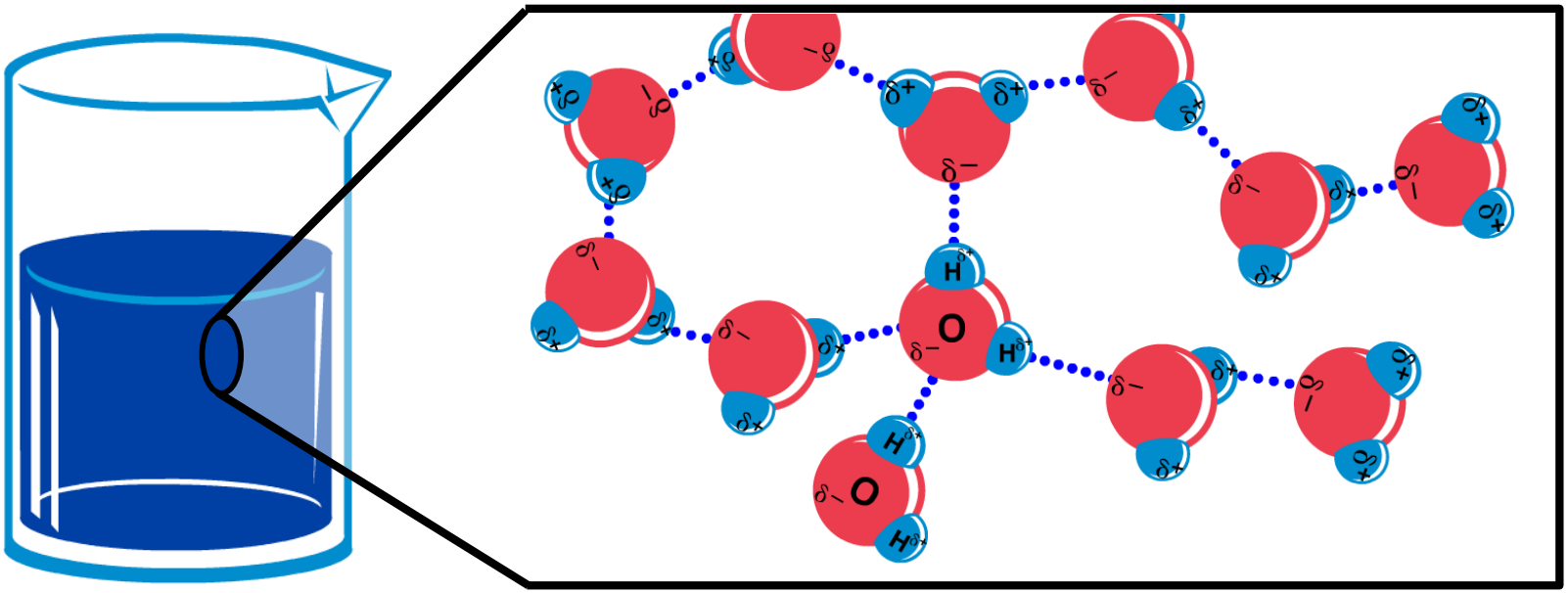
- **inside & outside the cell**



Chemistry of water

- H_2O molecules form H-bonds with each other
  - **+H attracted to –O**
  - **creates a sticky molecule**



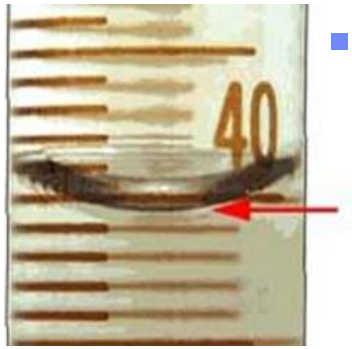


Elixir of Life

- **Special properties of water**
  1. **cohesion & adhesion**
     - surface tension, capillary action
  2. **good solvent**
     - many molecules dissolve in H_2O
     - **hydrophilic** vs. **hydrophobic**
  3. **lower density as a solid**
     - ice floats!
  4. **high specific heat**
     - water stores heat
  5. **high heat of vaporization**
     - heats & cools slowly

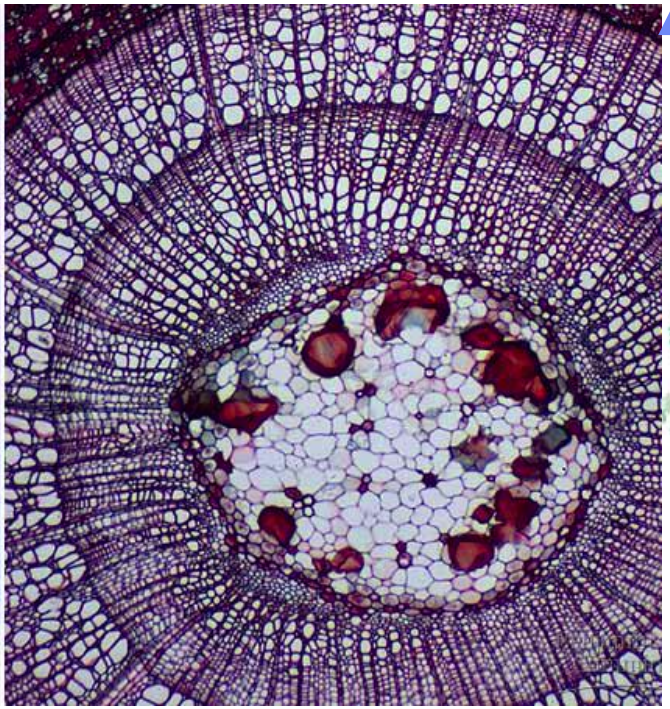
1. Cohesion & Adhesion

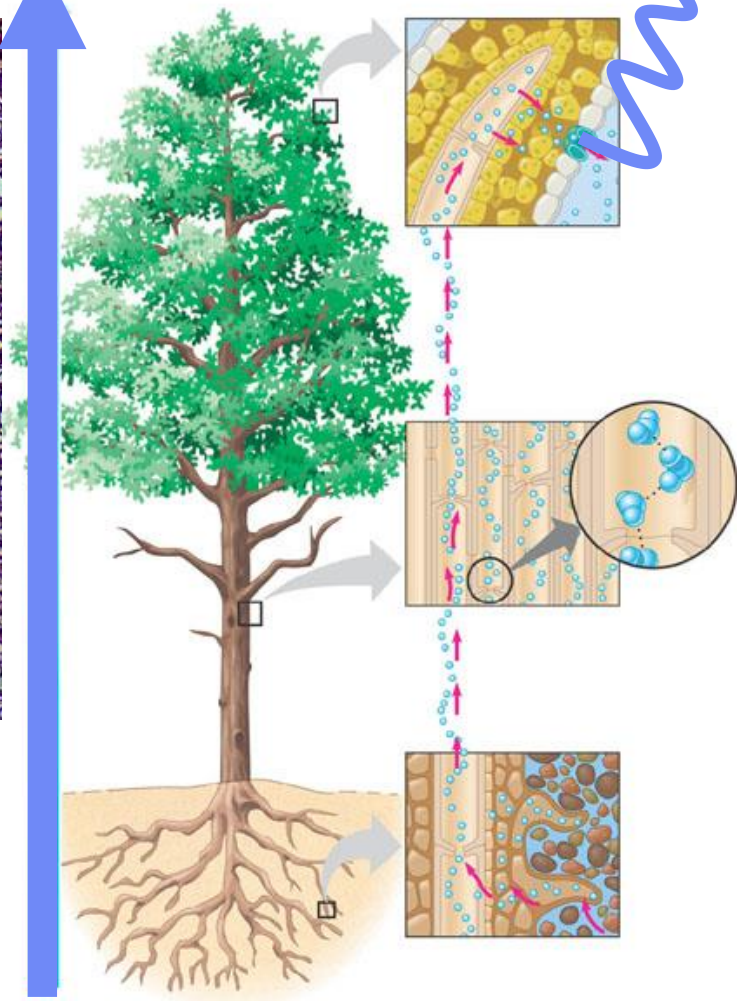
- **Cohesion**
  - H bonding between H_2O molecules
  - water is "sticky"
    - surface tension
    - drinking straw
- **Adhesion**
  - H bonding between H_2O & other substances
    - capillary action
    - meniscus
    - water climbs up paper towel or cloth



How does H_2O get to top of trees?

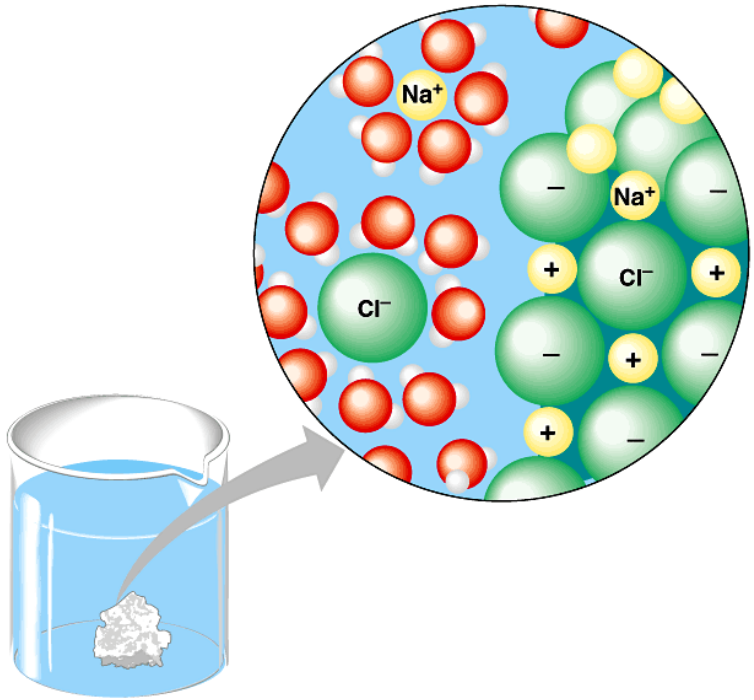
Transpiration is built on cohesion & adhesion

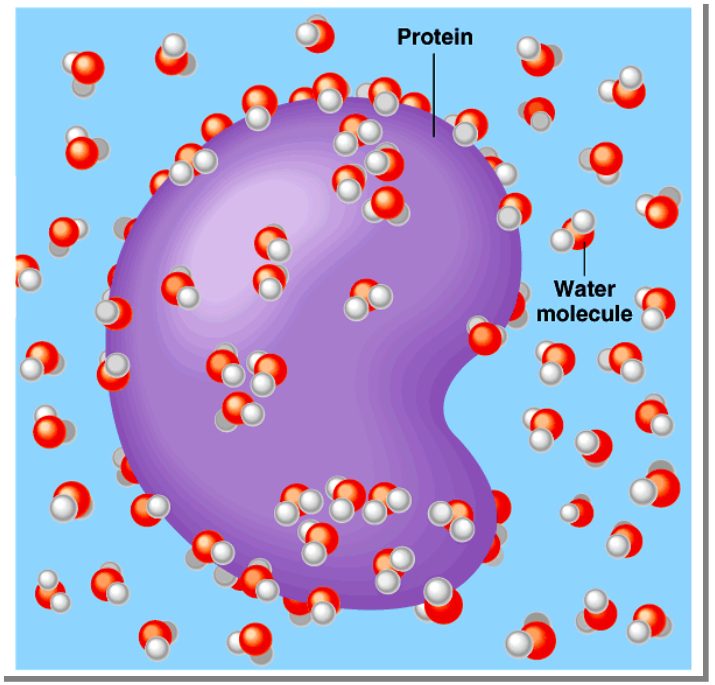




2. Water is the solvent of life

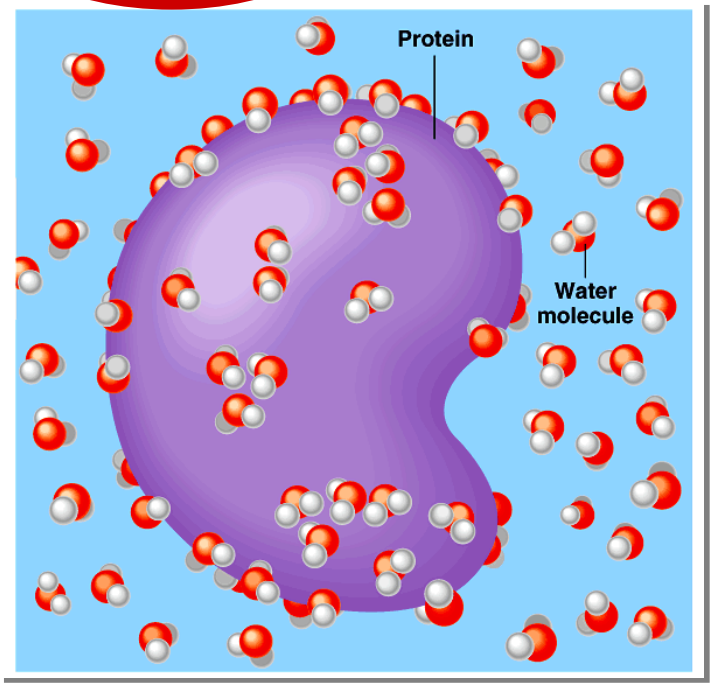
- Polarity makes H_2O a good solvent
  - polar H_2O molecules surround + & – ions
  - solvents dissolve solutes creating solutions

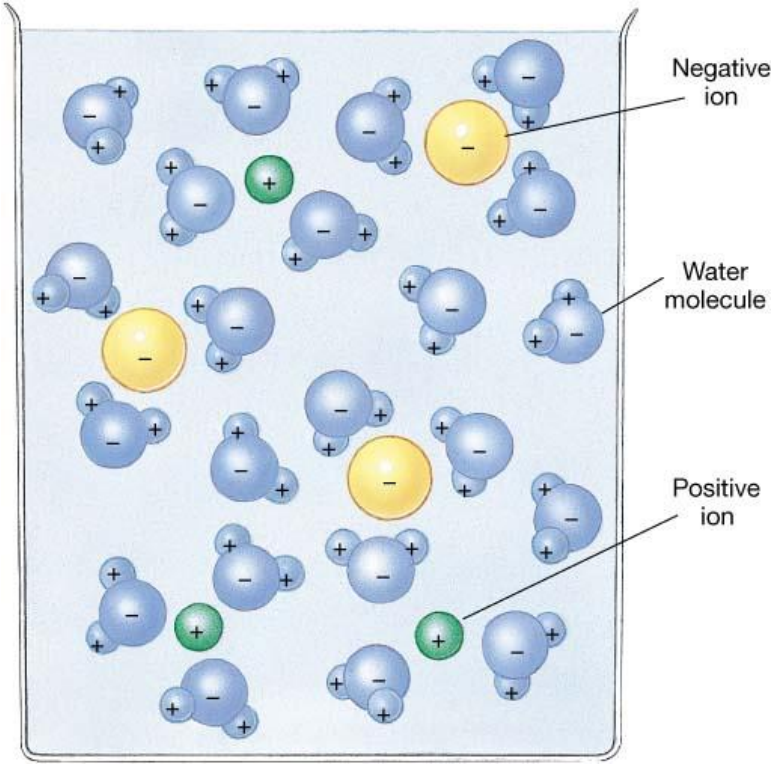




What dissolves in water?

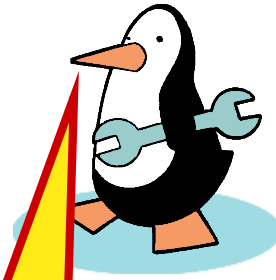
- **Hydrophilic**
  - substances have attraction to H_2O
  - **polar** or **non-polar**?



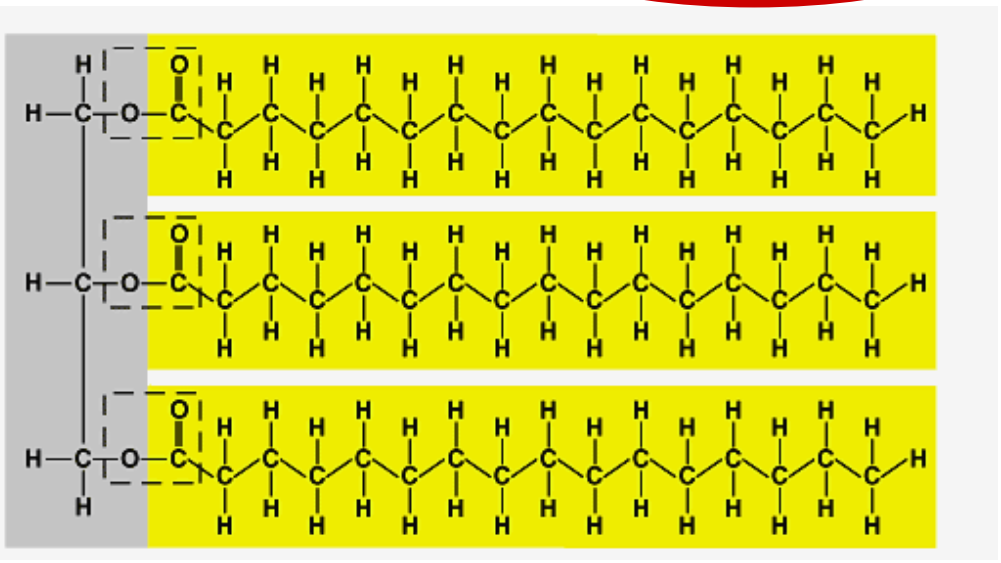


What doesn't dissolve in water?

- **Hydrophobic**
  - substances that don't have an attraction to H_2O
  - **polar** or **non-polar**?



Oh, look hydrocarbons!



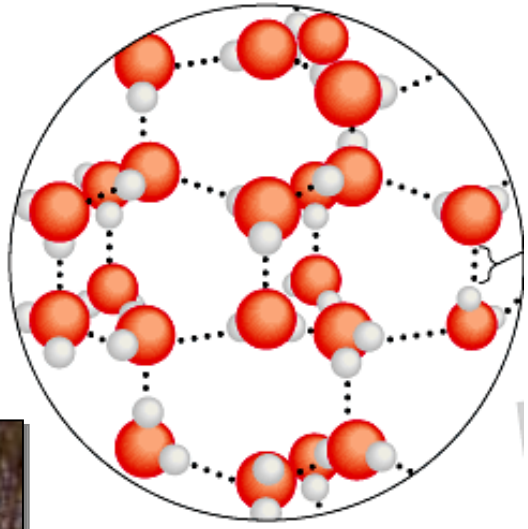
fat (triglycerol)

3. The special case of ice

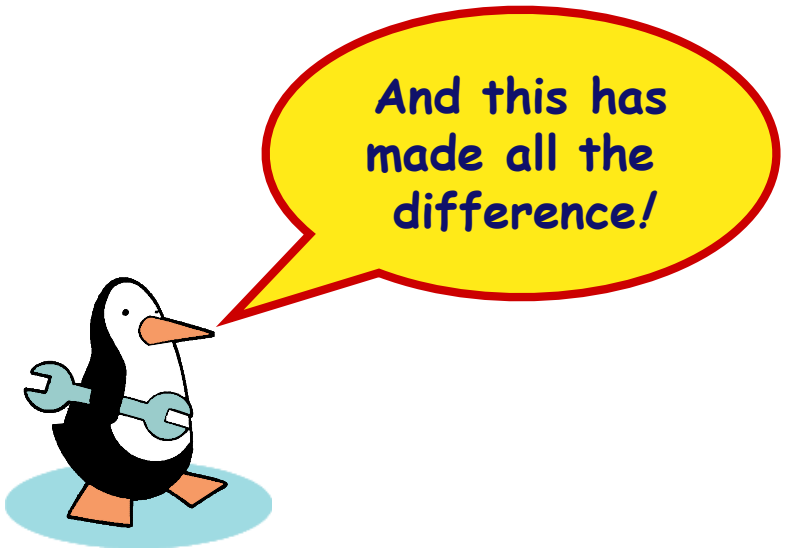
- Most (all?) substances are more dense when they are solid, but

  not water…

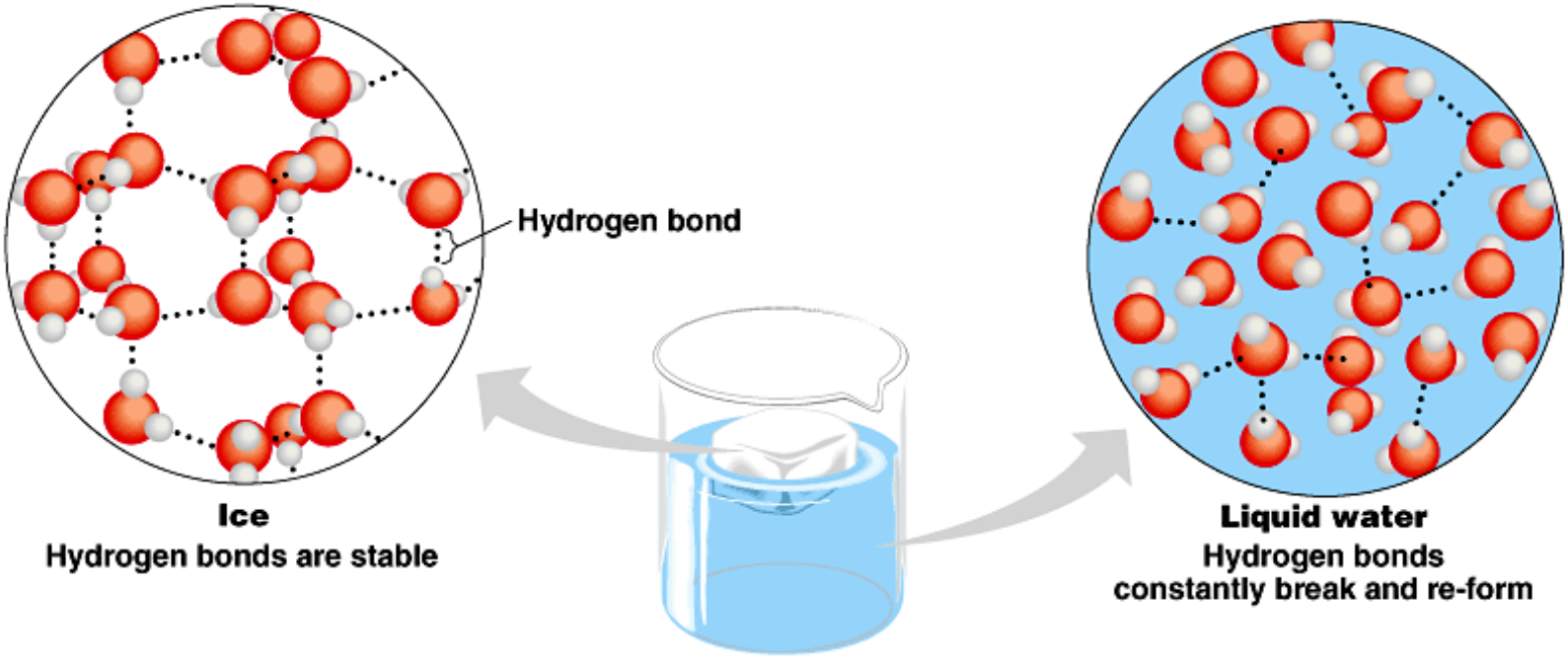
- Ice floats!
  - H bonds form a crystal



Ice
Hydrogen bonds are stable

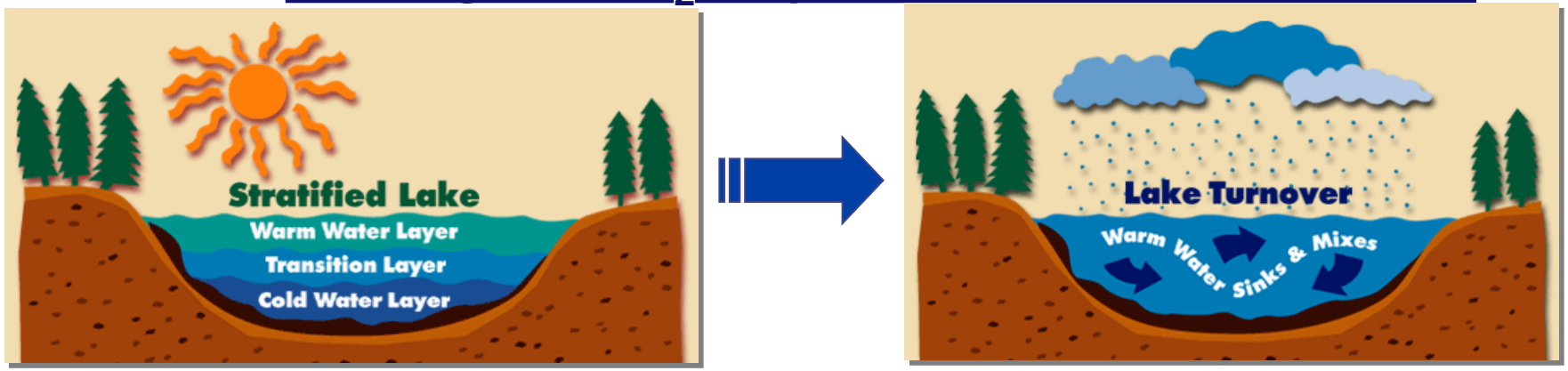


Ice floats


Hydrogen bond
Ice
Hydrogen bonds are stable
Liquid water
Hydrogen bonds
constantly break and re-form

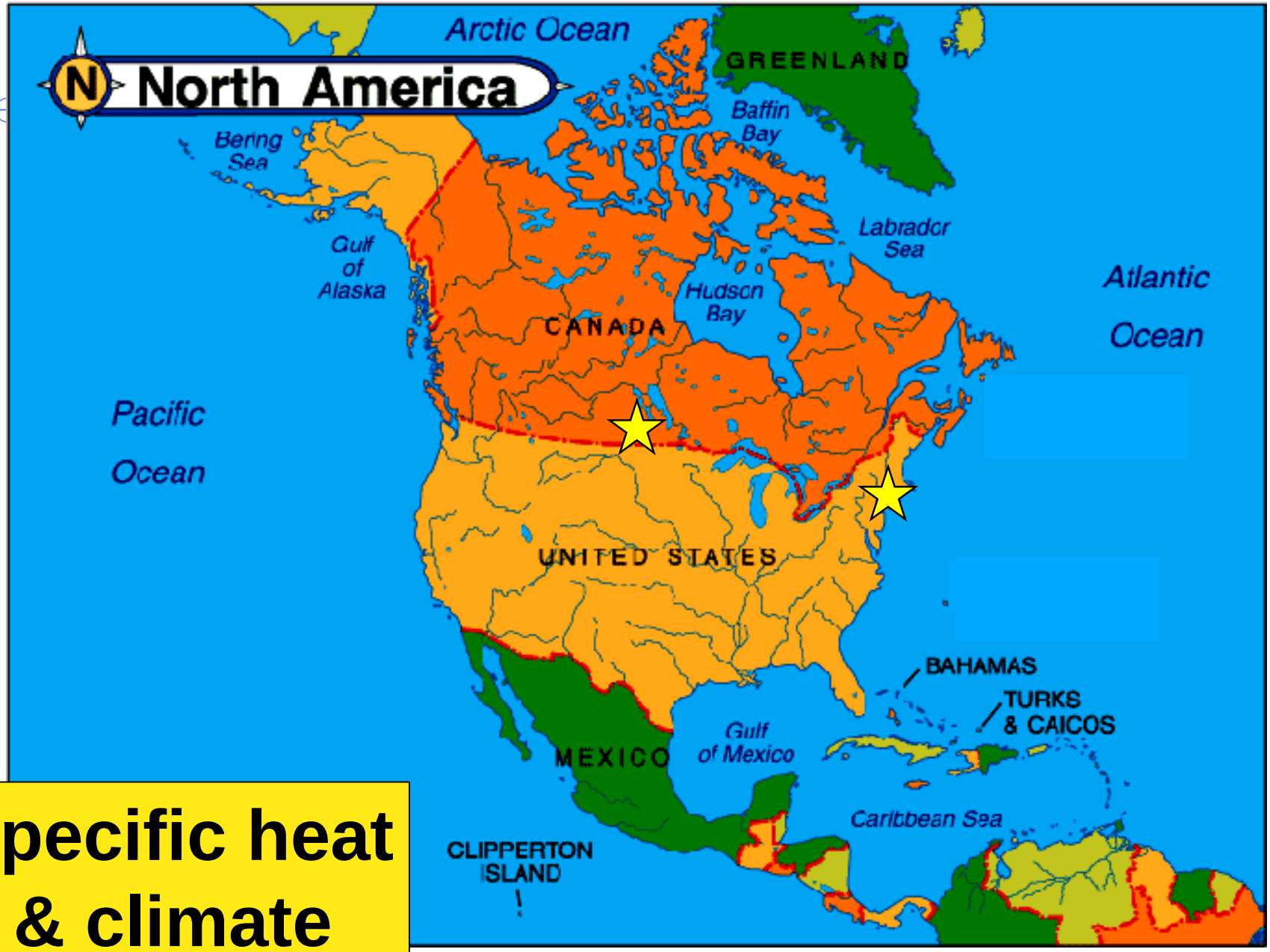
Why is “ice floats” important?

- Oceans & lakes don’t freeze solid
  - surface ice insulates water below
    - allowing life to survive the winter
  - if ice sank…
    - ponds, lakes & even oceans would freeze solid
    - in summer, only upper few inches would thaw
  - seasonal turnover of lakes
    - sinking cold H_2O cycles nutrients in autumn



4. Specific heat

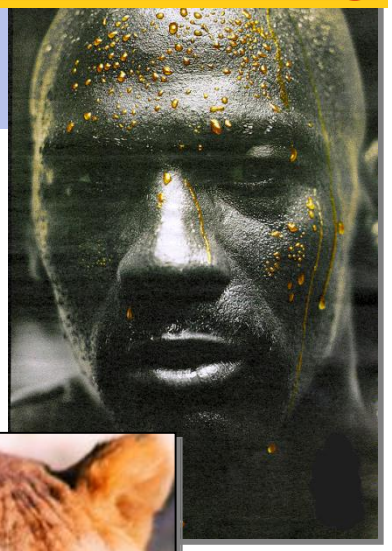
- H_2O resists changes in temperature
  - high specific heat
  - takes a lot to heat it up
  - takes a lot to cool it down
- H_2O moderates temperatures on Earth

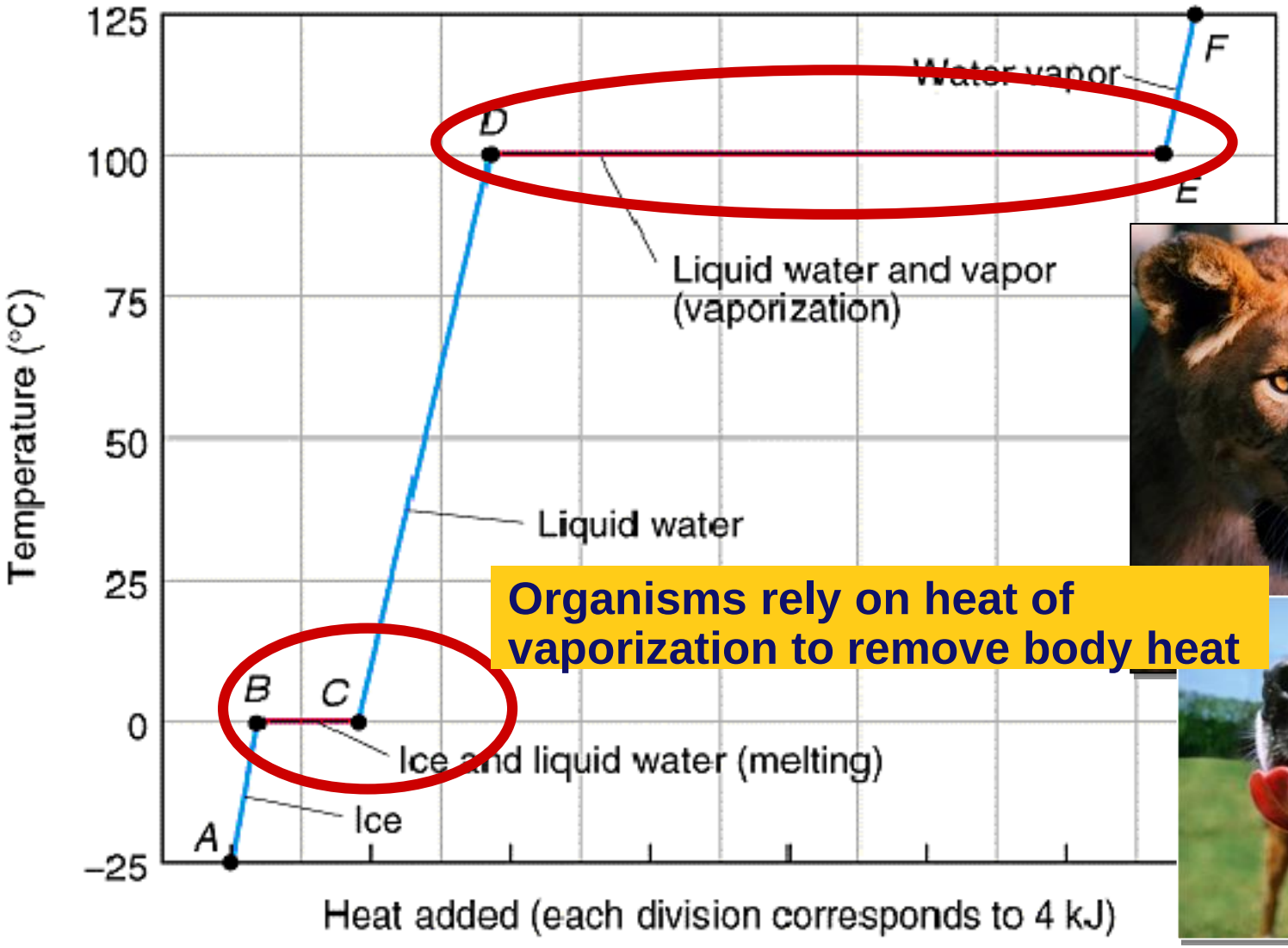


Specific heat & climate

5. Heat of vaporization

Evaporative cooling





Organisms rely on heat of vaporization to remove body heat

Ionization of water & pH

- **Water ionizes**
  - **H^+ splits off from H_2O, leaving OH^-**
    - **if $[H^+] = [^-OH]$, water is <u>neutral</u>**
    - **if $[H^+] > [^-OH]$, water is <u>acidic</u>**
    - **if $[H^+] < [^-OH]$, water is <u>basic</u>**
- **<u>pH scale</u>**
  - **how acid or basic solution is**
  - **$1 \rightarrow 7 \rightarrow 14$**

$$H_2O \rightarrow H^+ + OH^-$$

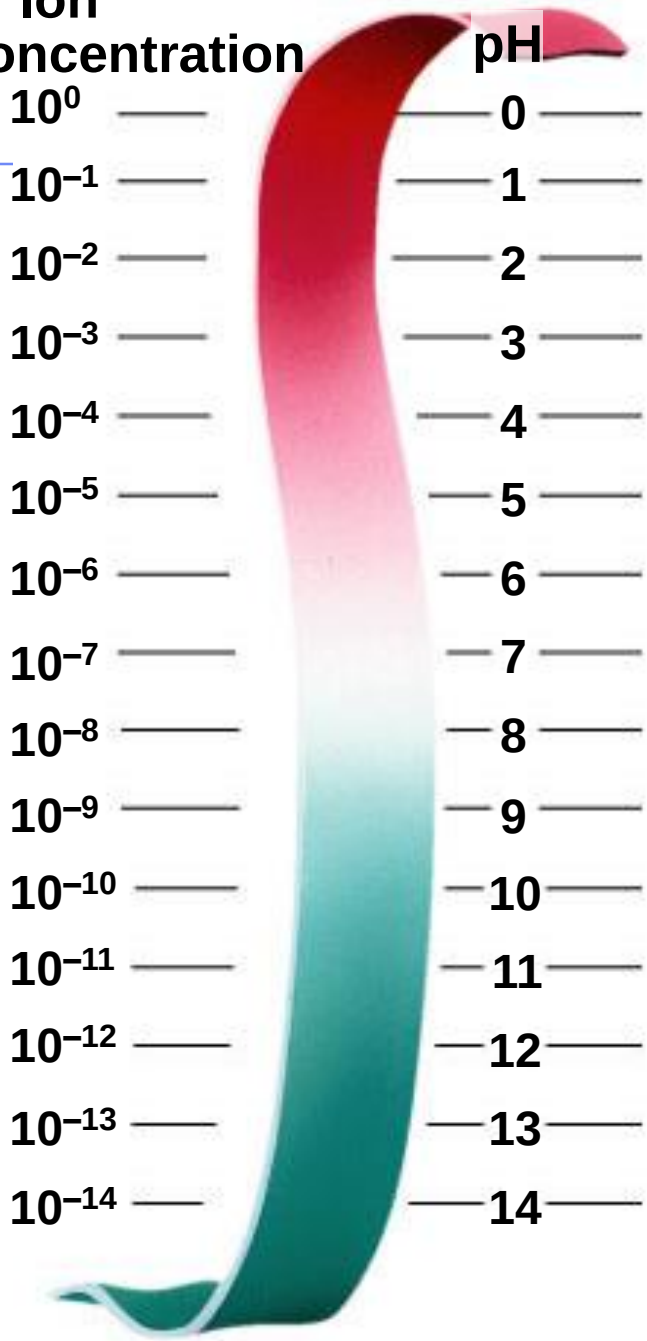
pH Scale

tenfold change in H+ ions

pH1 → pH2
$10^{-1} \rightarrow 10^{-2}$
10 times less H^+

pH8 → pH7
$10^{-8} \rightarrow 10^{-7}$
10 times more H^+

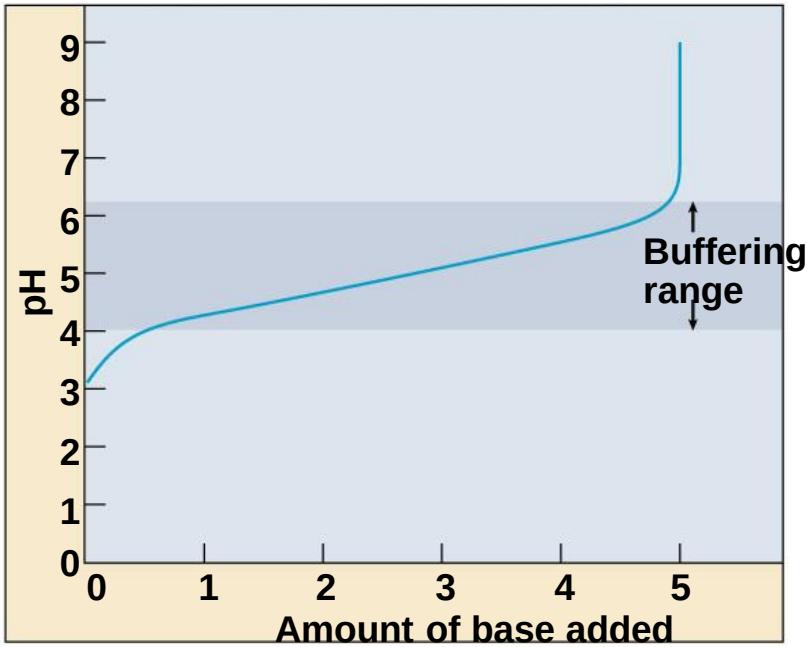
pH10 → pH8
$10^{-10} \rightarrow 10^{-8}$
100 times more H^+



H^+ Ion Concentration	pH	Examples of Solutions
10^{0}	0	Hydrochloric acid
10^{-1}	1	
10^{-2}	2	Stomach acid, Lemon juice
10^{-3}	3	Vinegar, cola, beer
10^{-4}	4	Tomatoes
10^{-5}	5	Black coffee, Rainwater
10^{-6}	6	Urine, Saliva
10^{-7}	7	Pure water, Blood
10^{-8}	8	Seawater
10^{-9}	9	Baking soda
10^{-10}	10	Great Salt Lake
10^{-11}	11	Household ammonia
10^{-12}	12	Household bleach
10^{-13}	13	Oven cleaner
10^{-14}	14	Sodium hydroxide

Buffers & cellular regulation

- pH of cells must be kept ~7
  - pH affects shape of molecules
  - shape of molecules affect function
  - pH affects cellular function
- Control pH by buffers
  - reservoir of H^+
    - donate H+ when $[H^+]$ falls
    - absorb H+ when $[H^+]$ rises




He's gonna
earn a
Darwin Award!


Any
Questions?
Do one brave thing today…then run like hell!

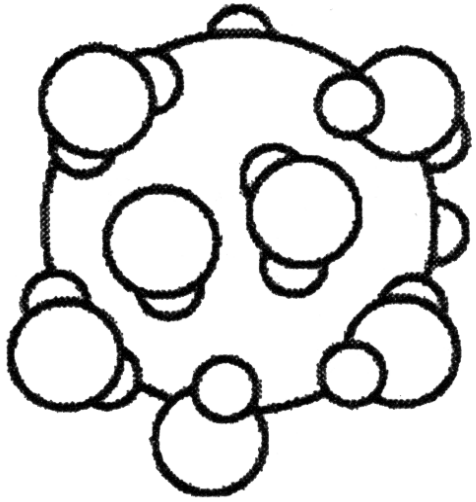
Review Questions

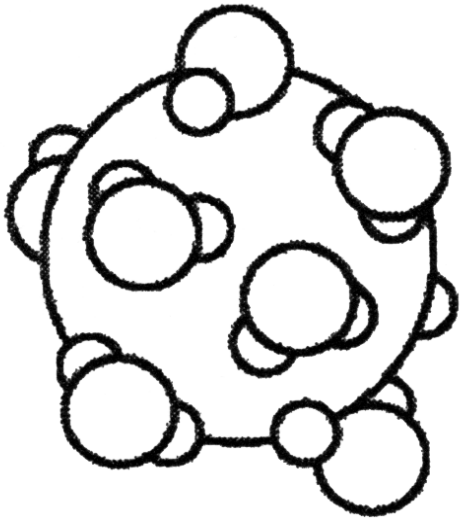
A. The following are *pH* values: cola-2; orange juice-3; beer-4; coffee-5; human blood-7.4. Which of these liquids has the highest molar concentration of OH-?

1. cola
2. orange juice
3. beer
4. coffee
5. human blood

B. Based on your knowledge of the polarity of water, the solute molecule is most likely *

1. positively charged.
2. negatively charged.
3. neutral in charge.
4. hydrophobic.
5. nonpolar.





C. If the pH of a solution is increased from pH 8 to pH 9, it means that the

1. concentration of H+ is 10 times greater than what it was at pH 8.
2. concentration of H+ is 100 times less than what it was at pH 8.
3. concentration of OH- is 10 times greater than what it was at pH 8.
4. concentration of OH- is 100 times less than what it was at pH 8.
5. concentration of H+ is greater and the concentration of OH- is less than at pH 8.

D. Acid precipitation has lowered the pH of a particular lake to 4.0. What is the *hydroxide* ion concentration of the lake?

1. 10^{-7} *M*
2. 10^{-4} *M*
3. 10^{-10} *M*
4. 10^{-14} *M*
5. 10 *M*