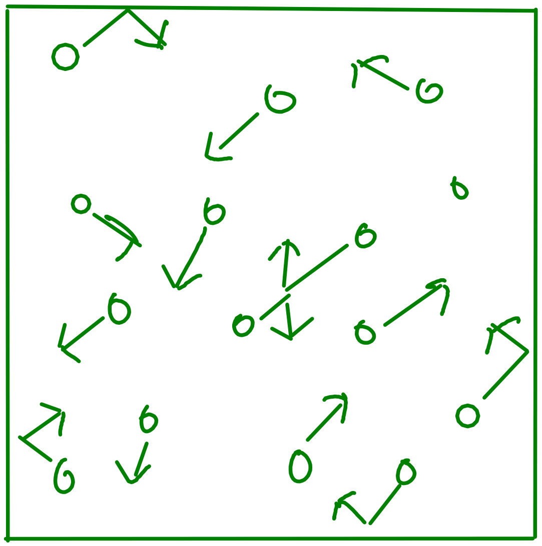
SOLIDS AND LIQUIDS

- Here's a brief review of the atomic picture or gases, liquids, and solids

GASES



kinetic theory says...

* Gas molecules are small compared to the space between them.

* Gas molecules move in straight lines until they hit another gas molecule or the walls of the container.

* There are no attractive or repulsive forces between gas molecules except during a collision.

* When gas molecules collide, energy may be transferred, but no energy is lost as heat.

* The temperature of a gas is proportional to the average kinetic energy of the gas molecules.

... kinetic energy depends on velocity of gas molecules!

$$E_K = \frac{1}{2}mv^2$$

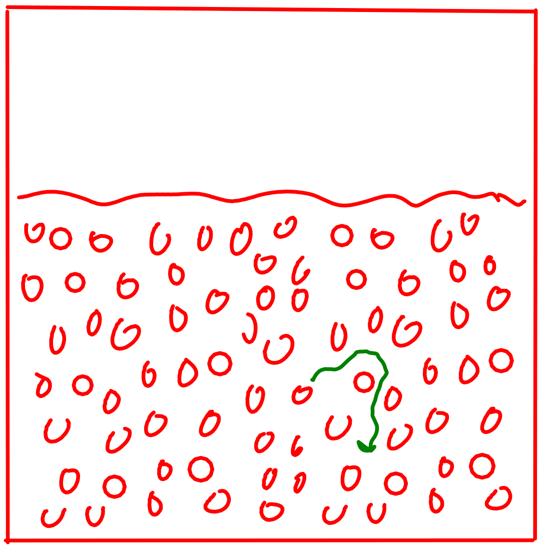
Gases are FLUID, COMPRESSIBLE, and DIFFUSE (NOT DENSE)!

↑ variable volume!

- The properties of different gases are very similar to one another. At moderate conditions, different gases obey the simple IDEAL GAS EQUATION.

$$PV = nRT$$

LIQUIDS



* Molecules are much closer together than in the gas phase.

* Molecules are free to move around each other, but there is much less freedom of motion than in the gas phase

* Molecules in the liquid state are held together by attractive forces that we will call INTERMOLECULAR FORCES

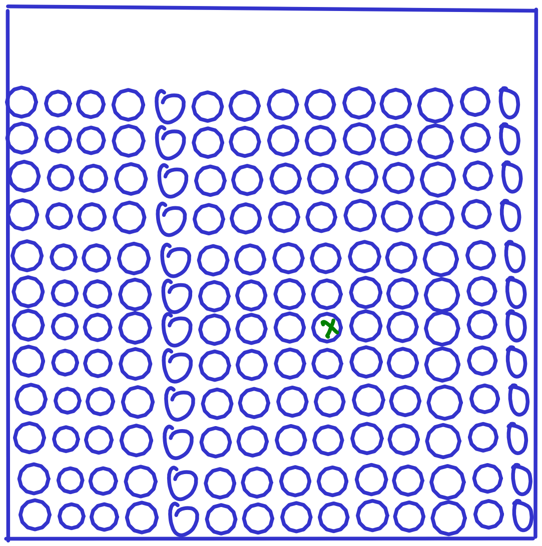
Liquids are FLUID, DENSE, and INCOMPRESSIBLE!

fixed volume!

- The properties of different liquids are often very different from one another, Compare liquids like water and motor oil, which are different enough so that they won't readily mix with one another!

no simple "$PV = nRT$" for liquids!

SOLIDS



* Molecules are usually packed closer together in the solid phase than in the gas or liquid phases.

* Molecules are not free to move around each other as in the liquid phase. Molecular/atomic motion in the solid phase is limited to vibration.

* Most solids have a regular structure - unlike liquids or gases. This structure is called a CRYSTAL LATTICE.

* Molecules are held together by INTERMOLECULAR FORCES. These are usually stronger than in the liquid phase.

Solids are RIGID, DENSE, and INCOMPRESSIBLE!

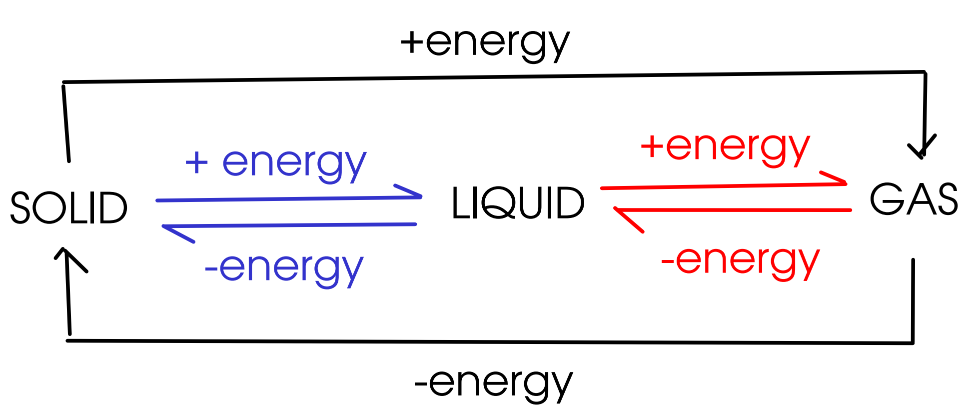
- As for the liquids, the properties of different solids often differ considerably. Compare a sample of candle wax to a sample of quartz.

PHASE CHANGES

- To understand solids and liquids at the molecular level, it will help to examine PHASE CHANGES in a little more detail.

A quick review of the phase changes...

Phase change	Description	Energy change
Melting	Solid to liquid	Endothermic
Sublimation	Solid to gas	Endothermic
Vaporization	Liquid to gas	Endothermic
Deposition	Gas to solid	Exothermic
Freezing	Liquid to solid	Exothermic
Condensation	Gas to liquid	Exothermic

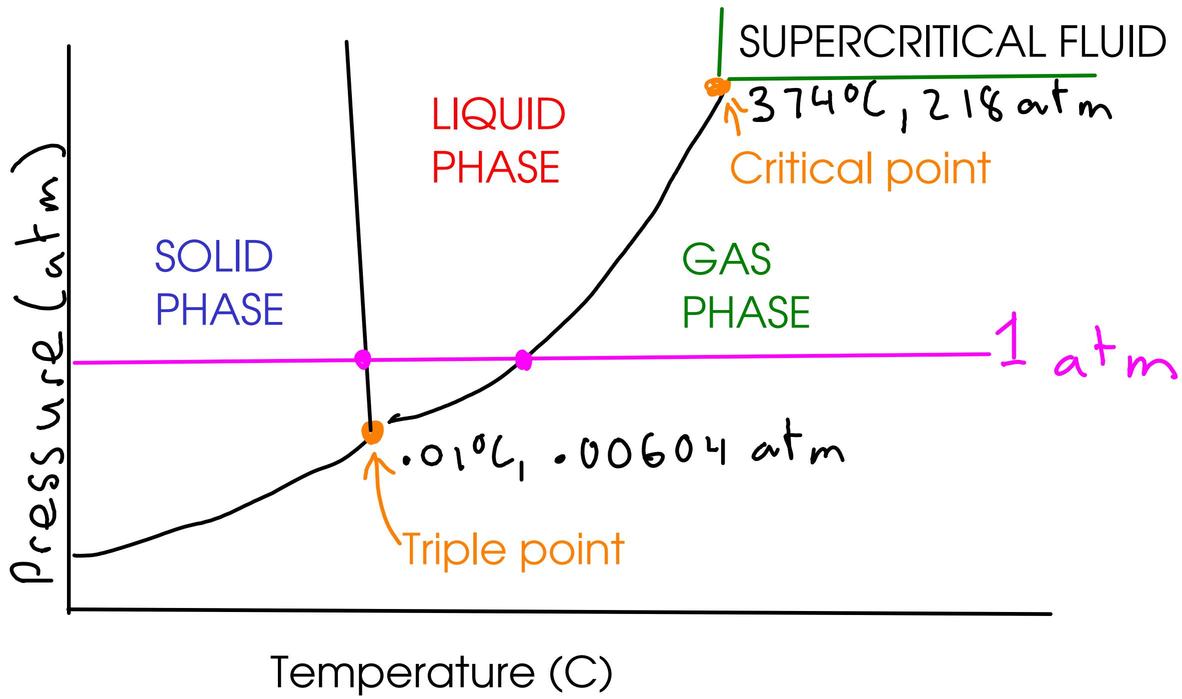


ΔH_{fus} : enthalpy change to melt 1 mol of solid

ΔH_{vap} : enthalpy change to vaporize 1 mol of liquid

PHASE DIAGRAMS

- are a convenient way to show experimental data on when bulk phase changes occur.



SAMPLE PHASE DIAGRAM FOR WATER

See p 439-440 for more!

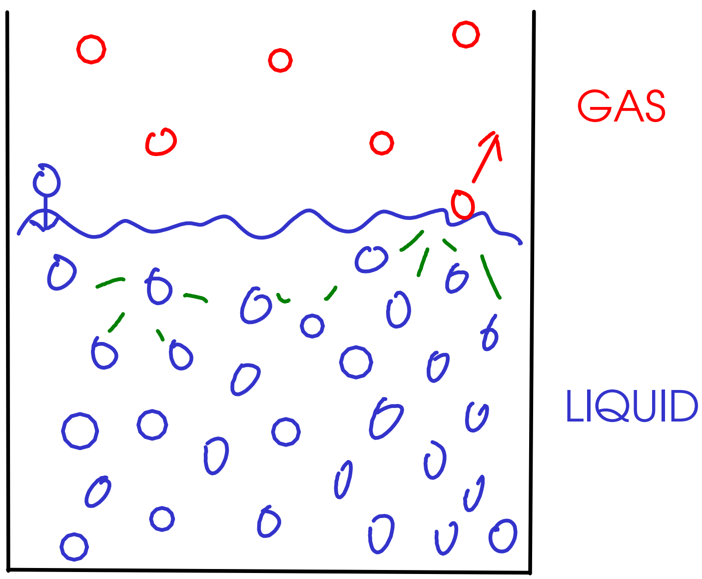
- The curves on the phase diagram represent bulk phase changes.

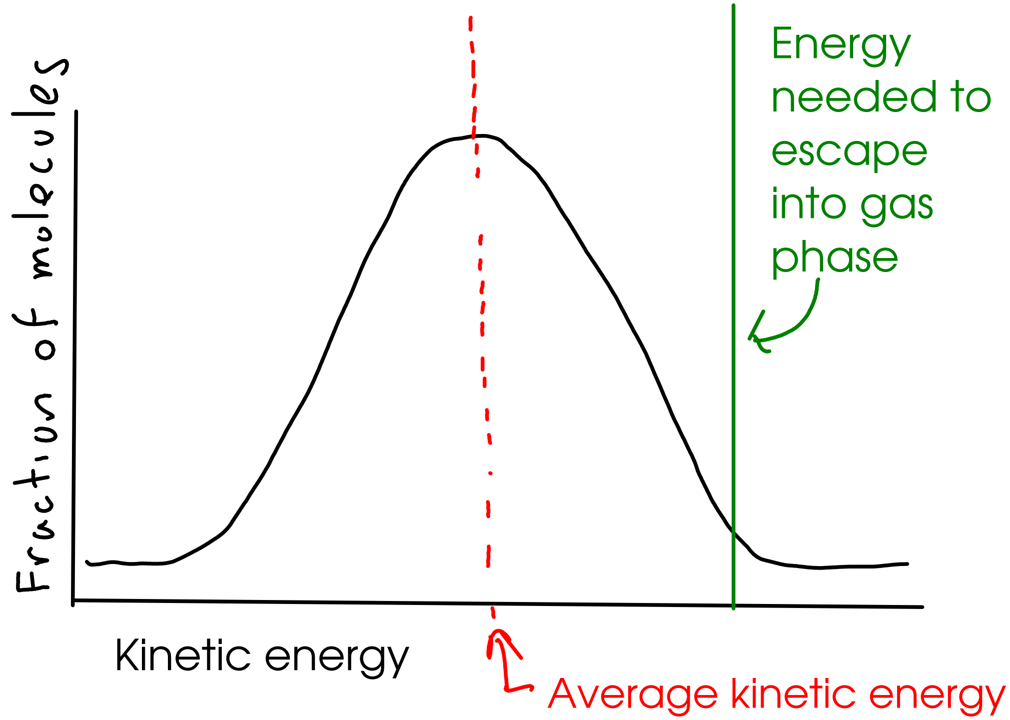
- The TRIPLE POINT is a set of conditions where all six phase changes occur at the same time; in other words all three phases coexist

- The CRITICAL POINT occurs where there stops being a distinction between the gas and liquid states. This occurs at high pressure and high temperature, where the substance has the density of a liquid but the fluidity of a gas. This is called a SUPERCRITICAL FLUID. Supercritical fluids - like supercritical carbon dioxide - are often used as envorinmentally friendly SOLVENTS.

- The normal boiling point and freezing points are on the curves. The normal melting point is the point on the solid/liquid curve at 1 atm, while the normal boiling point is on the liquid/gas curve at 1 atm!

VAPORIZATION IN MORE DETAIL





- For a molecule to move from the liquid phase to the gas phase, it must acquire enough KINETIC ENERGY (which depends on molecular SPEED) to break away from the INTERMOLECULAR FORCES holding the molecule in the liquid.

- The AVERAGE KINETIC ENERGY of molecules is proportional to the TEMPERATURE. On average, molecules in both the liquid and the solid state move faster at higher temperatures.

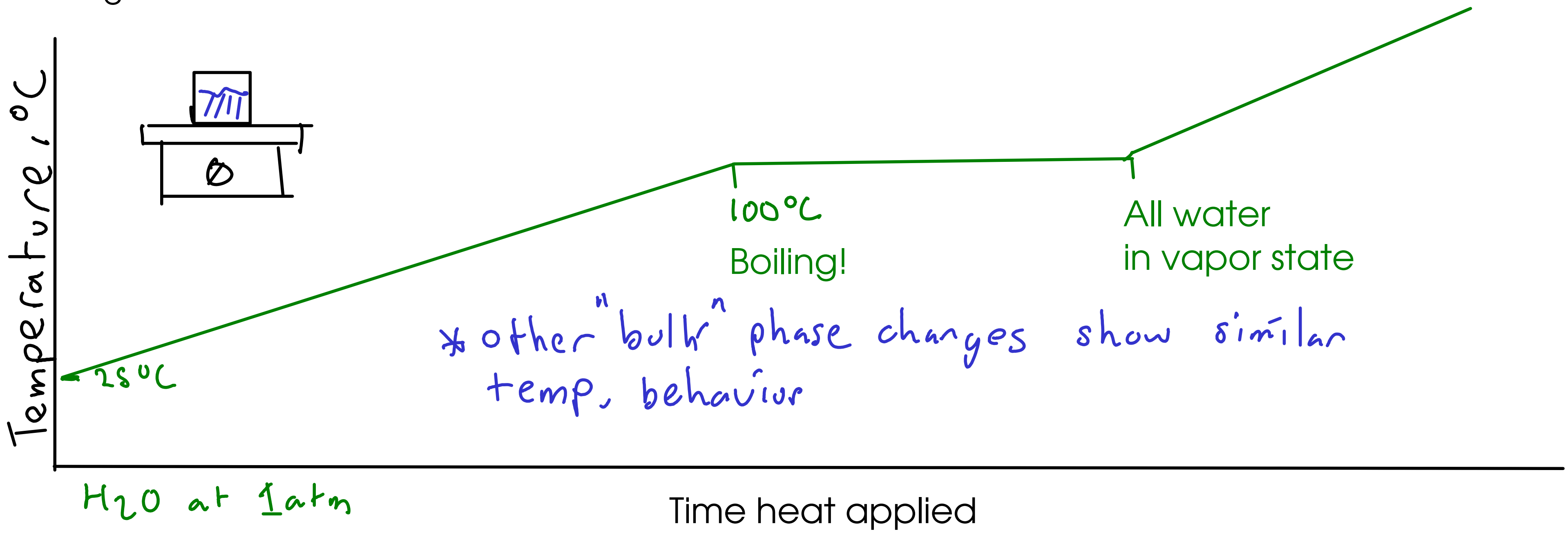
- Even at room temperature, some of the molecules have enough kinetic energy to escape into the gas phase. This accounts for the tendency of volatile liquids to evaporate from open containers even well away from the boiling point.

- As we increase temperature, the gaussian curve above shifts to the right, and a higher fraction of molecules have enough energy to vaporize.

TEMPERATURE PROFILE OF VAPORIZATION

- To increase the rate of vaporization, we can increase the temperature. At the BOILING POINT, the pressure of the vaporizing water is enough to push back against the liquid water and bubbles of vapor form in the liquid: BOILING

- If we look at the temperature changes up to and through the boiling point, we see something interesting...



DURING THE BOILING PROCESS, as long as you have some liquid water remaining, the temperature will remain constant - EVEN AS YOU CONTINUE TO APPLY HEAT!

How do we explain this behavior? ↙ ΔH_{vap}

- The VAPORIZATION itself requires an energy input. What's that energy doing? Breaking water molecules away from one another (breaking apart the water's intermolecular forces).

LIQUIDS

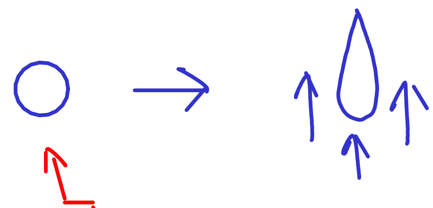
- FLUID, DENSE, INCOMPRESSIBLE

- Posess a few unique properties

① SURFACE TENSION

- a measure of the tendency of a liquid to minimize its surface area, or the resistance to the breaking of a liquid surface.

Liquid droplets tend to be spehrical...



... but friction causes falling droplets to take on the traditional "drop" shape.

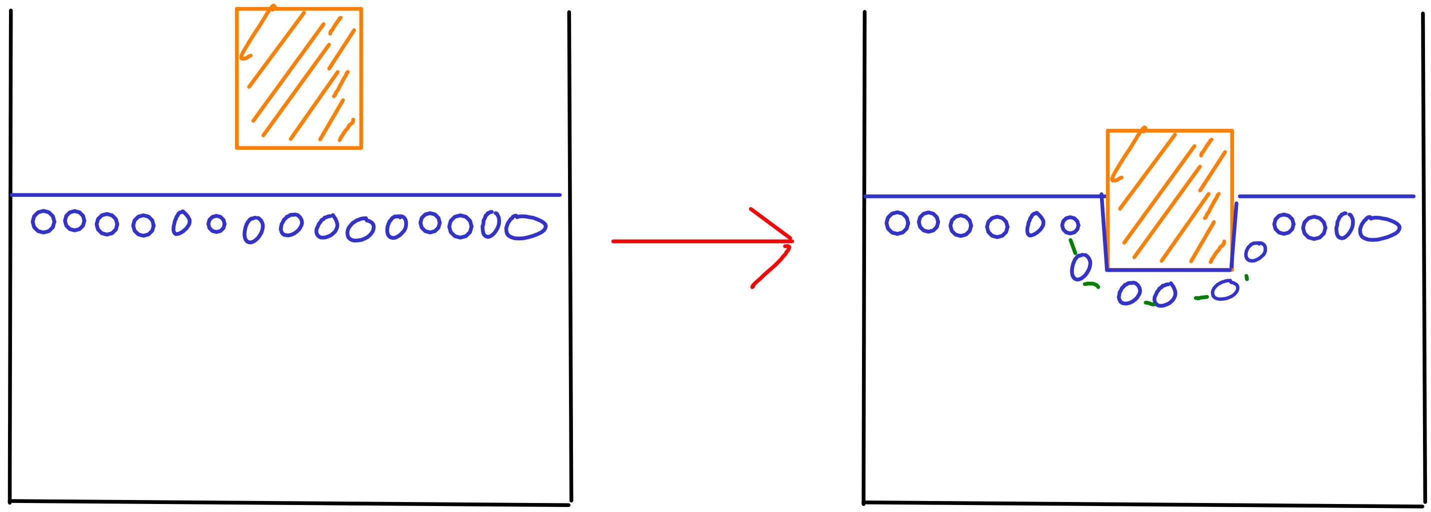
A sphere has the smallest surface area for a given volume.

② VISCOSITY (also for gases)

- a measure of a liquids resistance to flow, or "thickness"

SURFACE TENSION

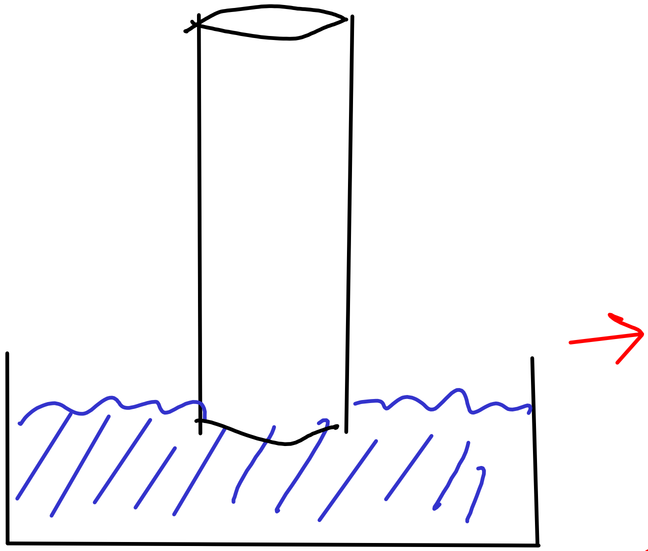
- Surface tension can be explained by looking at liquid molecules as being attracted to each other by INTERMOLECULAR FORCES.

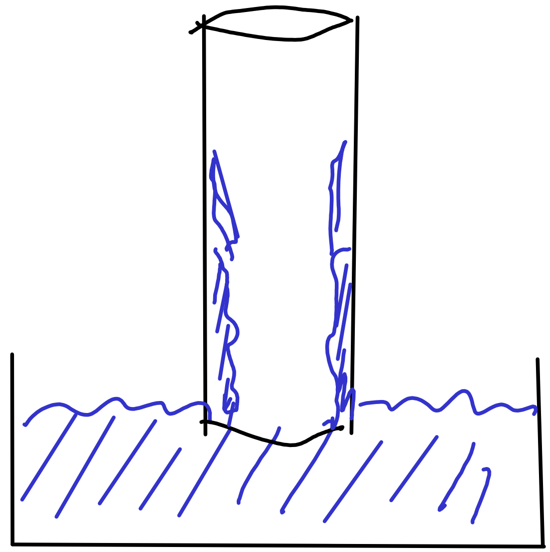


The object increases the surface area of the liquid!

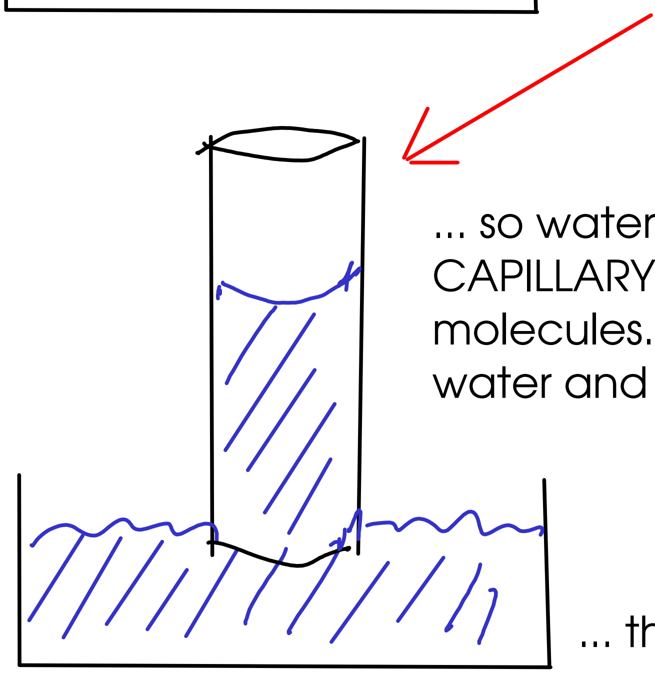
For the object to penetrate the liquid surface, it must push water molecules at the surface apart. Since these water molecules ARE ATTRACTED TO ONE ANOTHER, the liquid will resist!

[39] Surface tension also explains CAPILLARY ACTION, the drawing up of WATER into a glass tube. Water is attracted to glass, and will climb up the surface of a glass tube.





... but this greatly increases the SURFACE AREA of the water, and pulls the water molecules farther from each other.



... so water is PULLED UP THE MIDDLE OF THE CAPILLARY by the attractive forcea between water molecules. This minimizes the surface area of the water and gets water molecules closer to one another.

... the water is pulled up AGAINST GRAVITY!