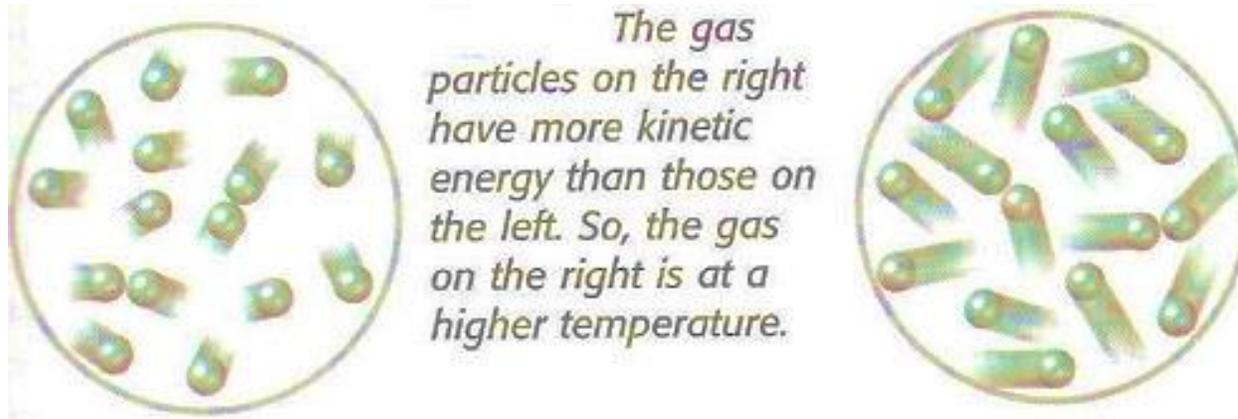


HEAT



Thermal Energy vs. Temperature

- **TEMPERATURE**: Measure of the AVERAGE kinetic energy in the particles of a substance.
 - how fast the particles are moving
- **THERMAL ENERGY**: Measure of the TOTAL amount of energy in ALL of the particles in an object or substance.
 - Add the energy of each particle together



Thermal Energy vs. Temperature

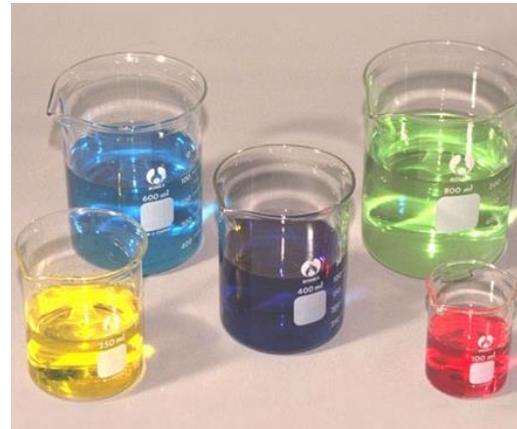
- Objects with the same thermal energy do NOT necessarily have the same temperature.

- Think of an example...



- Objects with the same temperature do NOT necessarily have the same thermal energy.

- Think of an example...



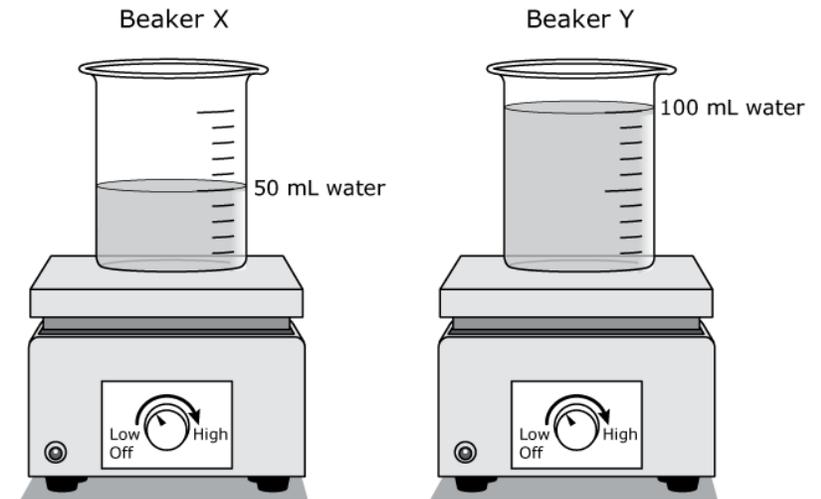
Thermal Energy vs. Temperature

- Compare the thermal energy and temperature of the water in beaker X and beaker Y.

1) Beaker X: 50mL at 22°C

Beaker Y: 100mL at 22°C

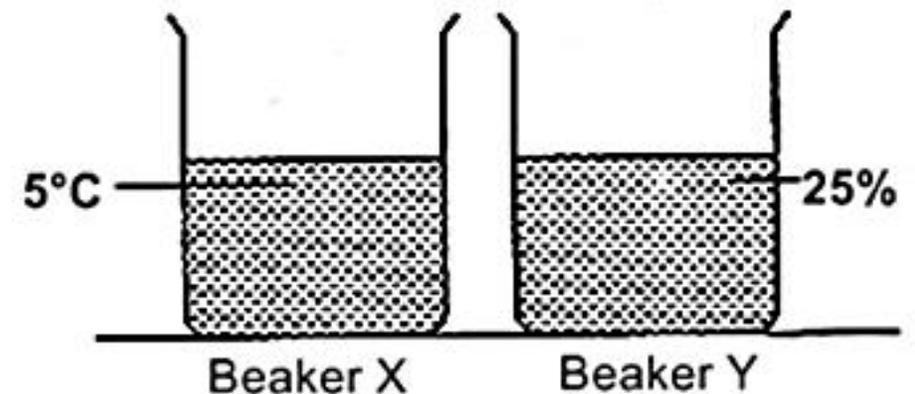
Beaker X and Beaker Y have the same temperature. Beaker Y has more thermal energy (more molecules).



2) Beaker X: 60mL at 5°C

Beaker Y: 60mL at 25°C

Beaker Y has more thermal energy because it has a higher temperature (same number of molecules).



Temperature Scales

- **Fahrenheit (°F)** - Commonly used in the U.S. – NOT METRIC
 - F.P. of H₂O = 32°F
 - B.P of H₂O = 212°F
- **Celsius (°C.)** - Commonly used in most of the World (as well as in science) – METRIC UNIT
 - F.P. of H₂O = 0°C
 - B.P of H₂O = 100°C
- **Kelvin (K)**- Commonly used in Physical Science – ALSO METRIC
 - F.P. of H₂O = 273K
 - B.P of H₂O = 373K
 - “Absolute Zero” (0 K) means **NO** particle motion

Temperature Scales

- **CONVERSIONS:**

- Fahrenheit to Celsius:

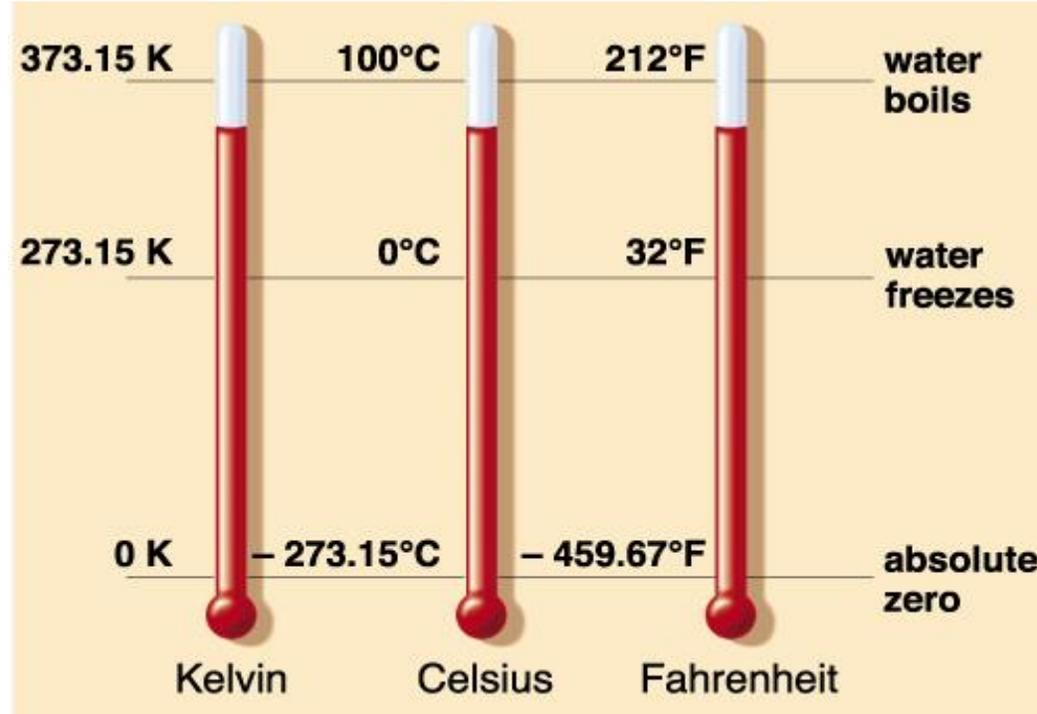
- $5/9 \times (^\circ\text{F} - 32) = ^\circ\text{C}$

- Celsius to Fahrenheit:

- $9/5 \times ^\circ\text{C} + 32 = ^\circ\text{F}$

- Celsius to Kelvin:

- $^\circ\text{C} + 273 = \text{K}$



To estimate:

°C to °F: Multiply the °C by 2 and then add 30

ex: 22°C is roughly equal to 74°F using this method, compared to the actual conversion of 71.6°F.

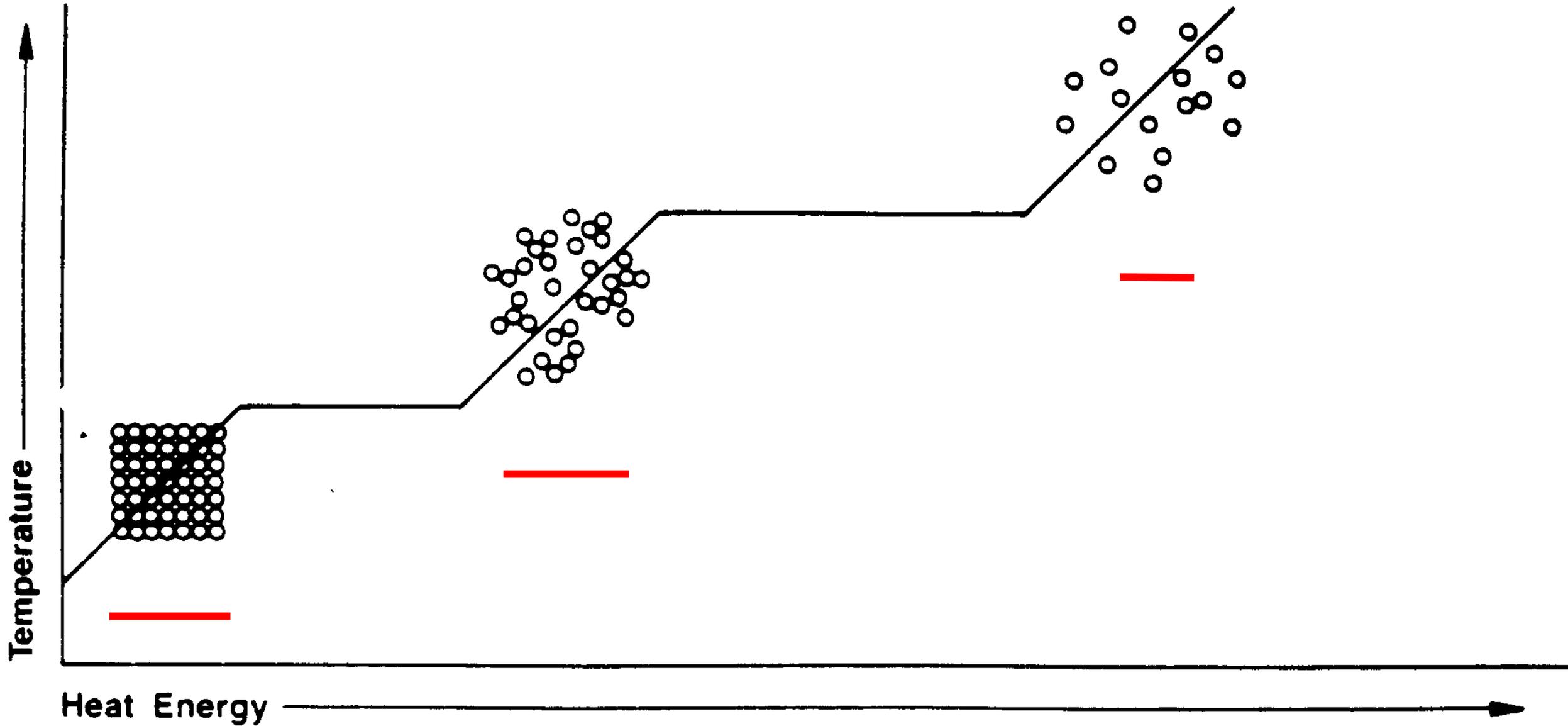
°F to °C: Work backwards, subtract 30 from the °F then divide by 2

ex: 80°F is roughly equal to 25°C using this method, compared to the actual conversion of 26.7°C.

Temperature & Molecules

- A rise in temperature indicates that the molecules of the substance have more kinetic energy (they are moving faster).
- A drop in temperature indicates that the molecules of the substance have less kinetic energy (they are moving slower).
- How does this relate to phase changes?
 - **Freezing Point** – the particles are moving slow enough to become solid
 - **Melting Point** – the particles are moving fast enough to become liquid
 - **Condensation Point** – the particles are moving slow enough to become liquid
 - **Boiling Point** – the particles are moving fast enough to become gas

Phase Changes



Temperature Change

- $Q = mc\Delta T$
 - Q = thermal energy added to the substance
 - m = mass of substance
 - c = specific heat of substance (a unique constant for each substance)
 - ΔT = change in temperature
- Remember that water has a high specific heat? This means that it takes a lot of energy to change the temperature of water, which allows it to help regulate temperatures on Earth!
 - $c (\text{H}_2\text{O}_{\text{liquid}}) = 4.186 \text{ J/g}^\circ\text{C}$
 - For comparison...

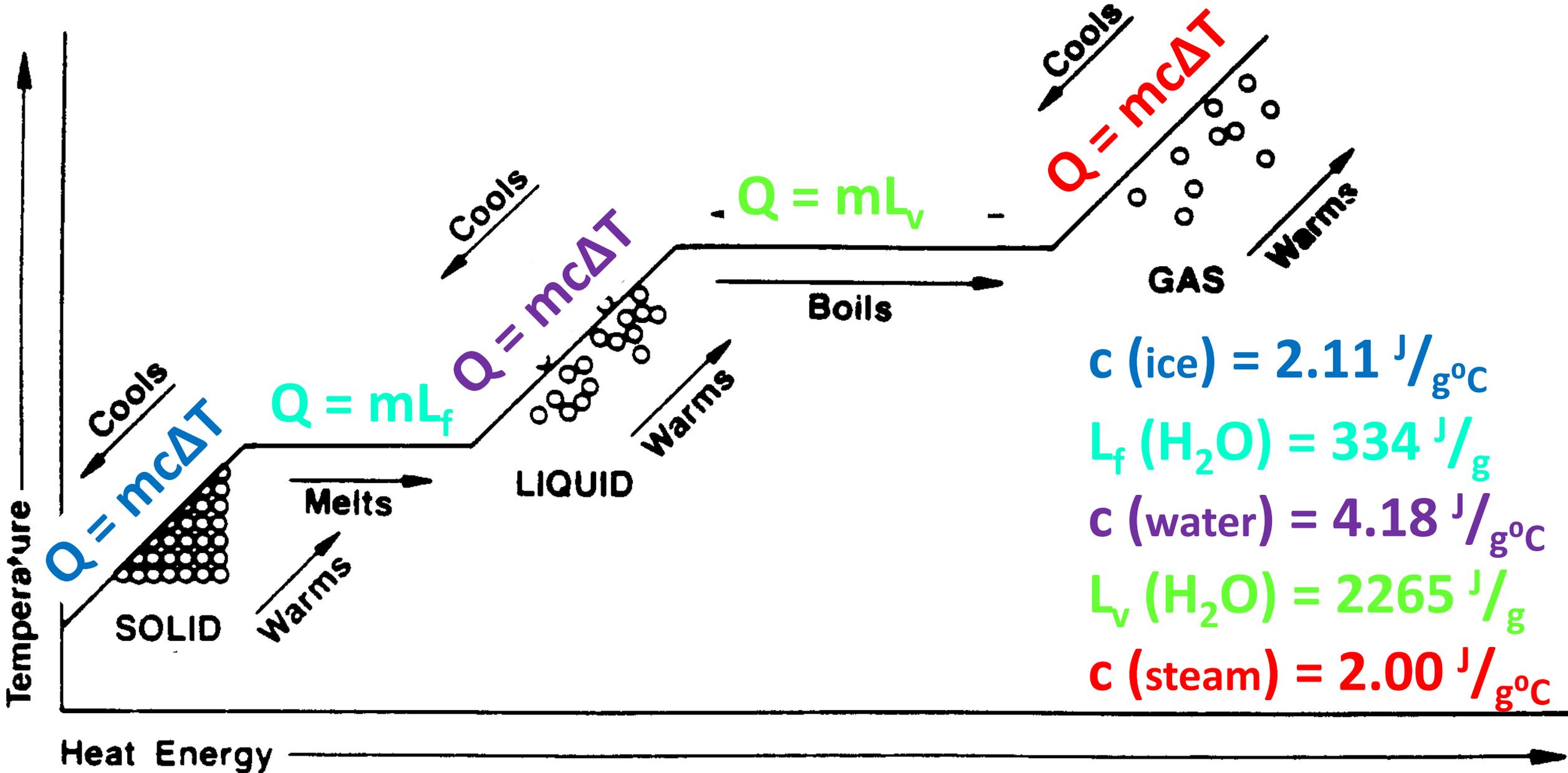
Specific Heats of Common Materials

MATERIAL	SPECIFIC HEAT (Joules/gram • °C)
Liquid water	4.18
Solid water (ice)	2.11
Water vapor	2.00
Dry air	1.01
Basalt	0.84
Granite	0.79
Iron	0.45
Copper	0.38
Lead	0.13

Phase Change

- *NOTE: The temperature stays relatively constant during a phase change...all of the energy transfer is used to change the state of the substance.*
- Solid → Liquid (melting)
 - $Q = mL_f$
 - Q = thermal energy added to the substance
 - m = mass of substance
 - L_f = latent heat of fusion (constant)
- Liquid → Gas (boiling)
 - $Q = mL_v$
 - Q = thermal energy added to the substance
 - m = mass of substance
 - L_v = latent heat of vaporization (constant)

Temperature/Phase Changes



Heat

- The movement of thermal energy from a substance with a higher temperature to a substance with a lower temperature.

- 3 types of heat:
 - Conduction
 - Convection
 - Radiation



Conduction

- Energy is transferred by contact between particles
 - The particles of one substance bump into the particles of another substance
- How did we observe conduction in the Heat Lab?



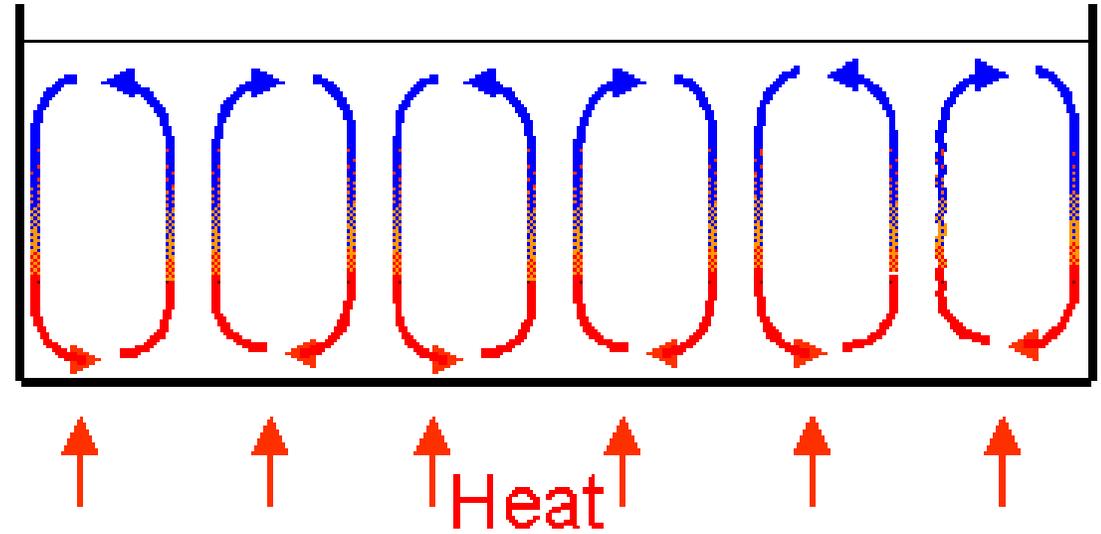
Conduction

- **CONDUCTOR** – Any material in which thermal energy is transferred **quickly**
 - Examples: Metals, Diamonds
 - What do these substances have in common?
 - High density
- **INSULATOR** – Any material in which thermal energy is transferred **slowly**
 - Examples: Cotton, Cardboard, Wood, Rubber, Plastic
 - What do these substances have in common?
 - Low density



Convection

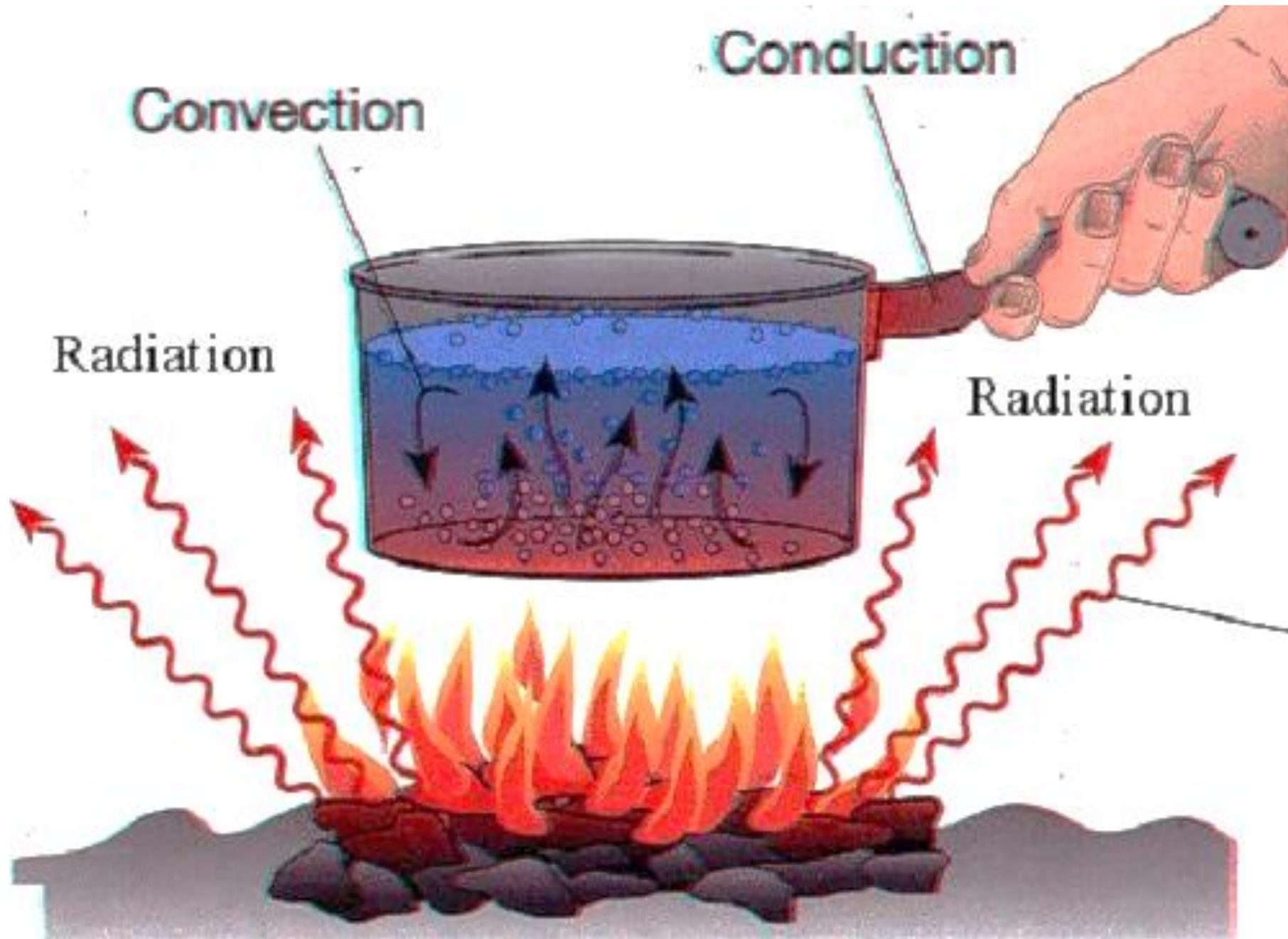
- Energy is transferred by the movement of CURRENTS within a fluid (liquid or gas)
 - **Convection Current** – The flow of heat through a fluid. **Warmer less-dense fluid rises while cooler more-dense fluid sinks, creating a flow or current**
- How did we observe convection in the lab?



Radiation

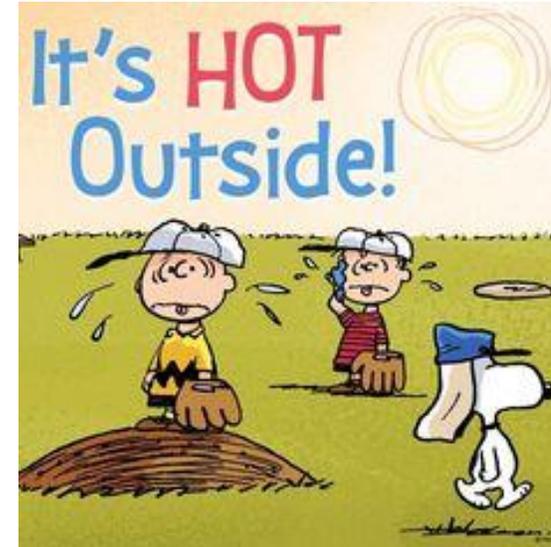
- Energy is transferred through electromagnetic waves
 - Ex: heat from sunlight...mainly infrared waves
 - Does not require matter to transfer energy (*can transfer heat through "outer space"*)
- How did we observe radiation in the lab?





“Heat flows in one direction.”

- Heat flows from WARMER objects to COOLER objects until both have the SAME temperature.
 - “EQUILIBRIUM” temperature



Which direction will heat flow...

...between your pillow and your head on a cool winter night?

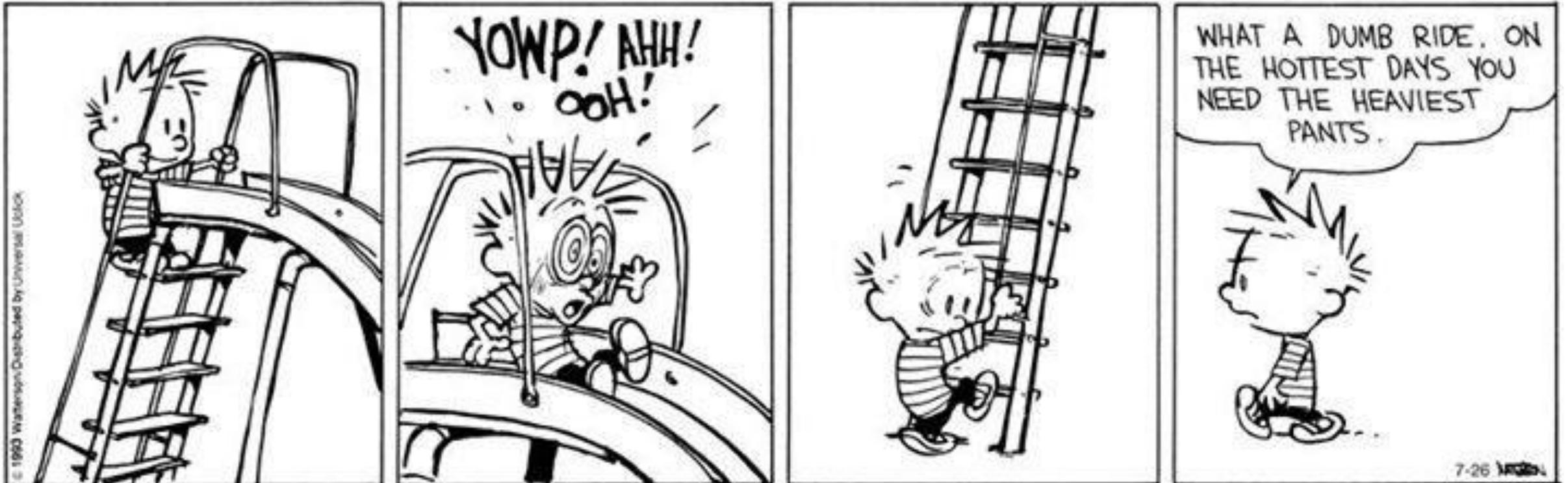
Head → Pillow



Which direction will heat flow...

...between your butt and a metal slide on a hot summer day?

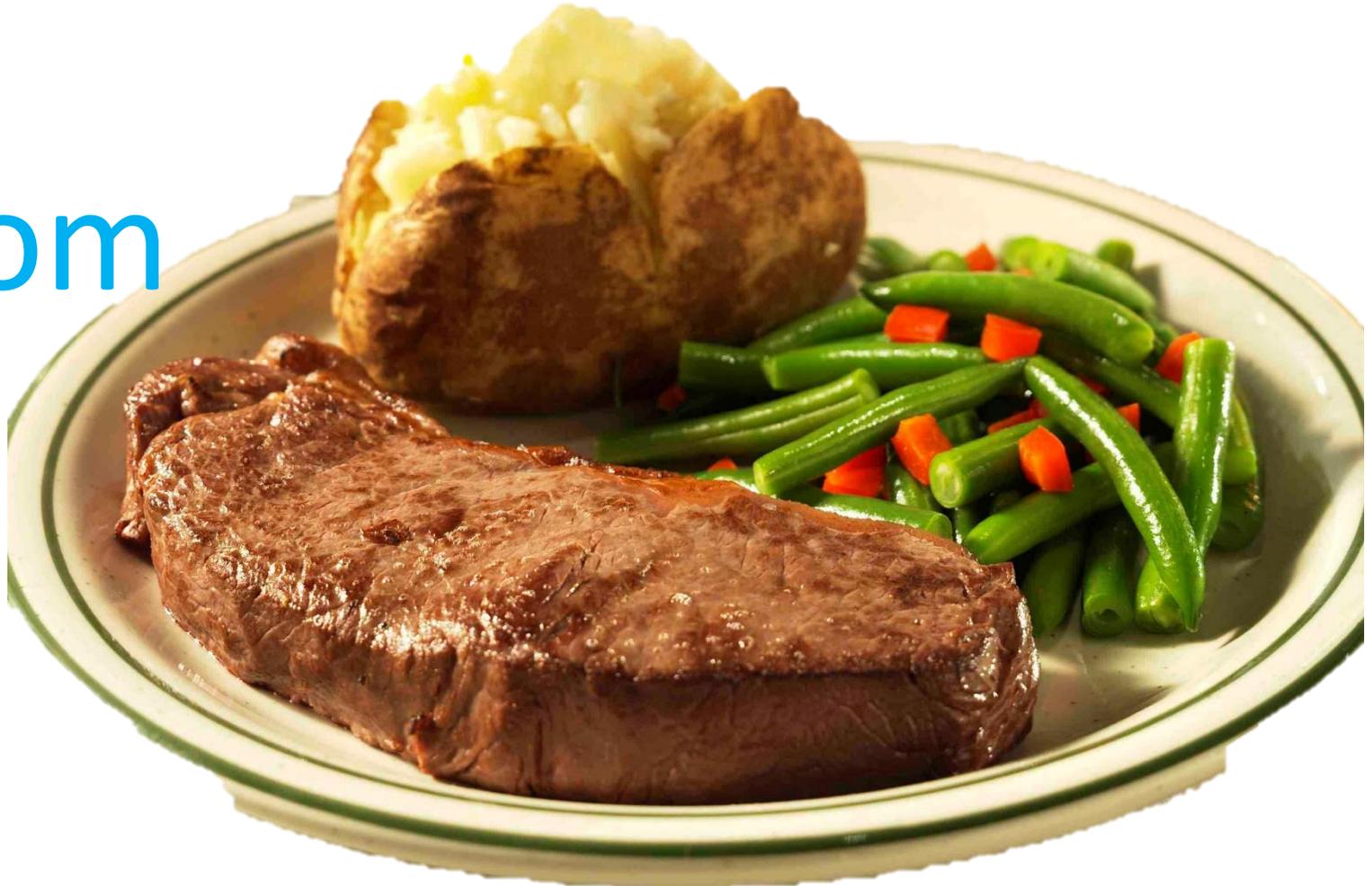
Slide → **Butt**



Which direction will heat flow...

...between a plate of hot food and the air at room temperature?

Food → Room



Write a short response to the item below.

- Why does your hand feel cold when you hold an ice cube?
 - Thermal energy flows from warmer substances to cooler substances. Your hand is warmer than the ice cube, so energy flows from your hand to the ice. As your hand loses energy, your body perceives this sensation as “cold”.
 - There is no such thing as “cold”...only an absence of thermal energy.
 - Like dark is the absence of light.

Write a short response to the item below.

- You place a can of soda in the freezer. You forget about it until the next day, only to discover it has frozen. Explain the transfer of heat in this case.
 - The soda is warmer than the freezer, so thermal energy flows out of the soda into the freezer (air/shelf) until the soda and the air reach the same temperature, which is below the freezing point of soda.

Thermal Energy Lab Reflection

- Table 1: Blue Ice

- What type of heat was observed?

- Convection

- The cooler water on the left sank as the warmer water on the right rose (floated). This created a cycle, or a current within the water. The blue food coloring followed the current.

- Where did heat flow?

- From the hot water into the ice cube

Thermal Energy Lab Reflection

• Table 2: Black Blocks

- What type of heat was observed?
 - Conduction
 - Heat flowed between the blocks and the ice as a result of contact between the particles (they were touching)
- Where did heat flow?
 - From the blocks into the ice
- The blocks were both room temperature. Why did block B feel cold?
 - It is a conductor. It easily draws thermal energy out of your hand when you touch it, resulting in the “cold” sensation

Thermal Energy Lab Reflection

- Table 3: Lamp
 - What type of heat was observed?
 - Radiation
 - Thermal energy was transmitted through electromagnetic radiation (light).
 - Where did heat flow?
 - From the light to the air

Thermal Energy Lab Reflection

- Table 4: Hand Bath

- What type of heat was observed?

- Conduction

- Thermal energy was transferred between the water and your hand through contact between the particles.

- Where did heat flow?

