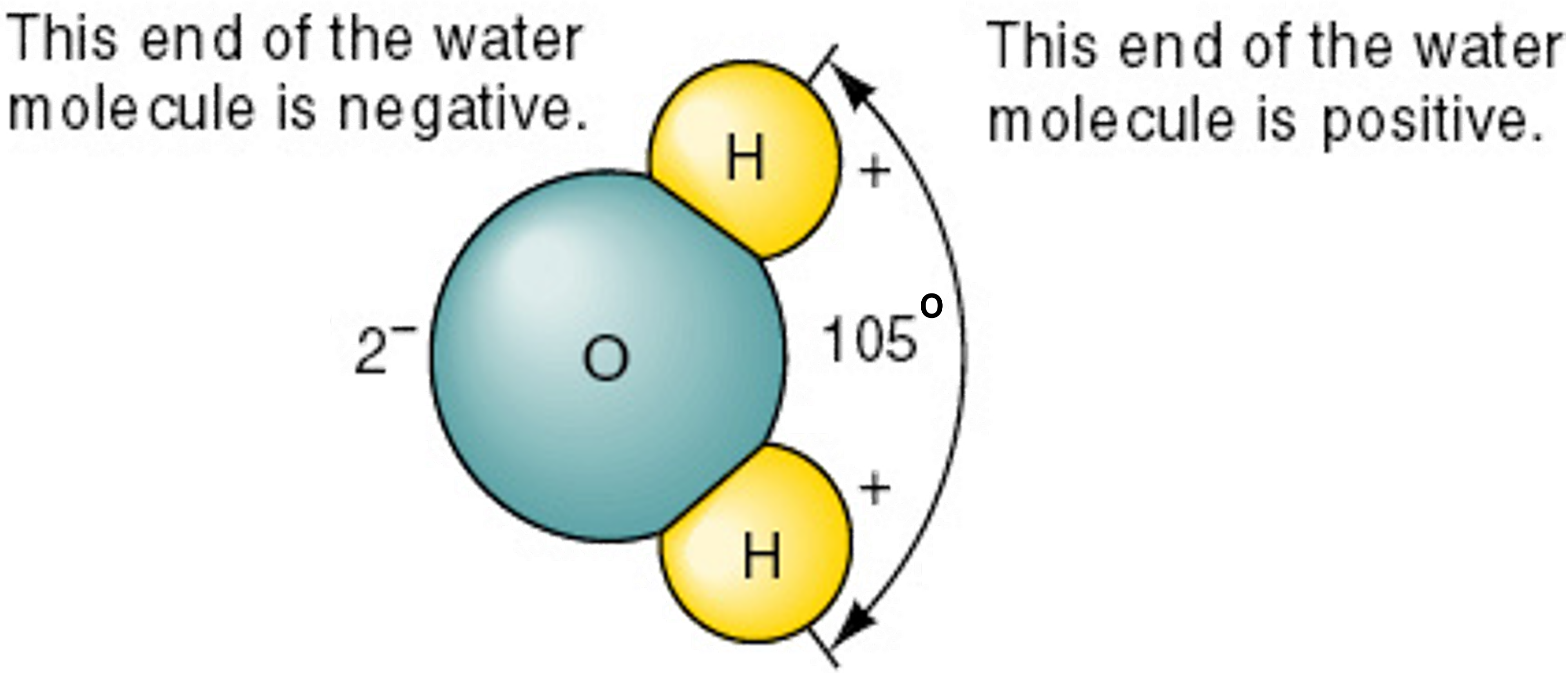
States of Matter & Bond Strength

- **Gas** = Molecules <u>not</u> bonded to one another; move independently. Takes the volume and shape of its container.
- **Liquid** = Molecules <u>loosely</u> bonded to one another; bonds easily broken, so liquids flow. Volume is fixed, but takes shape of container.
- **Solid** = Molecules <u>strongly</u> bonded to one another; fixed size and shape. Bend or break with applied force.

The Water Molecule



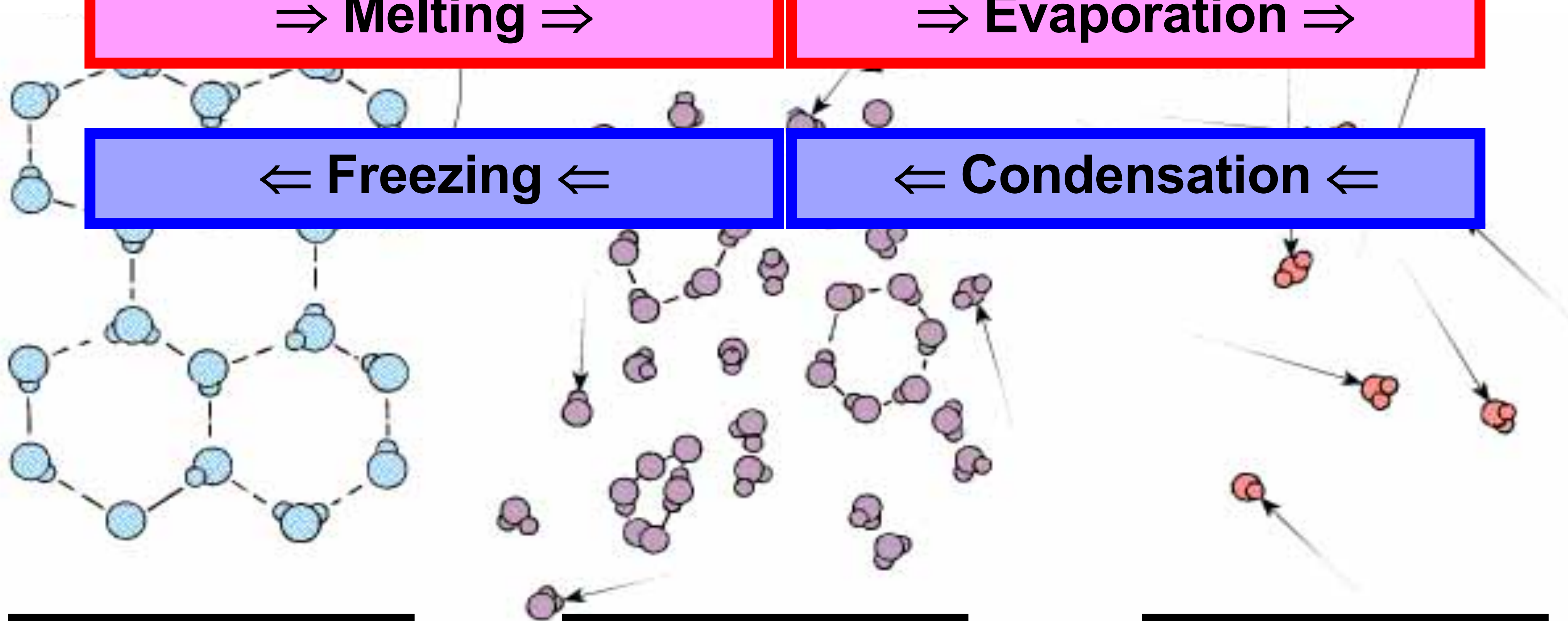
If water weren't polar, it would freeze at -90ºC (-130ºF) and boil at -68ºC (-90ºF).

And it wouldn't be nearly so good a solvent (dissolver of salts etc).

The Water Molecule

Strongly bonded — *Loosely* bonded — *Not* bonded

⇒ Melting ⇒	⇒ Evaporation ⇒
⇐ Freezing ⇐	⇐ Condensation ⇐



A. SOLID
(ice in glaciers & polar ice caps)

B. LIQUID
(oceans, rivers, & lakes)

C. GAS
(water vapor in the atmosphere)

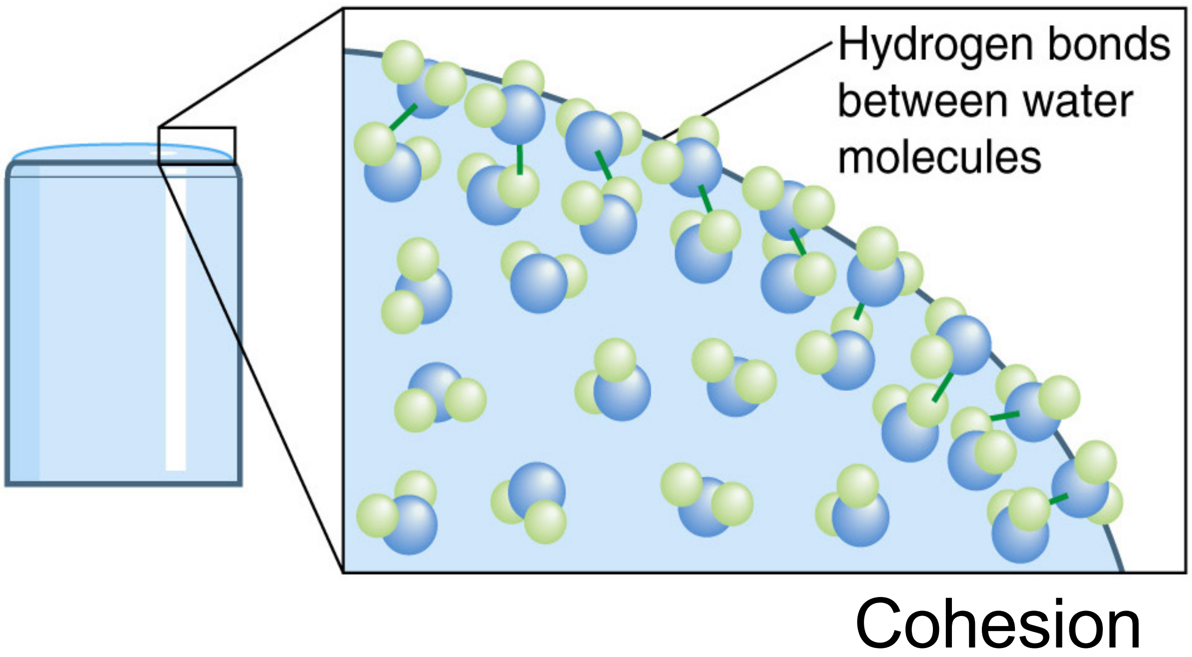
The Water Molecule - Types of Bonds

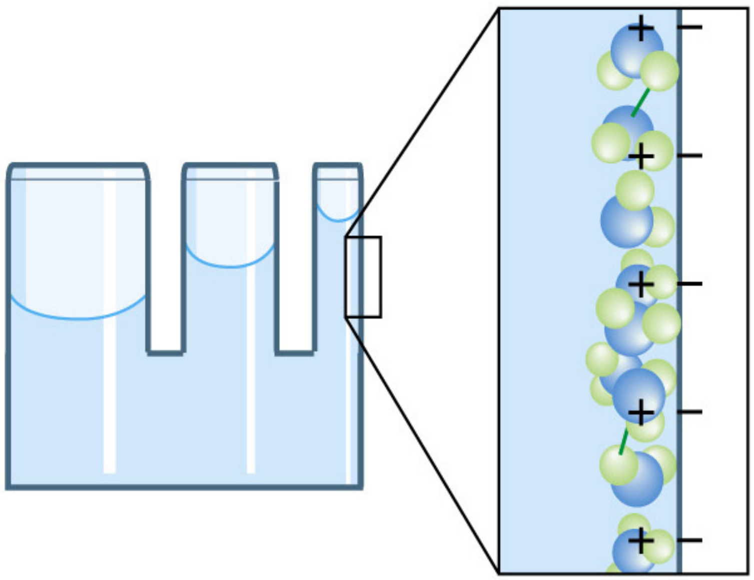
- **Covalent bonds**
  - Within each H_2O molecule
  - Bonds the H's to the O
  - Very strong! (sharing electrons)

- **Hydrogen bonds**
  - Between H_2O molecules
  - Bonds H_2O molecules to each other
  - Constantly forming and breaking in liquid water

The Water Molecule - Types of Bonds

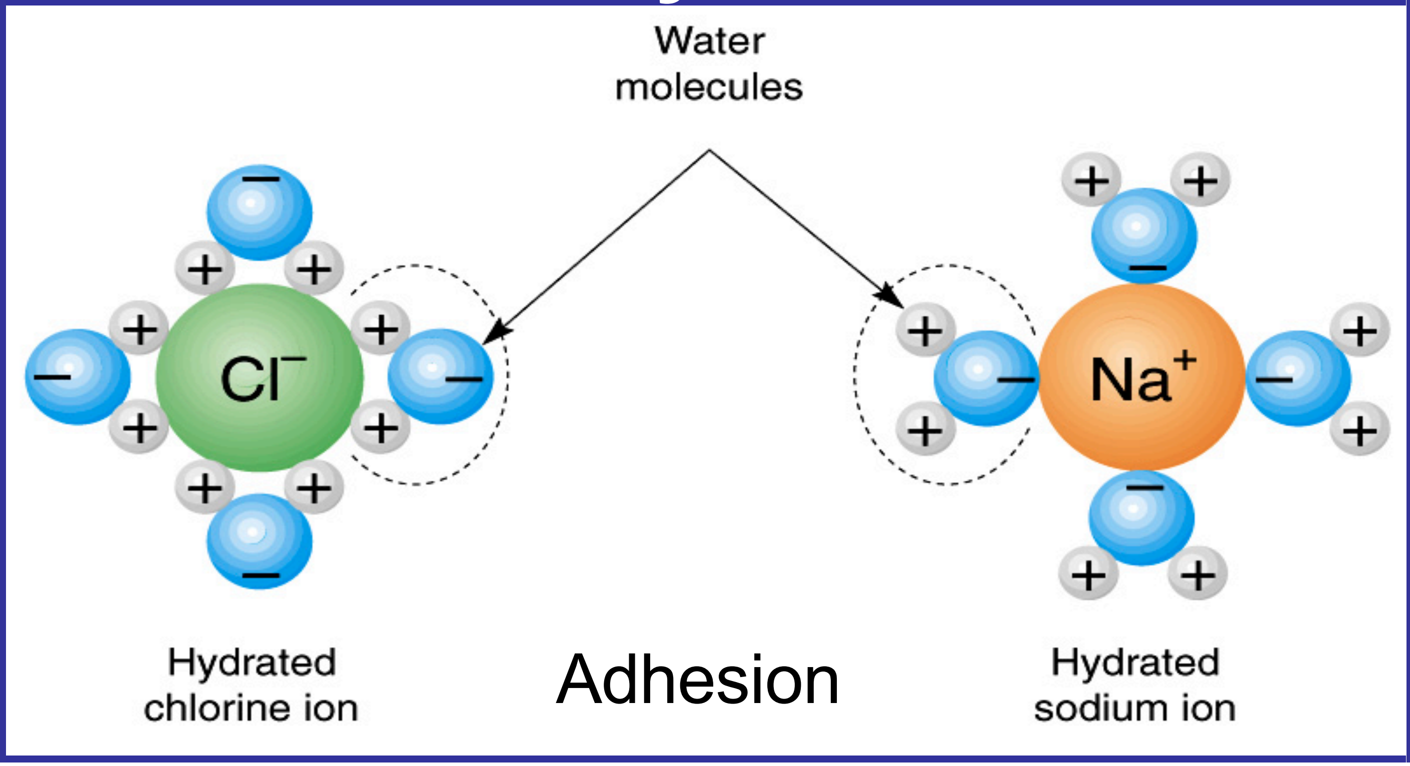
- High surface tension
  - Hydrogen bonding creates “skin”
  - Important for living organisms
    - Capillarity (e.g., in vascular plants)





The Water Molecule - Types of Bonds

- Universal solvent
  - Electrostatic bonds between dipolar water and ions
    - Ocean is salty ($NaCl \rightarrow Na^+ + Cl^-$)



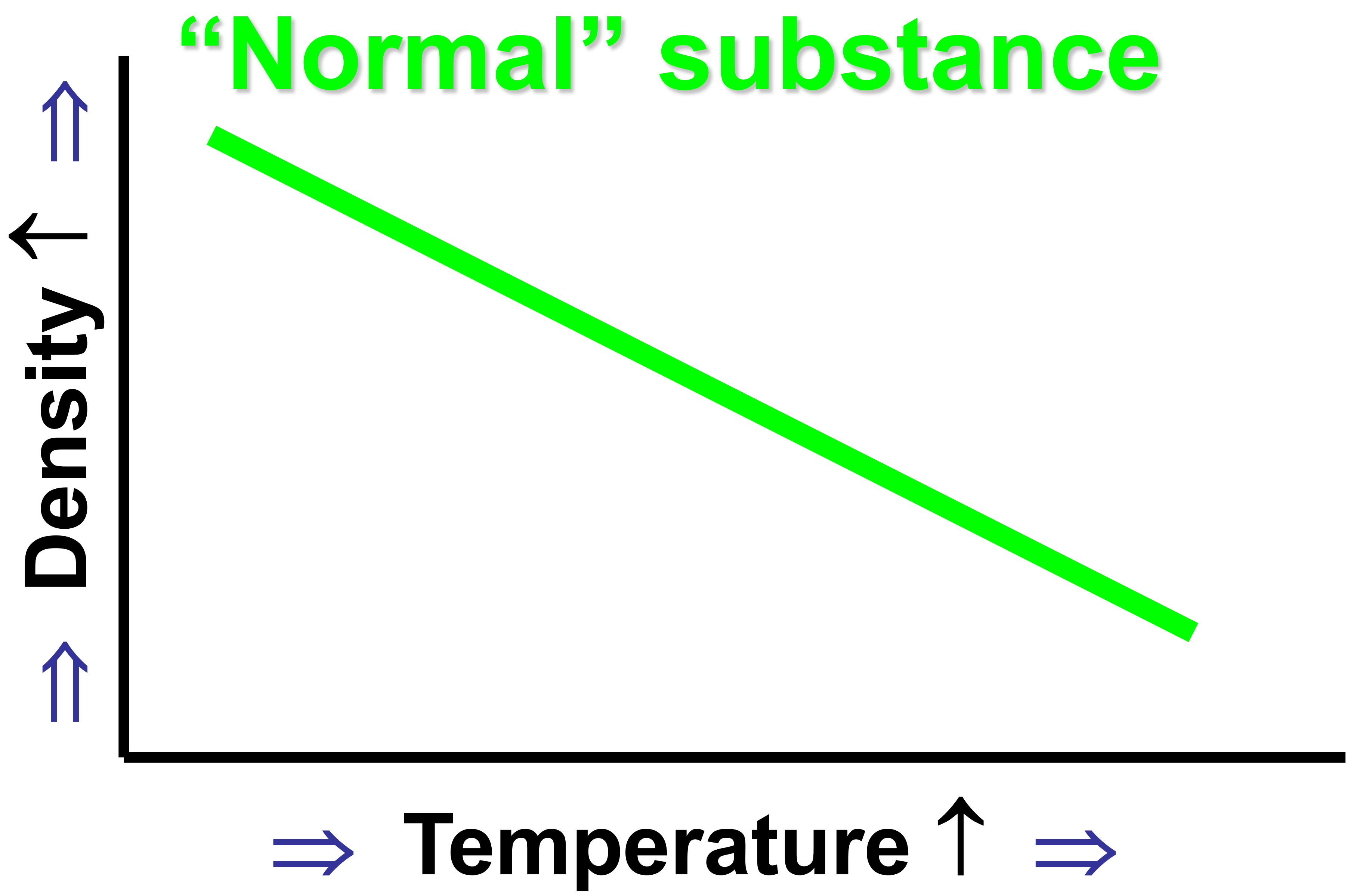
B. Density & Temperature

- **Density (ρ) = Mass / Volume** ***(in g/cm^3)***
- ***Ratio*, so ρ ↑ if mass ↑ or if volume ↓**
- **Relative water density affects water-current development**
- **Water-density vs. organism-density determines whether an organism will sink or float**
  - **Some floating organisms can *vary* their density!**

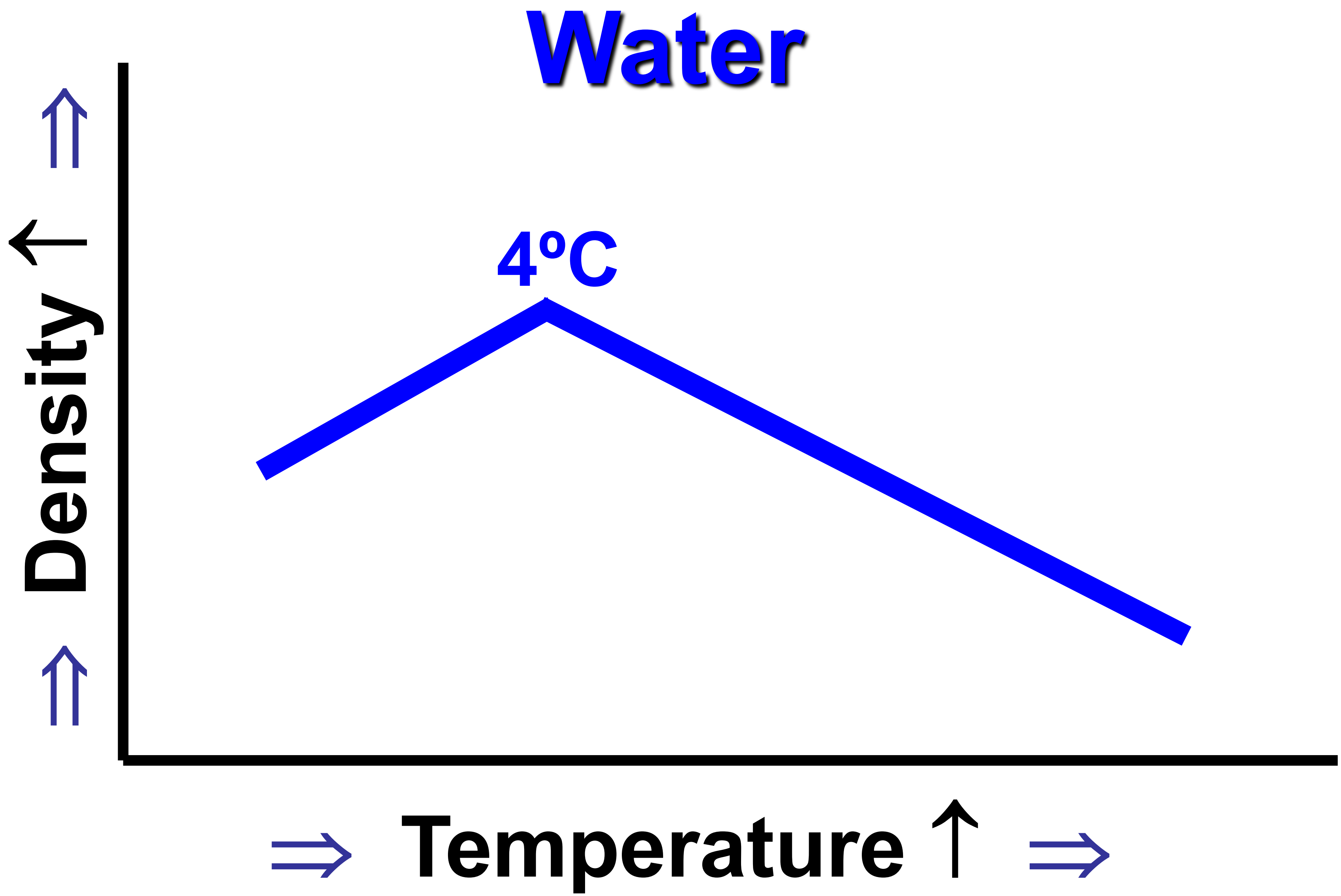
Density & Temperature

- **Density (ρ)** = Mass / Volume *(in g/cm^3)*
- Most substances get <u>denser</u> (that is, have *more* mass per unit volume) as they get <u>colder</u> (T↓ → ρ↑)
- This is only true for water down to ~4ºC (remember, water freezes at 0ºC)
- As water cools from ~4ºC to 0ºC, it becomes <u>less</u> dense! (T↓ → ρ↓)
- The maximum density of fresh water (ρ_{max}) is at 3.98ºC
- ***Let's draw all that on a graph***

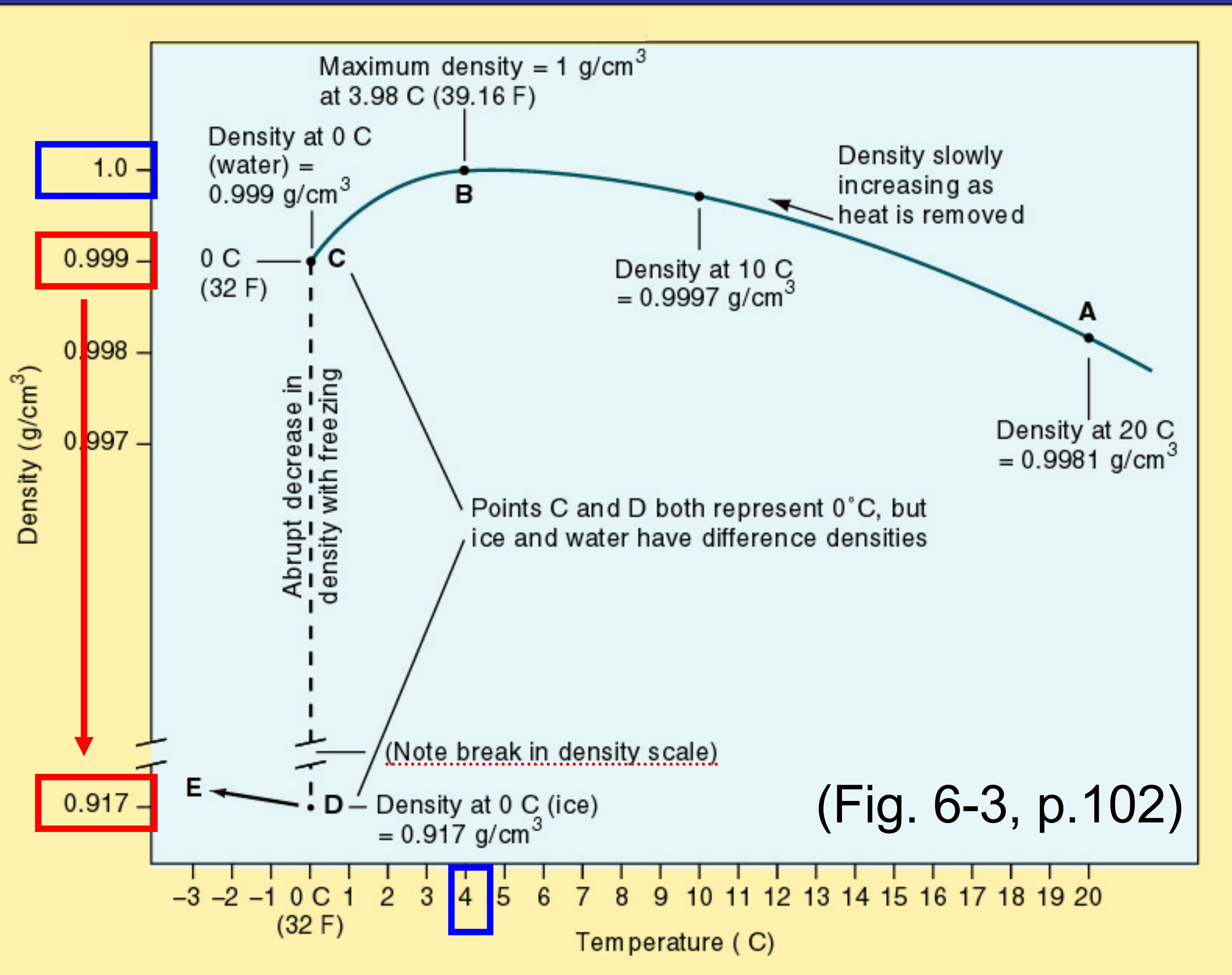
Density & Temperature



Density & Temperature

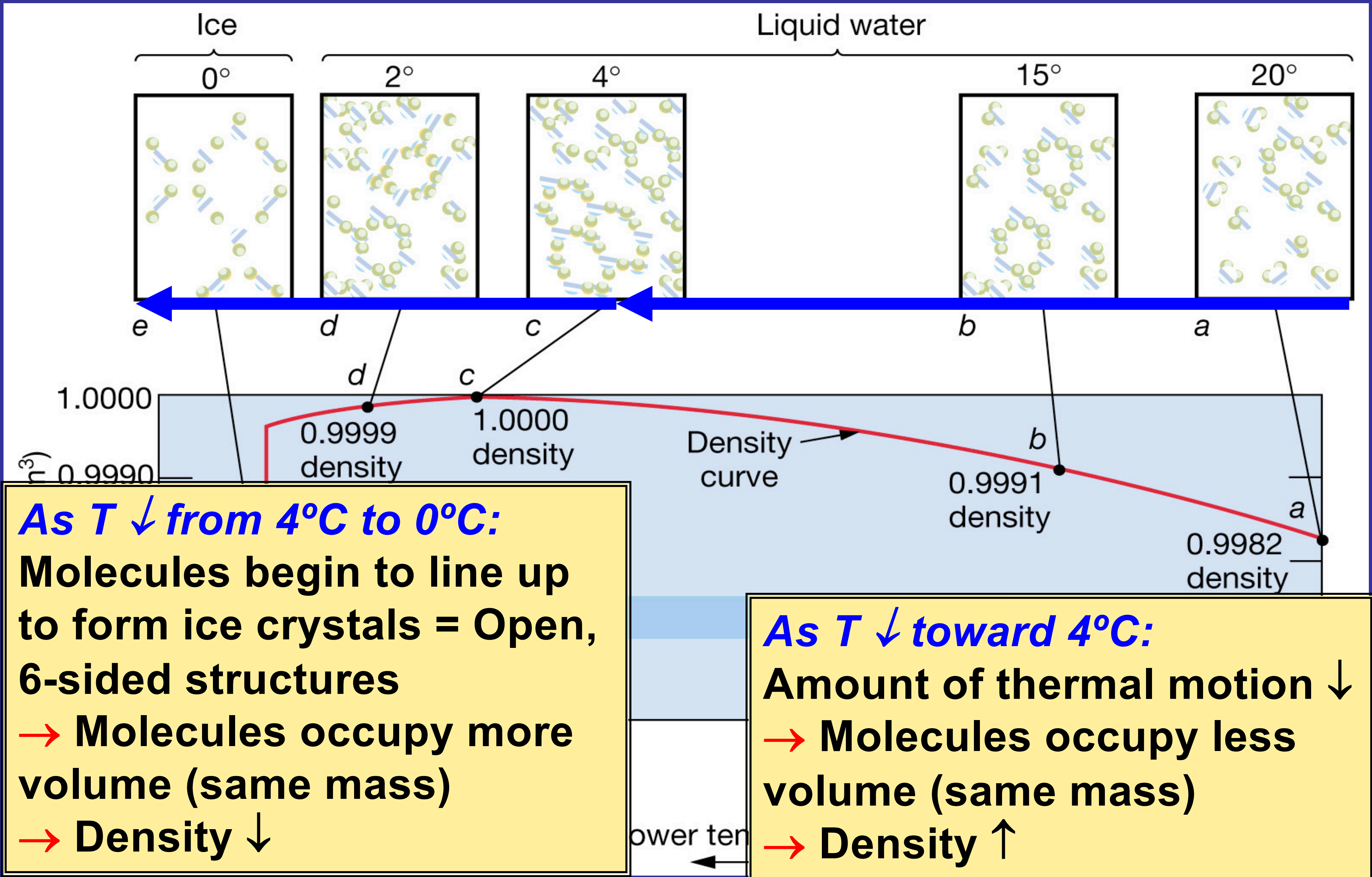


Density & Temperature



(Fig. 6-3, p.102)

Density & Temperature



As T ↓ from 4ºC to 0ºC:

Molecules begin to line up to form ice crystals = Open, 6-sided structures

→ Molecules occupy more volume (same mass)

→ Density ↓

As T ↓ toward 4ºC:

Amount of thermal motion ↓

→ Molecules occupy less volume (same mass)

→ Density ↑

C. Heat & Temperature

- **Heat**
  - = Energy produced by the random vibration of atoms or molecules
  - A measure of how *many* molecules are vibrating and how *rapidly* they're vibrating
- **Temperature**
  - = An object's response to an input or removal of heat
  - Records only how *rapidly* the molecules are vibrating
- **Heat Capacity** = *a link*
  - = The amount of heat required to raise the temperature of 1 gram of a substance by 1ºC

Heat & Temperature

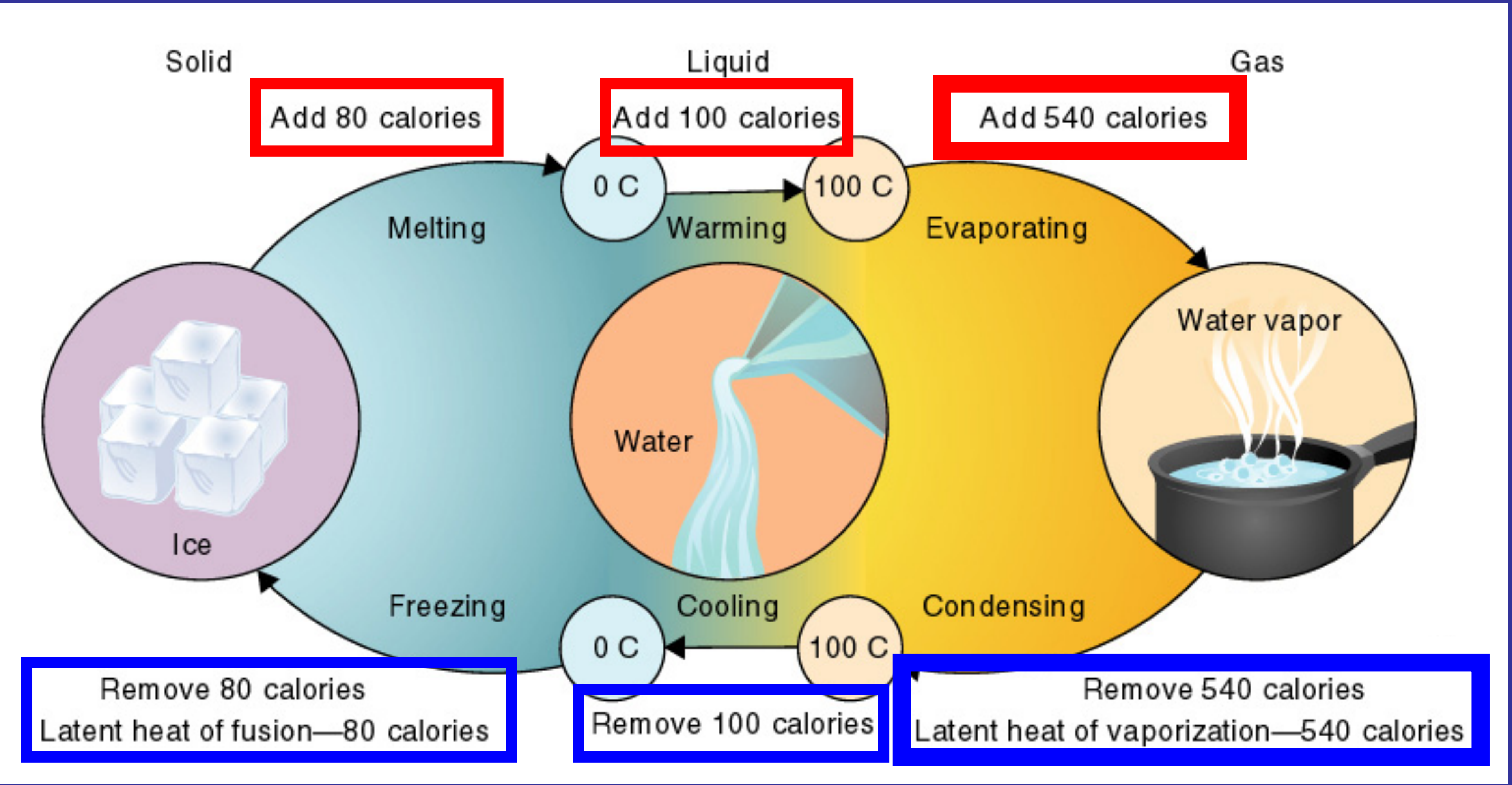
Table 6.1 Heat Capacity of Common Substances (p.102)

Substance	Heat Capacity in calories/gram/°C
Silver	0.06
Granite	0.20
Aluminum	0.22
Alcohol (ethyl)	0.30
Gasoline	0.50
Acetone	0.51
Pure water — **VERY HIGH!**	**1.00**
Ammonia (liquid)	1.13

1 <u>calorie</u> ≡ Amount of heat required to raise 1 gram of pure *liquid water* by 1ºC

Water resists changing temperature when it absorbs or releases heat

D. Changes of State



Let's draw all that on a graph (Fig. 6-6, p.104)

Summary of the properties of water and their significance.

Property	Comparison with other substances	Physical and/or biological significance
Physical states: gas (*water vapor*), liquid (*water*), solid (*ice*).	Water is the only substance that occurs as a gas, liquid, and solid within the range of surface temperatures on Earth.	*Water vapor* is an important component of the atmosphere, because water vapor transfers great quantities of heat from warm, low latitudes to cold, high latitudes. *Liquid water* runs across land, dissolving minerals and carrying them to the oceans. Most organisms are composed primarily of water. Serves as a transport medium and facilitates chemical reactions. *Ice* formation at the surface protects the water and life below it from freezing.
Solvent property: the ability to dissolve substances.	Water can dissolve more substances than any other liquid; hence it is often called "the universal solvent."	*Wide-ranging implications* in both physical and biological phenomena. Helps explain why seawater is "salty." In addition, seawater carries dissolved within it the nutrients required by marine algae and the oxygen needed by animals.
Surface tension: cohesive attraction of hydrogen bonds causes a molecule-thick "skin" to form on water surfaces.	Water has the greatest surface tension of all common liquids, which makes capillarity possible.	*Causes water to form drops*, to "bead up," and to overfill a glass without spilling. Water striders use this "skin" as a walking surface, while other organisms hang from its undersurface. Capillarity assists in raising water to the tops of tall plants such as trees.

Summary of the properties of water and their significance. (Cont.)

Property	Comparison with other substances	Physical and/or biological significance
Heat capacity: the quantity of heat required to change the temperature of 1 g of a substance by 1°C. The heat capacity of water is used as the unit of heat quantity, the *calorie (cal)*.	Water has the highest heat capacity of all common liquids and gains or loses much more heat than other common substances while undergoing an equal temperature change.	*A major factor* in moderating Earth's climate, it helps explain the narrow range of temperature change occurring near the oceans as compared to interior regions.
Latent heat of melting: the quantity of heat gained or lost per gram by a substance changing from a solid to a liquid, or from a liquid to a solid, without a temperature change.	For water, it is 80 cal at 0°C (32°F), the highest of any common substance.	*Heat energy lost when ice forms* is mostly absorbed by the heat-deficient atmosphere at high latitudes. *Heat energy gained by water when ice melts* is manifested as molecular energy of the liquid water. This prevents the high-latitude ocean from becoming much warmer or colder than the freezing temperature of ocean water.

Summary of the properties of water and their significance. (Cont.)

Property	Comparison with other substances	Physical and/or biological significance
Latent heat of vaporization: the quantity of heat gained or lost per gram by a substance changing from a liquid to a gas, or from a gas to a liquid, without a temperature change.	It is greater for water, 540 cal at 100°C (212°F), than for any other common substance. At ocean surface temperatures of 20°C (68°F), it is 585 cal.	*Extremely important* in global heat and water transfer in the atmosphere. Evaporation from the low-latitude ocean removes a great amount of excess heat energy that is released through precipitation at heat-deficient higher latitudes. This greatly moderates temperatures at the poles and Equator, which otherwise would be far more extreme.
Density: mass per unit volume (g/cm^3).	Water's density increases as water cools, but it *decreases* below 4°C (39°F), which is highly unusual. Water density also increases as salinity andpressure increase.	*Plankton* that stay near the surface through buoyancy and frictional resistance to sinking are greatly influenced by the effect of temperature on density. In low-density warm water, plankton must be smaller or more ornate to obtain the increased ratio of surface area to body mass necessary to remain afloat. Also produces layering of ocean water.
Thermal expansion: the expansion of a substance when it is heated, and the contraction of a substance when it is cooled.	As water is cooled, it contracts. Below 4°C (39°F), it expands, which is highly unusual for a substance.	*Water expands* by 9% when frozen, causing ice to float. In the ocean at high latitudes where sea ice forms, ice provides a layer below which seawater does not freeze, protecting marine life.