TOPIC #8
THERMODYNAMICS & ENERGY TRANSFORMATIONS

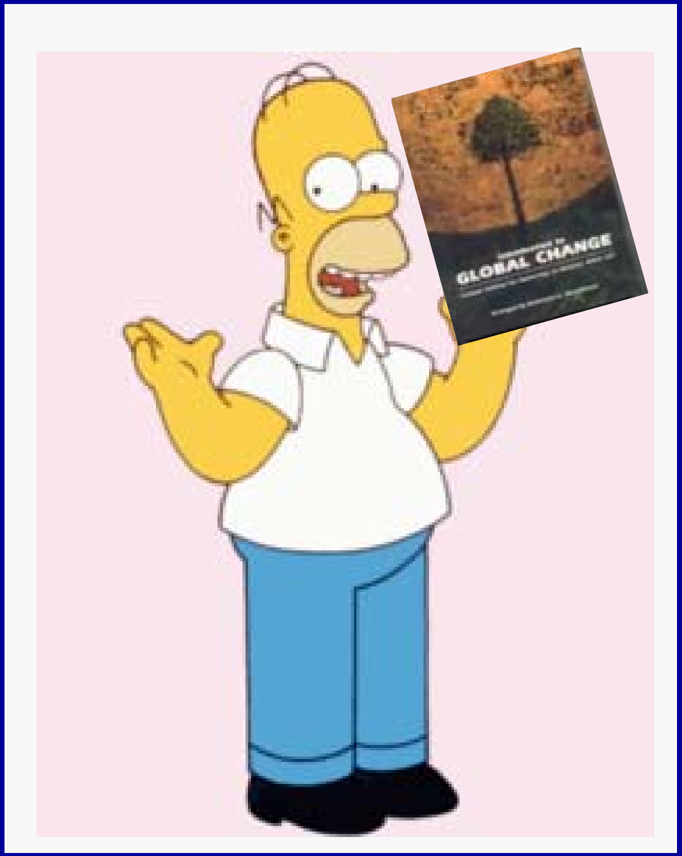
The Next Piece in the Puzzle to Understand Global Changes

CLASS NOTES: pp 49-53

QUOTE OF THE DAY:

In this house, we OBEY
the laws of thermodynamics!

~ Homer Simpson



Forms of Energy - Review

- **Kinetic** (KE or KinE) = energy of *motion or* the ability of a mass to do work.

  KE = ½ (mass x velocity^2)

- **Potential** (PE) = energy a system possesses if it is capable of doing work, but is *not* doing work now
  - Includes: **gravitational, elastic, chemical, electrical, and magnetic**

☺

Thermal Energy

Thermal energy (def) = the grand total of all energies inside a substance

(internal energy)

-- a measure of the quantity of *atomic kinetic & potential energy* contained in every object;

-- the total kinetic energy of molecules in matter.

Thermal Energy

Atoms and molecules are constantly "jiggling" in some sort of back-and-forth vibratory motion.

The greater this molecular kinetic energy is in a substance, the <u>hotter</u> the substance is.

THERMODYNAMICS

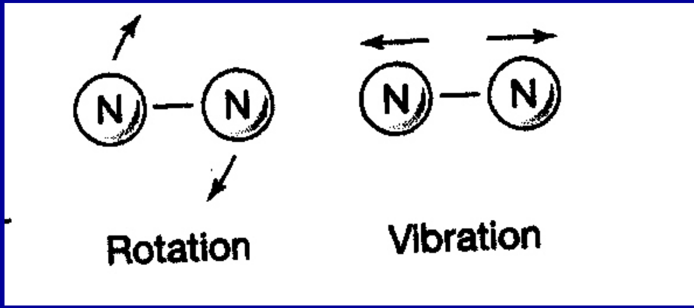
(def) = The study of the general properties of ENERGY.

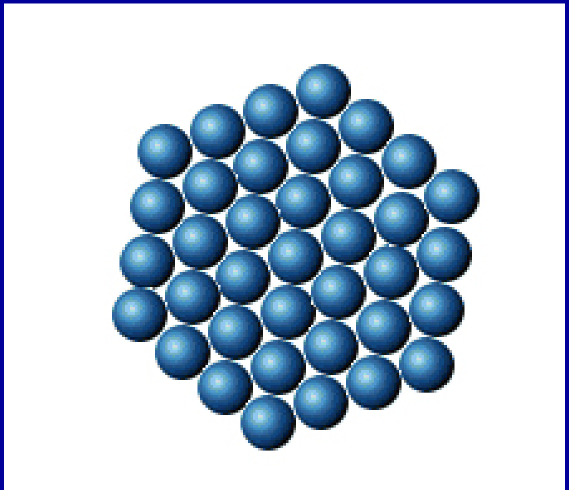
Thermal energy plays a central role in understanding these properties, hence the study of energy can also be called "thermodynamics."

☺

Thermal Energy

Remember vibrating molecules?

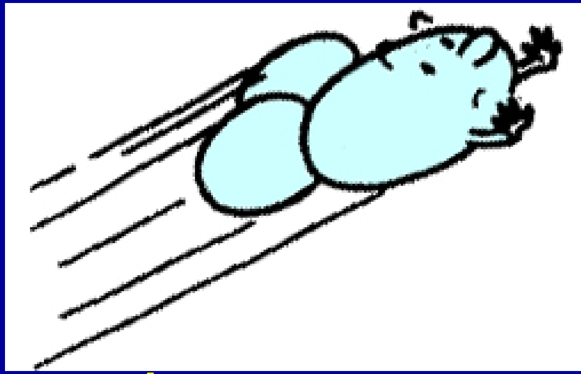




Thermal Energy & Temperature

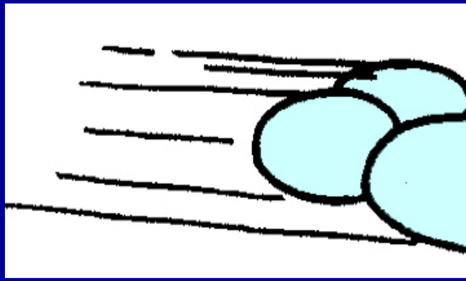
- ***Temperature*** = tells how warm or cold a body is with respect to some standard (e.g., Fahrenheit (°F), Celsius (°C), or Kelvin (K) standard scales).

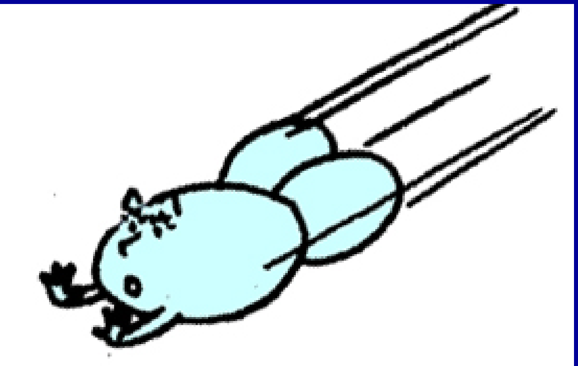
- **Temperature is a measure of the average kinetic energy of each molecule in a body.**



If a body has a high temperature, each of its molecules has, on the average, a large amount of kinetic energy.

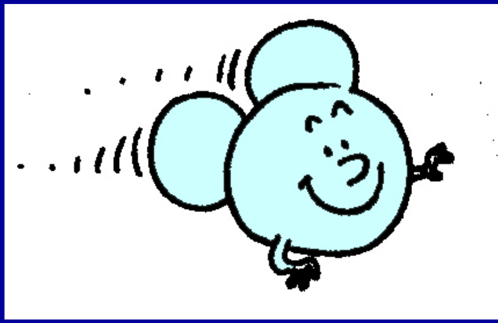
e.g. water vapor -- H_2O molecule at high temperatures





if a body has a low temperature, each molecule on the average has a small amount of kinetic energy.

e.g. water vapor molecule – H_2O at lower temperature



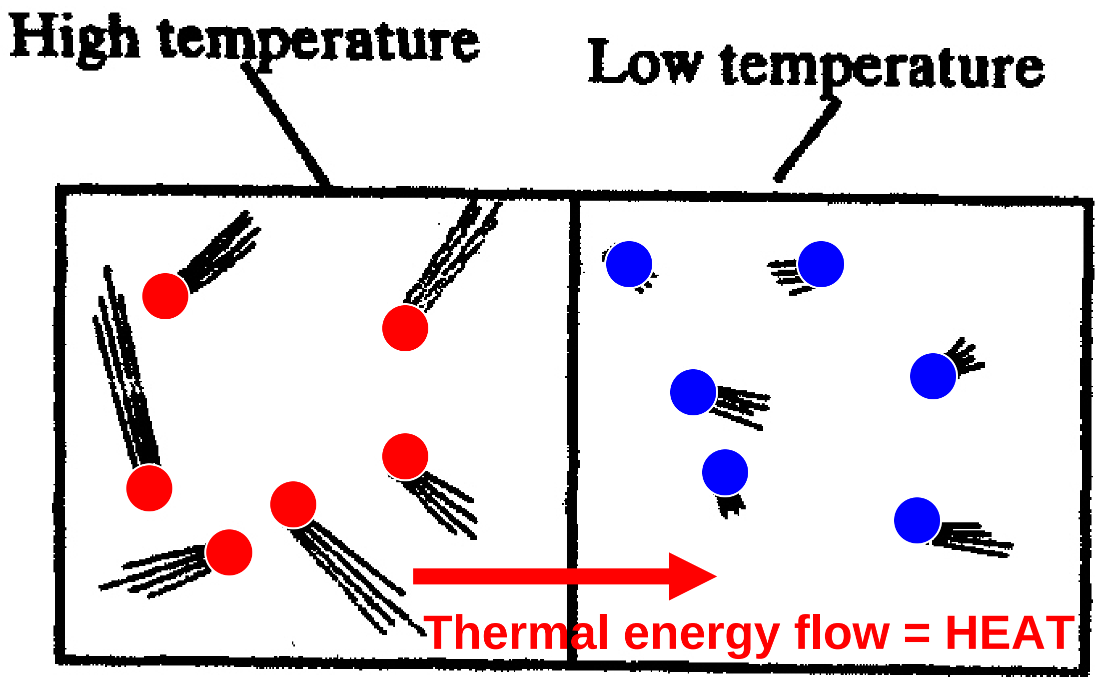
Thermal Energy

- When atoms and molecules cool so much that they lose all their kinetic energy, they reach the **"absolute zero"** of temperature

(-273.15°C = - 459.69°F = 0 Kelvin)

http://www.colorado.edu/physics/2000/bec/temperature.html

Thermal Energy



(a) A hot box of gas and a cold box of gas, at the instant they are put into contact: Most of the molecules in the hot box move rapidly, while most of the molecules in the cold box move slowly.

In which direction will THERMAL ENERGY be transferred?

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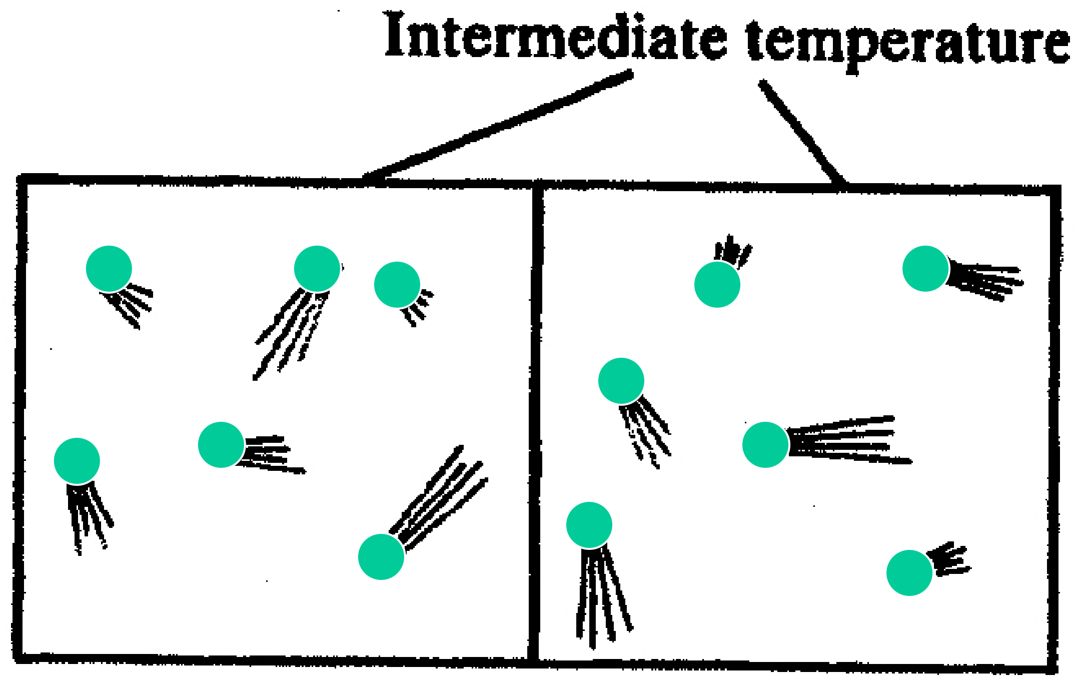
Thermal Energy vs. Heat

Heat = the thermal energy that is *transferred* from one body to another because of a temperature difference.

Heat will always pass from a substance of higher temperature to a substance of lower temperature, until both come to a common temperature.

Higher T → Lower T



(b) ***After there has been time for the hot box to warm up the cold box, the molecules in the left-hand box have slowed down while those in the right-hand box have sped up.***

RESPONDER TIME!!!

Which way is heat being transferred?

1. From the cold beer can into Homer's warmer beer belly

2. From Homer's beer belly to the colder beer can

3. From BOTH the beer can to Homer and Homer to the beer can

Q1 - Which way is heat being transferred?

1. From the cold beer can into Homer's beer belly
2. From Homer's beer belly to the colder beer can
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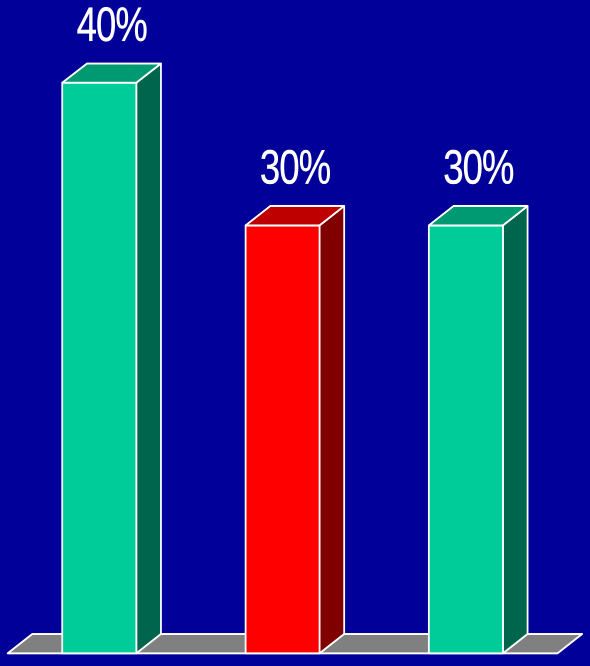

Correct answer in RED

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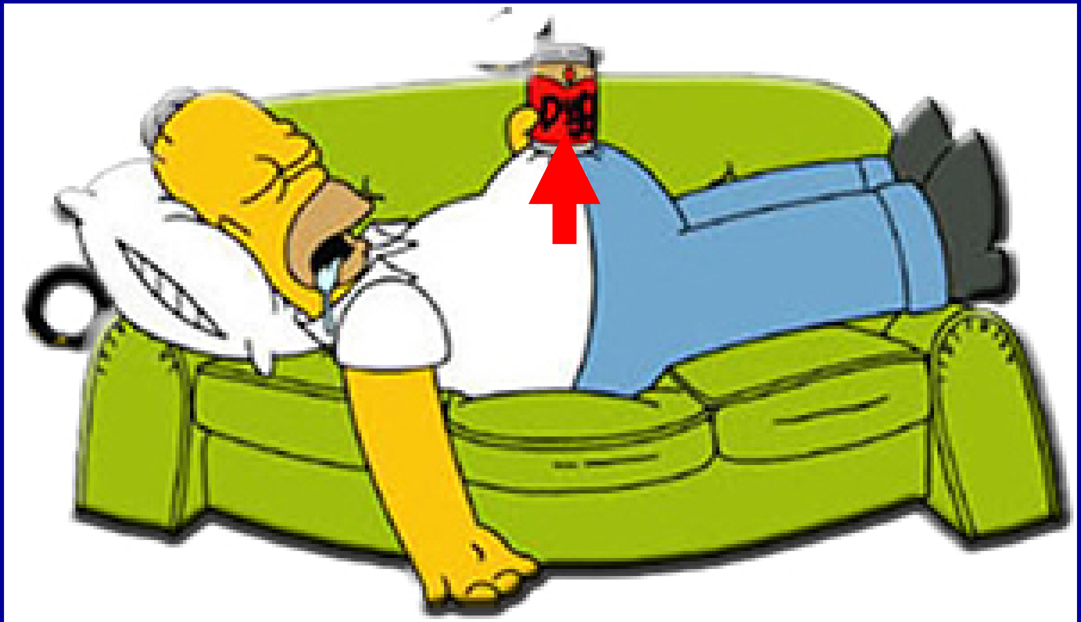

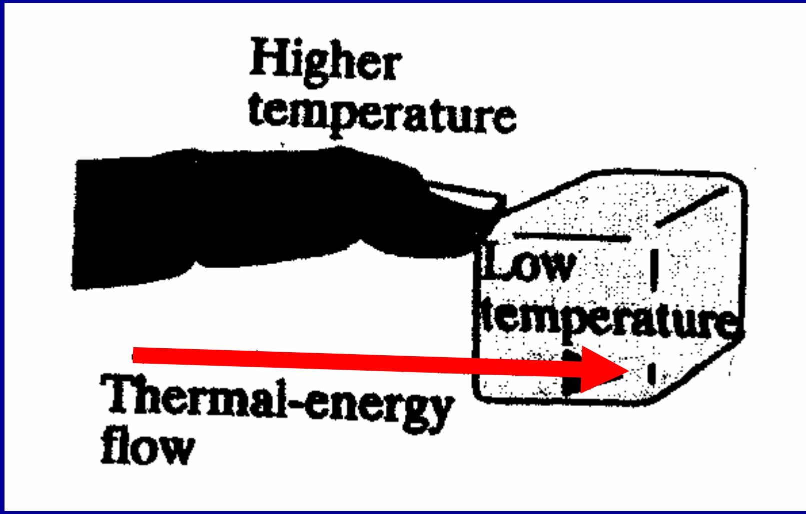

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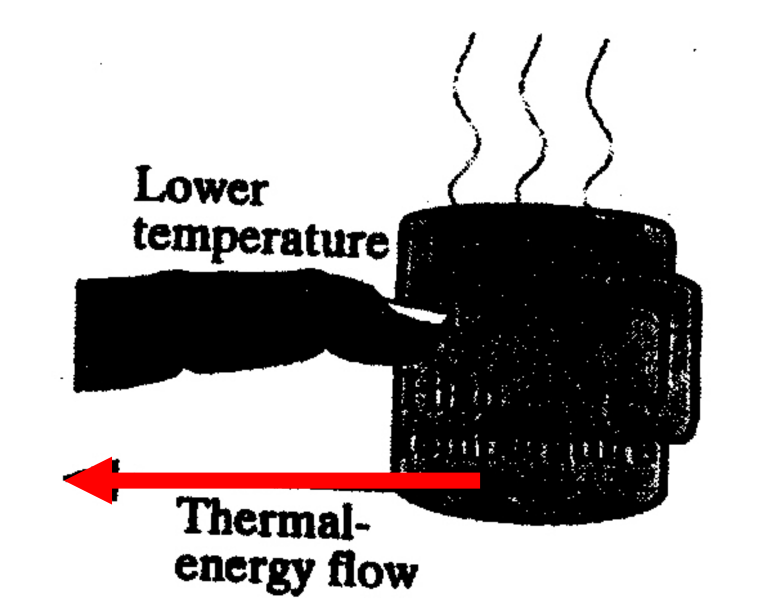

Thermal Energy Units

Unit for Thermal Energy
= the *joule* or *calorie*.

"Low Joule Cola"

A CALORIE is the amount of thermal energy required to change the temperature of 1 gram of water by 1°C (specifically from 14.5°C to 15.5°C)

(one gram of water is roughly equivalent to the weight of one cubic centimeter of water)

Thermal energy calorie vs "nutrition" kilocalorie:

Calorie (def) = the amount of **heat** required to raise 1 gram of room-temperature water 1 degree Celsius in temperature

1 calorie = 4.186 joules

1 calorie per second = 4.186 watts

1 "calorie" in nutrition context = 1000 calories

or 1 kilogram calorie

or kilocalorie (Kcal)

Other Important Terms:

Specific Heat = the amount of thermal energy (in calories) required to raise the temperature of 1 gram of ***any substance*** by 1°C.

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Heat Capacity =

specific heat x mass (density) of a substance for a given volume.

(Density is measured in grams per cubic centimeter.)

(Heat capacity represents the capacity of a substance to absorb heat in relation to its ***volume*** and ***density***.)

Specific Heat & Heat Capacity for Different Substances

Substance	Specific Heat		Heat Capacity
	cal	*joules*	
water	1.00	4.186	1.00
air	0.24	1.005	0.00024 - 0.00034
concrete	0.21	.879	0.50
sand	0.20	.837	0.10 - 0.60 (higher if wet)
rock	0.185	.774	---
iron	0.105	.440	0.82
silver	0.056	.234	0.59

Q2 - Assume you have an equal volume of WATER, AIR & SAND.

Which will HEAT UP THE FASTEST if the same amount of thermal energy is transferred into the substance?

1. WATER
2. AIR
3. SAND

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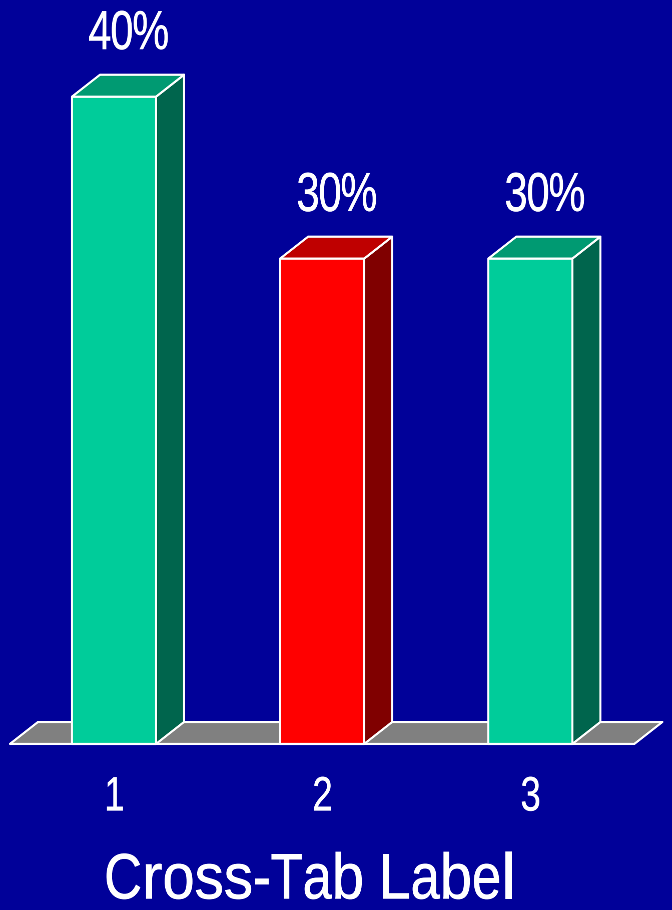

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Q3 – If global warming is occurring we will be able to detect it FIRST in:

1 = the ocean temperature

2 = the land surface temperature (i.e., soil)

3 = neither, they will both heat up at the same rate

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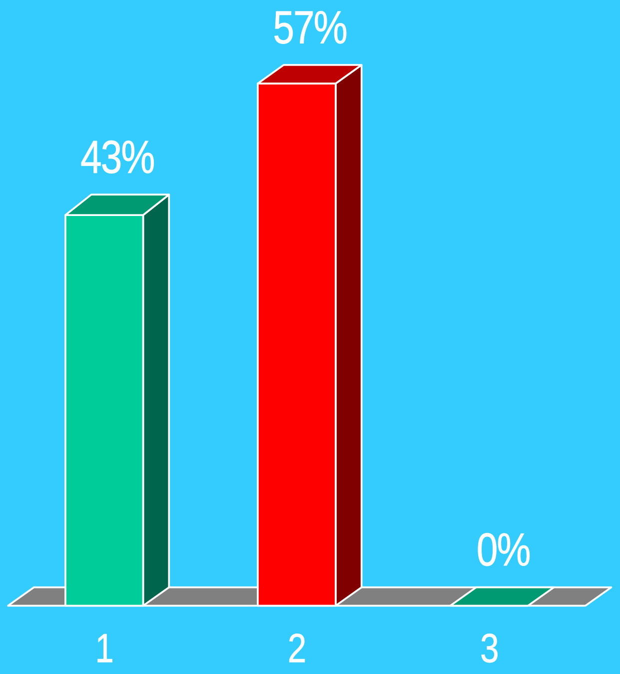

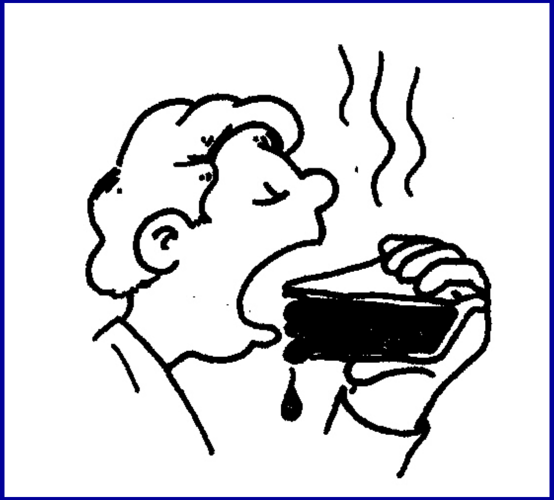

Q4 - Why will he burn his tongue, even if the crust is cool enough to hold?

1 - Because due to the high specific heat & heat capacity of the water in the apple pie filling, the filling will hold the thermal energy longer

2 – Because, due to the high specific heat & heat capacity of the water in the apple pie filling, the filling will heat up faster and to a much higher temperature than the crust will

3 - BOTH

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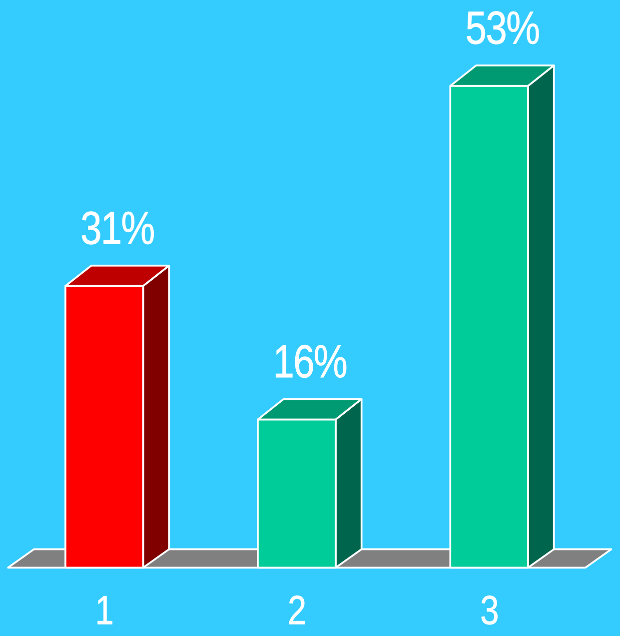
3. Both



Q5 - Which component of the EARTH SYSTEM has the ability to store thermal energy the longest once it heats up?

1. The ATMOSPHERE
2. The CONTINENTS
3. The OCEAN

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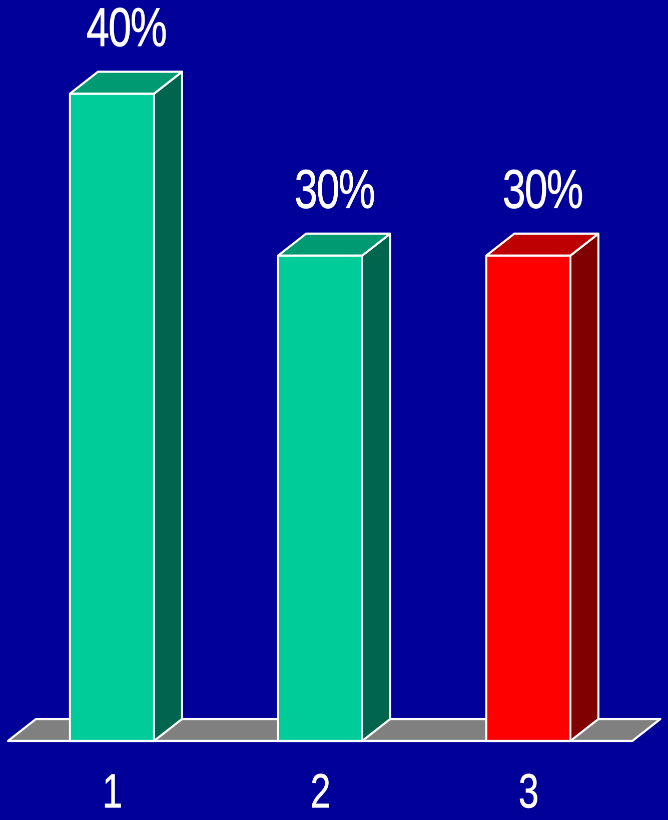

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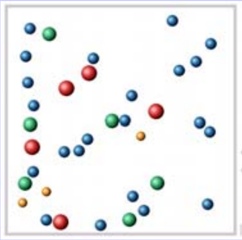
More on HEAT

Heat generally causes *expansion* of a substance.

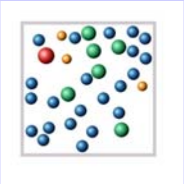
WHY?

When the temperature of the substance is increased, the molecules jiggle faster and the more energetic collisions between the molecules force them to move farther apart, thus expanding the substance (and making it less dense).

HOT



COLD



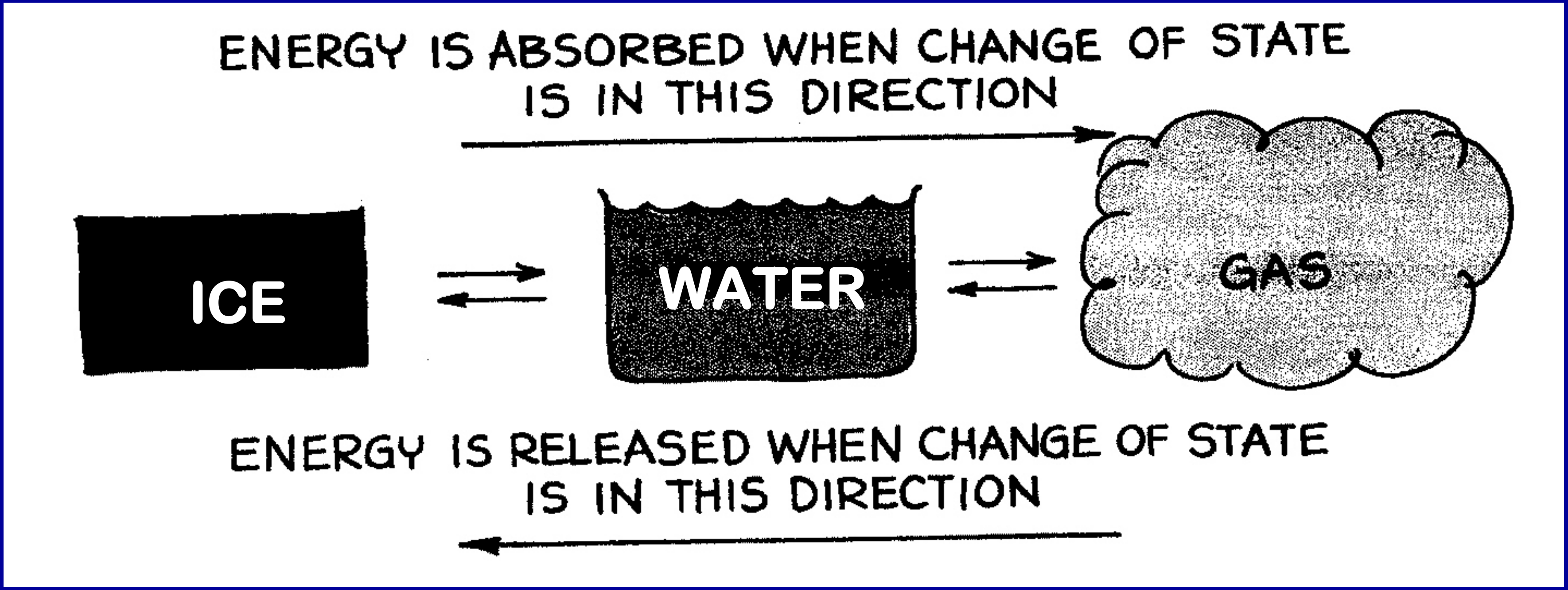
As air heats up, it expands, hence hot air is less dense than cold air & tends to RISE.

Likewise, cold air is more dense than hot air & tends to SINK

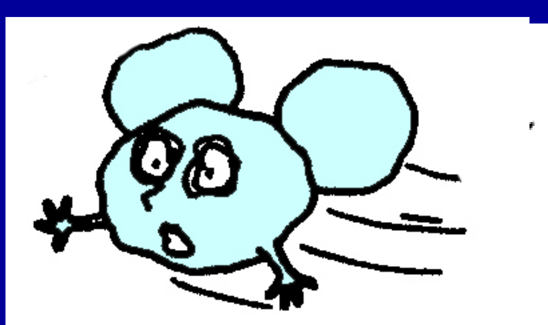
These thermal differences play an important role in driving ATMOSPHERIC CIRCULATION.

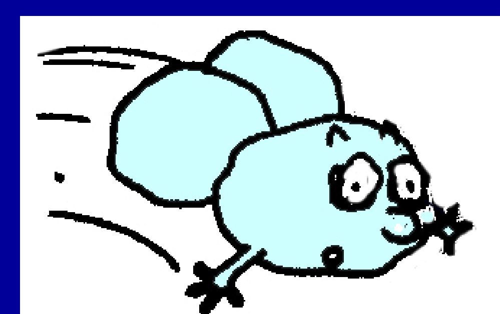
http://www.colorado.edu/physics/2000/bec/temperature.html

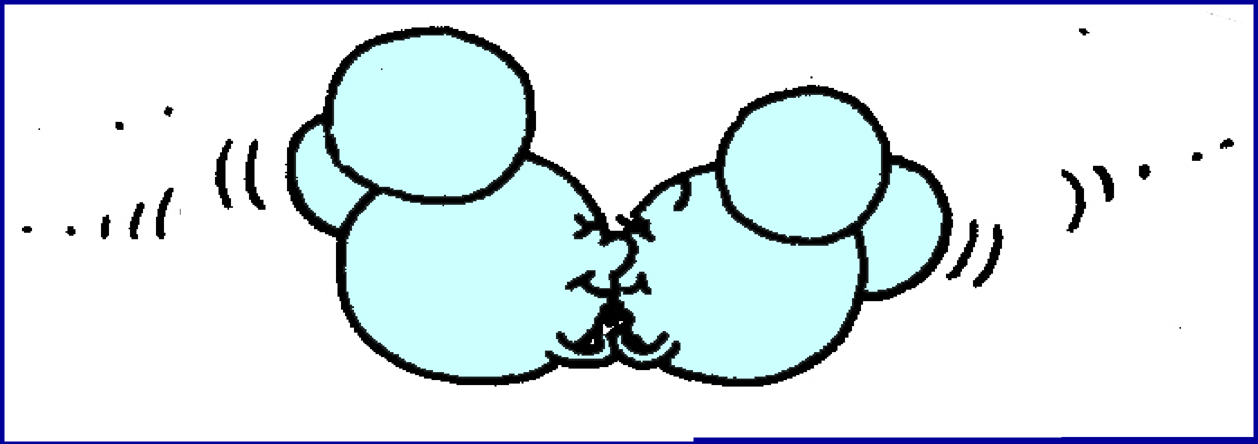
THERMODYNAMICS & PHASE CHANGES IN H_2O

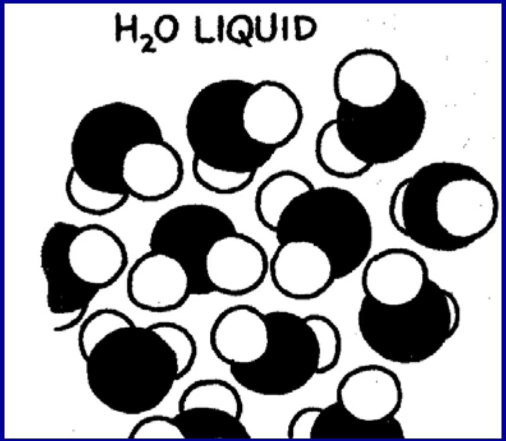


At higher air temperatures, H_2O molecules collide & rebound more frequently, leading to expansion of the air & the water vapor in the air.



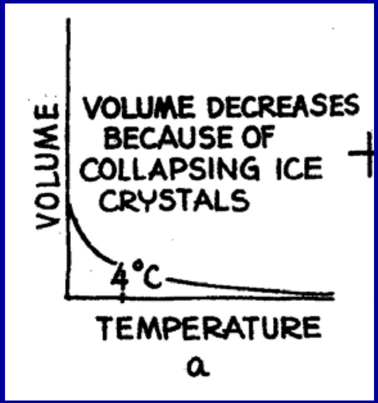




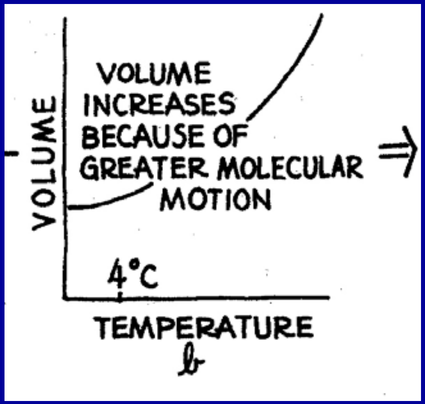


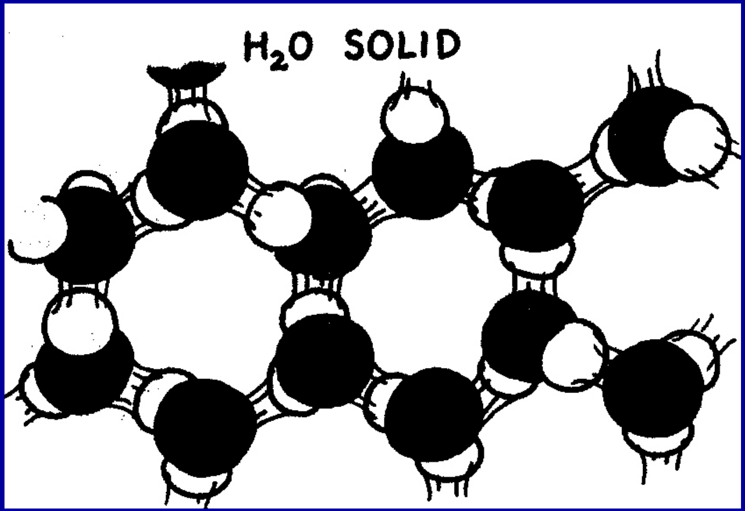
At lower air temperatures as air gets more dense, H_2O molecules are more likely to bond so that a phase change to liquid water or even solid ice can occur.

H_2O's UNIQUE EXCEPTION
to heating → expansion
cooling → contraction

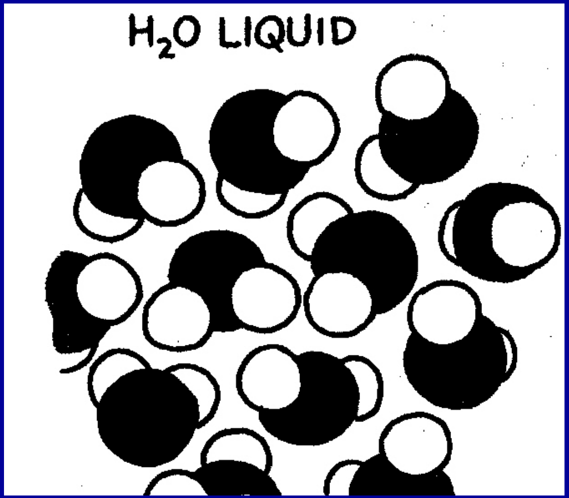


SLIGHT DECREASE in volume until water heats up beyond 4 ºC

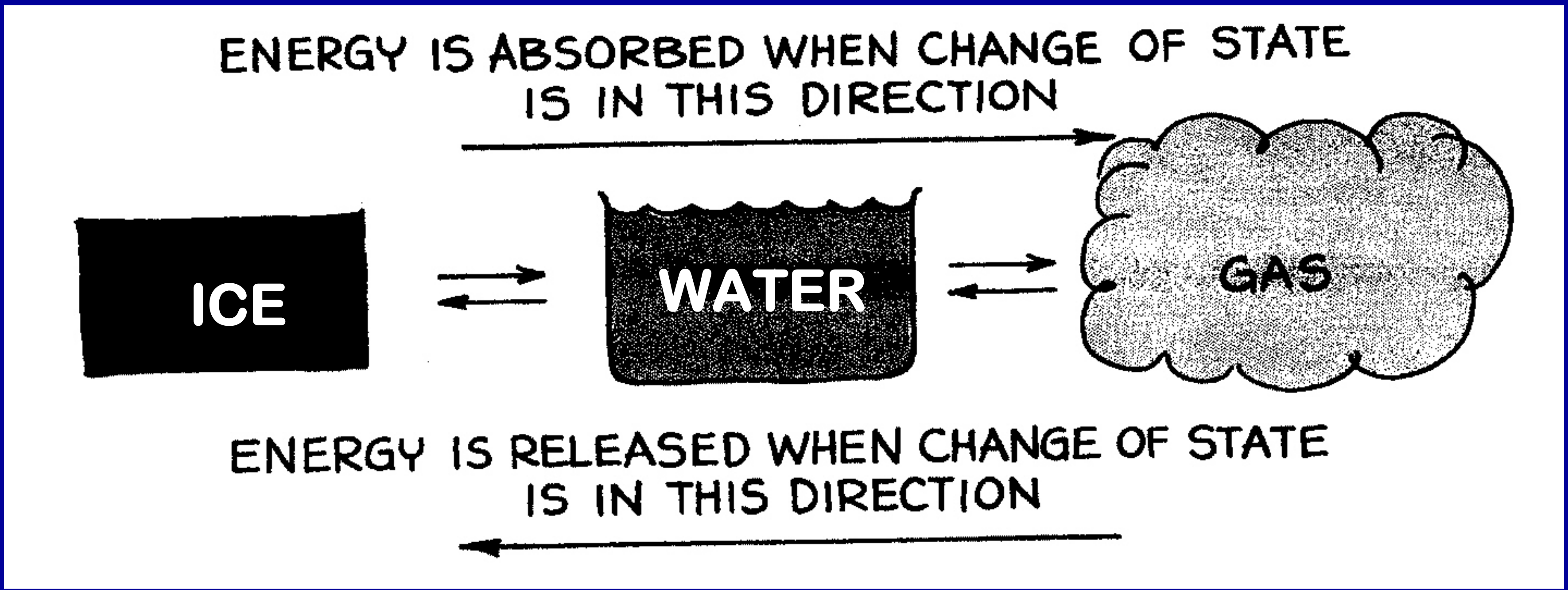




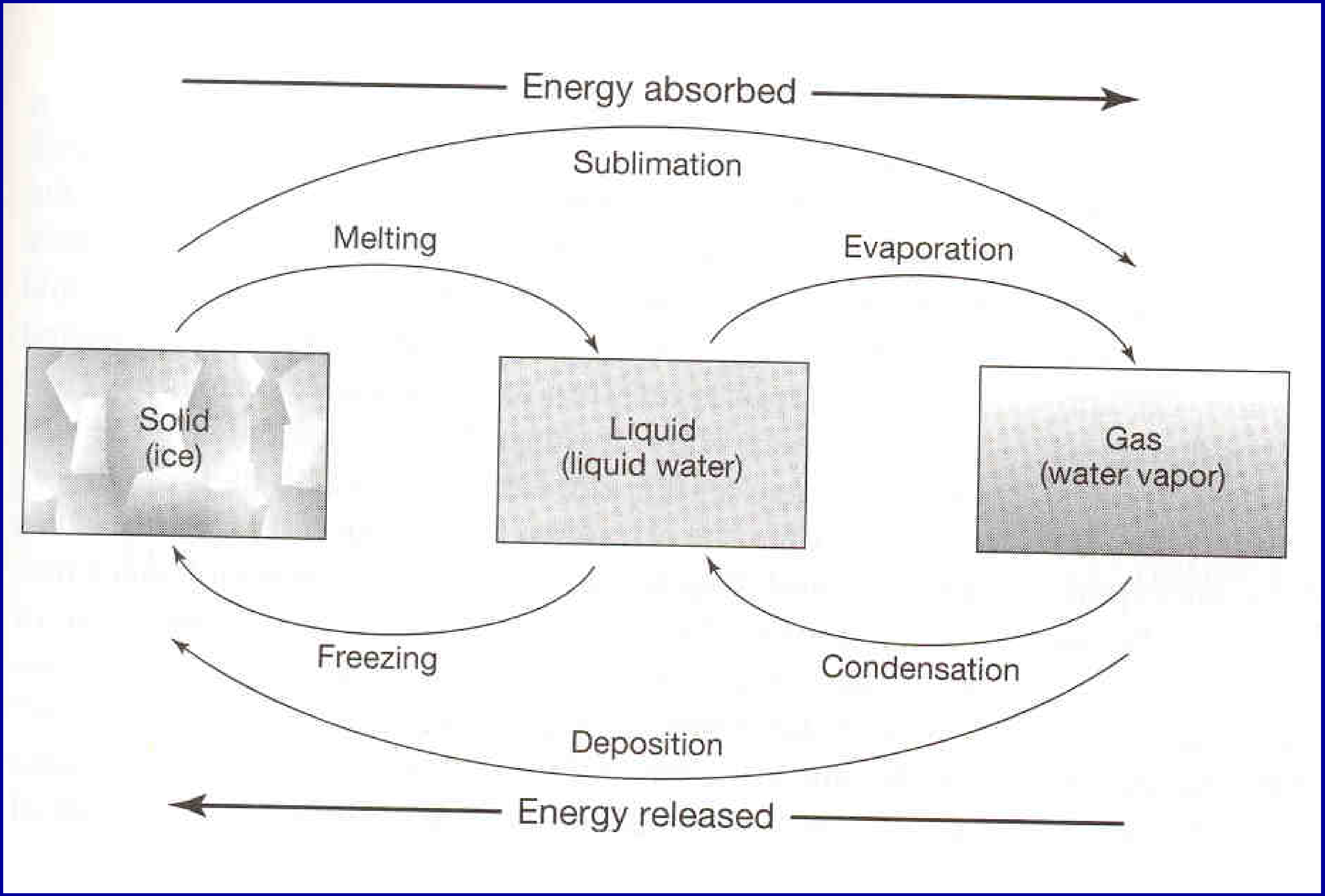
Ice → water
PHASE CHANGE



PHASE CHANGES IN H_2O

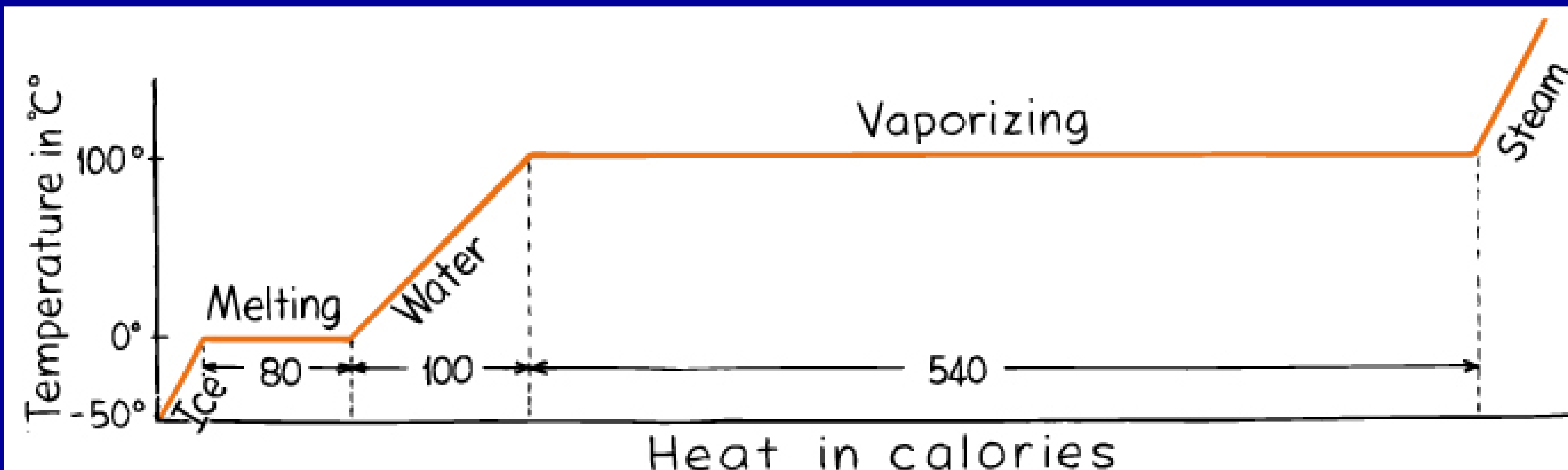


PHASE CHANGES (another view)



See Fig 4-23 p 76 in IGC text

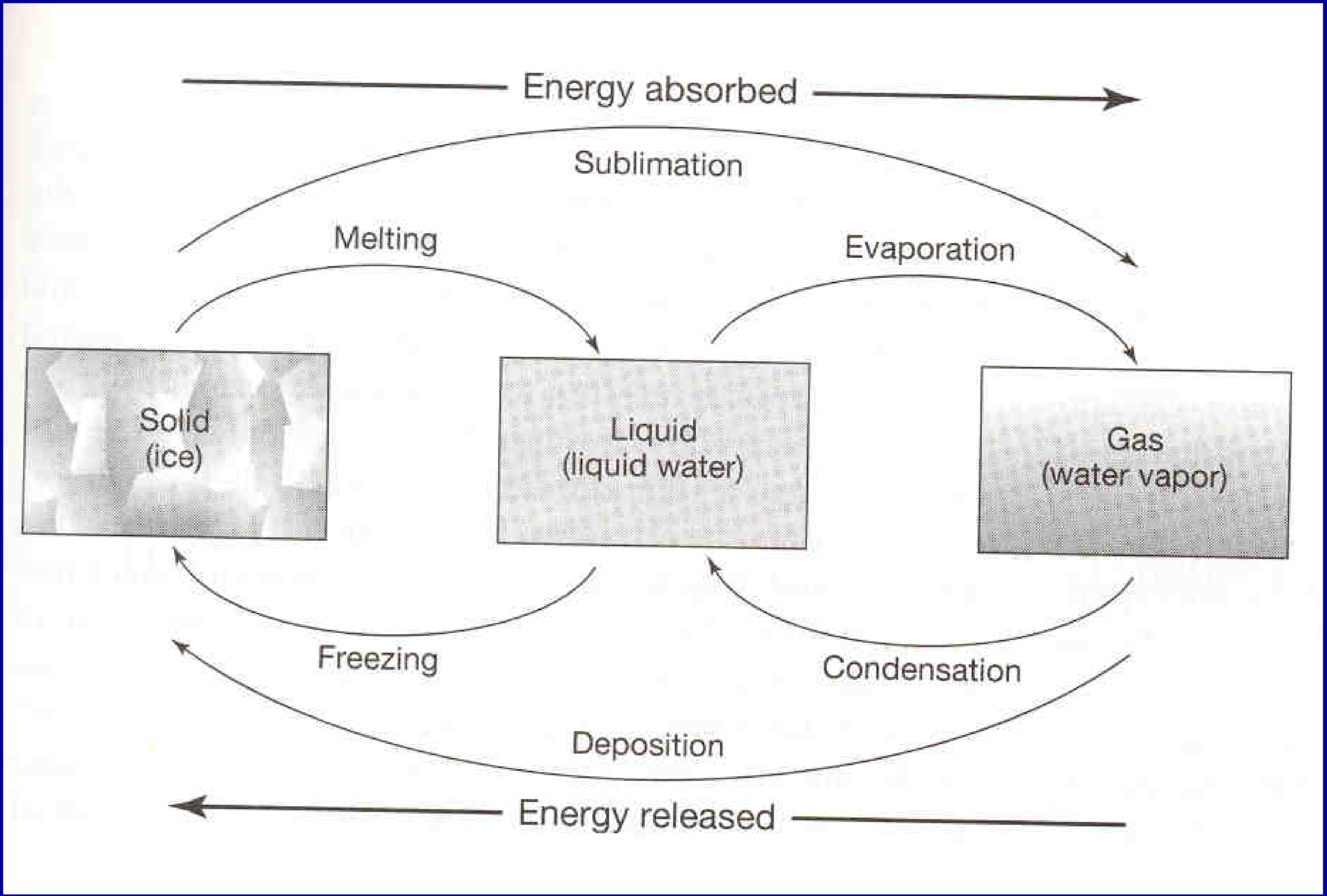
What's happening to the energy at the points the graph is horizontal?



SENSIBLE HEAT (H)

LATENT HEAT (LATENT ENERGY) LE

PHASE CHANGES (another view)



In Ch 4 of IGC Text: Fig 4-23 p 76

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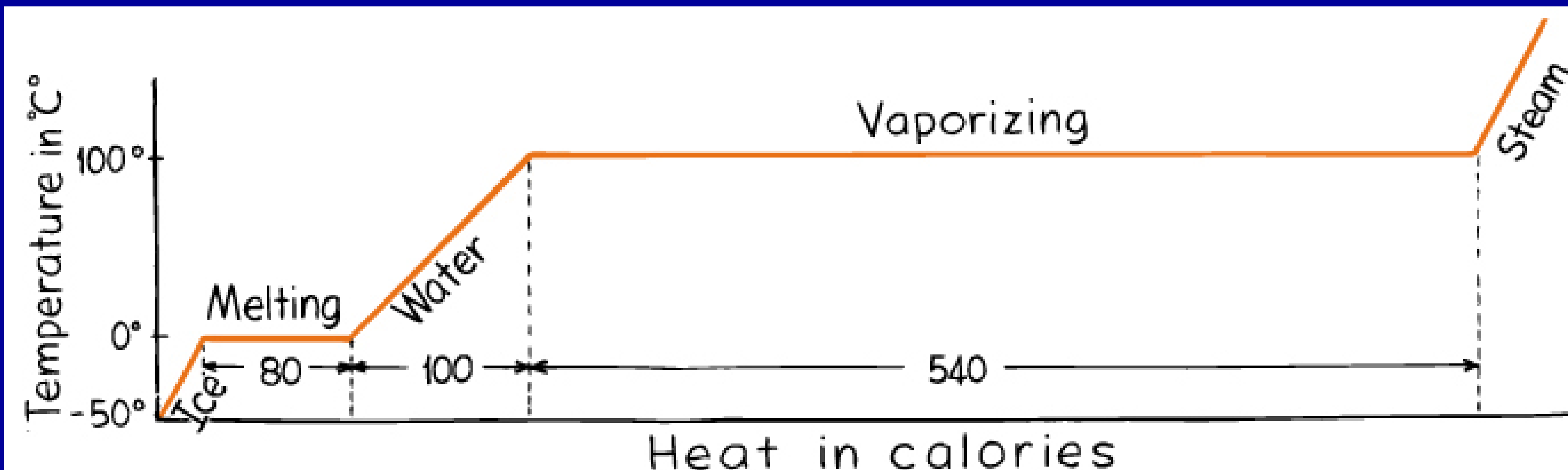

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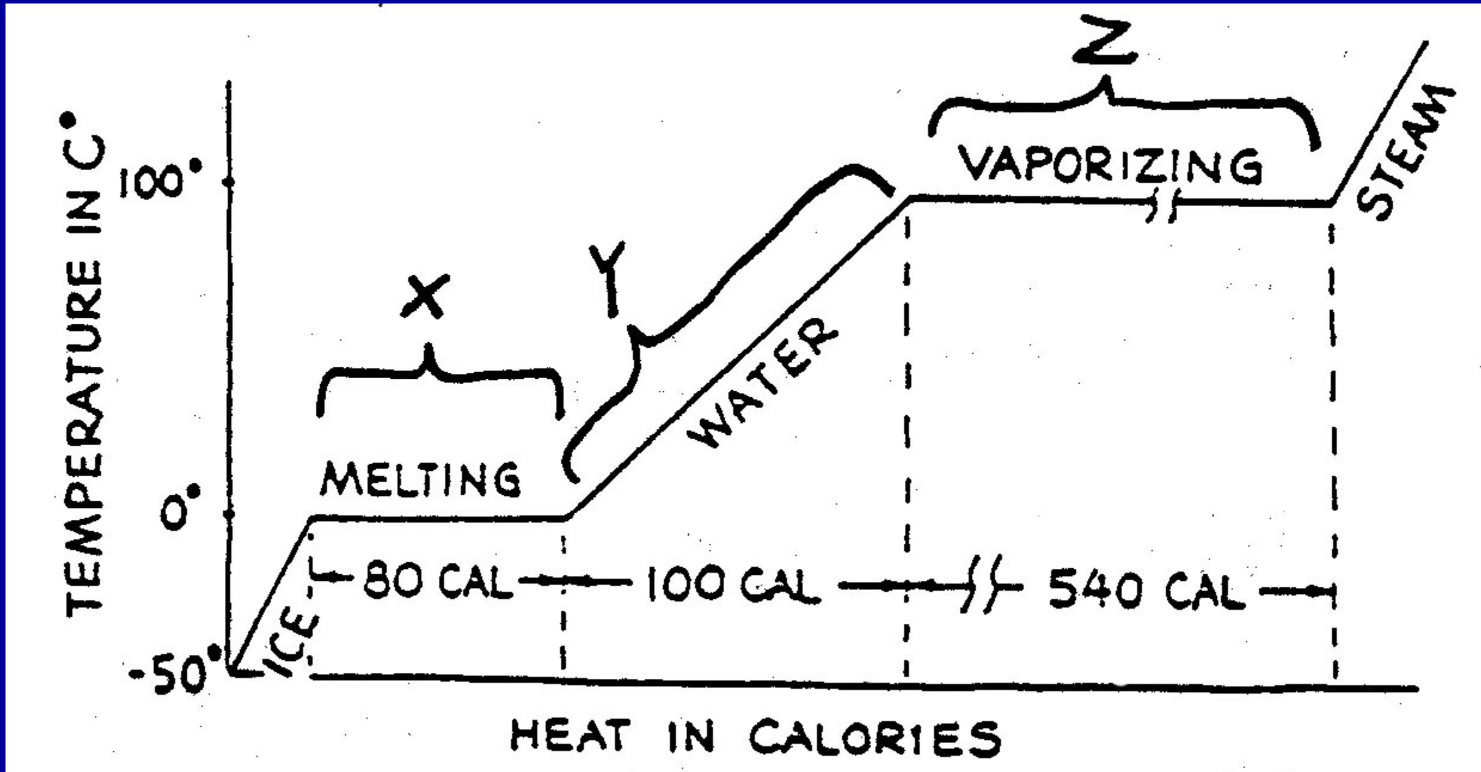
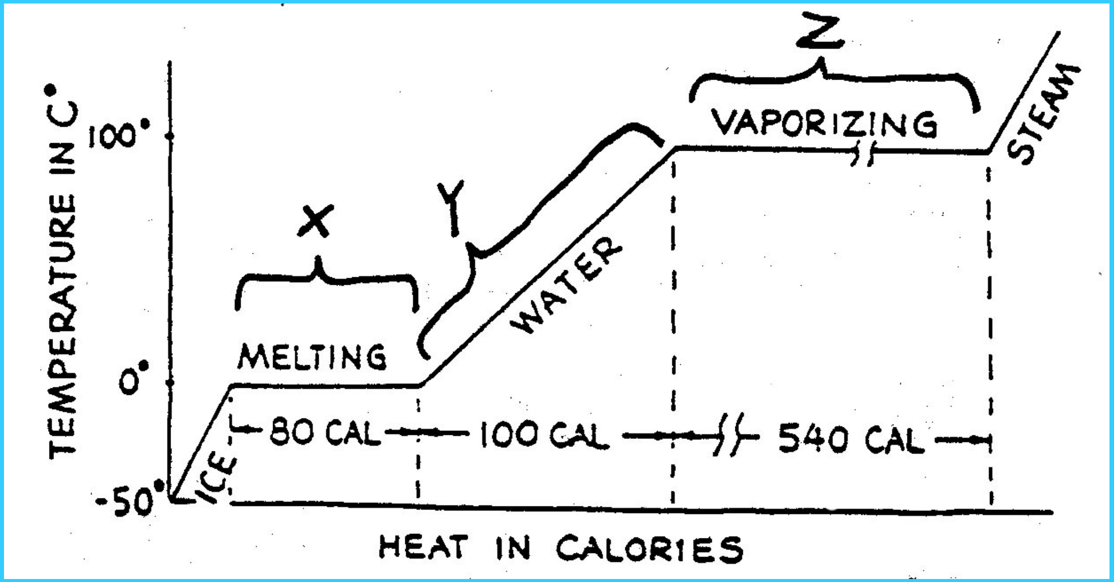


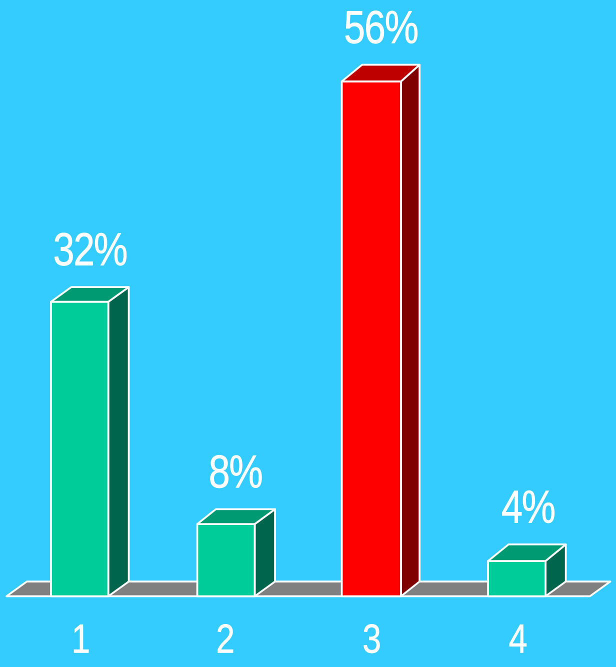
Q6 Which segment (s) of the graph represent SENSIBLE HEAT (H)?

1 = X & Z 2 = X only 3 = Y only 4 = Z only

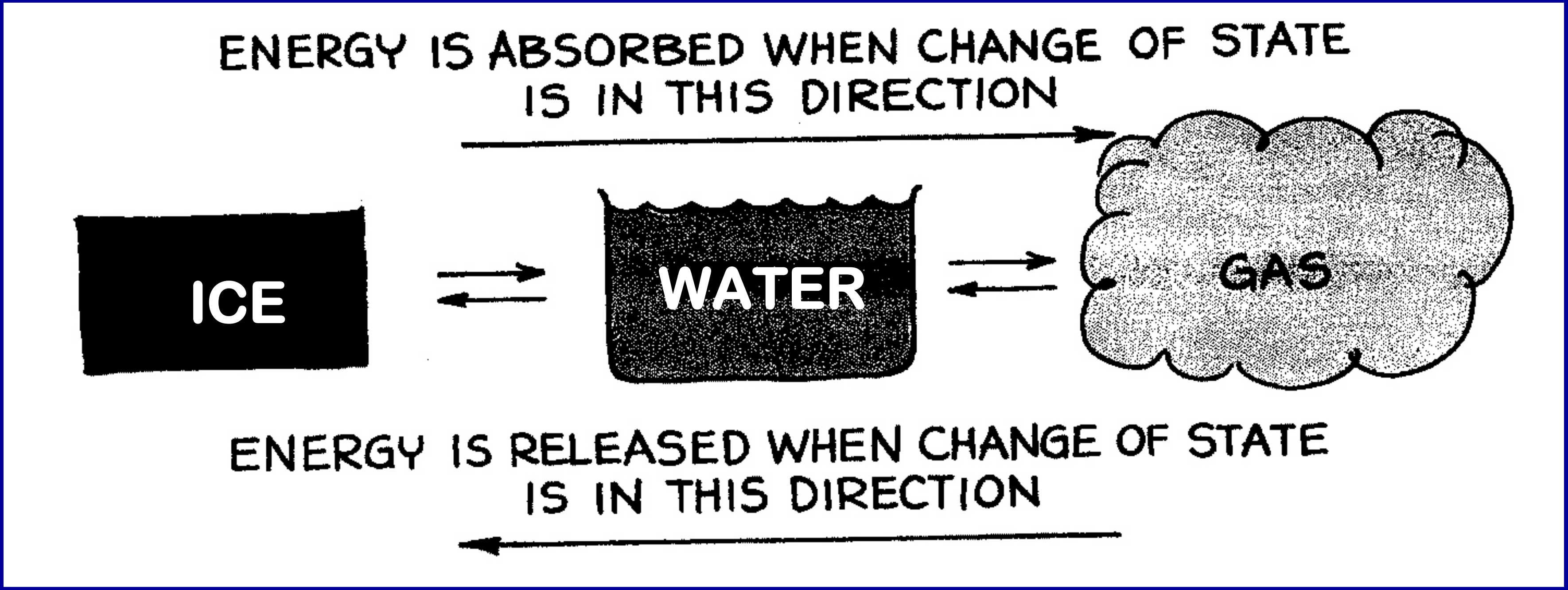


Q6. **Which segment(s) of the graph represent SENSIBLE HEAT (H)?**

1. X & Z
2. X only
3. Y only
4. Z only



PHASE CHANGES IN H_2O

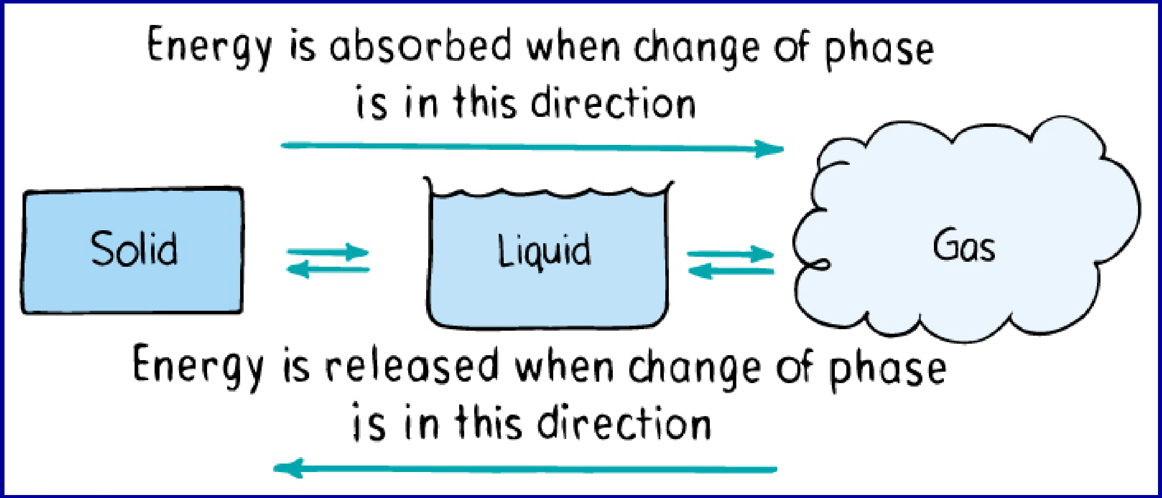


Q7 = In a phase change from ice to water or water to water vapor, WHAT is absorbing the energy?

1 = the surrounding environment

2 = the H_2O molecules

3 = both the environment & the H_2O



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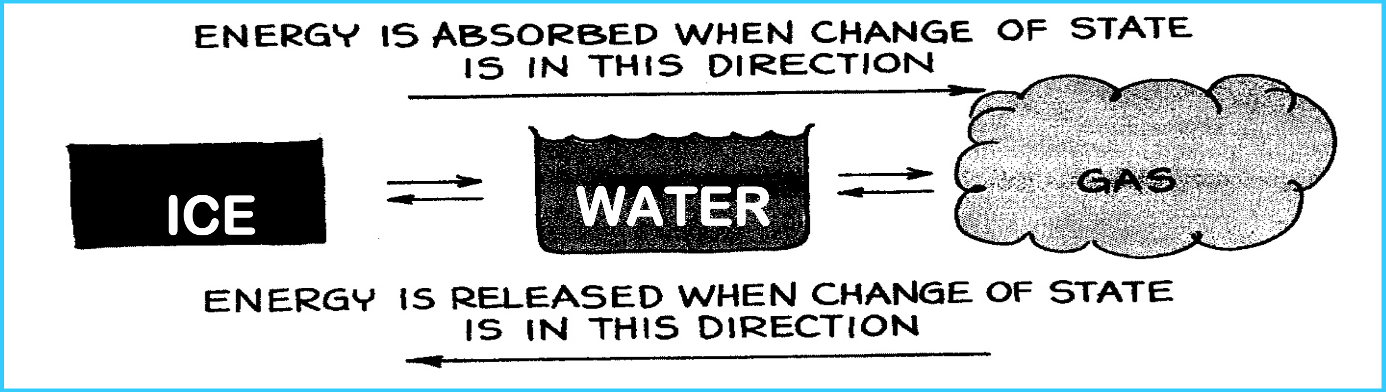
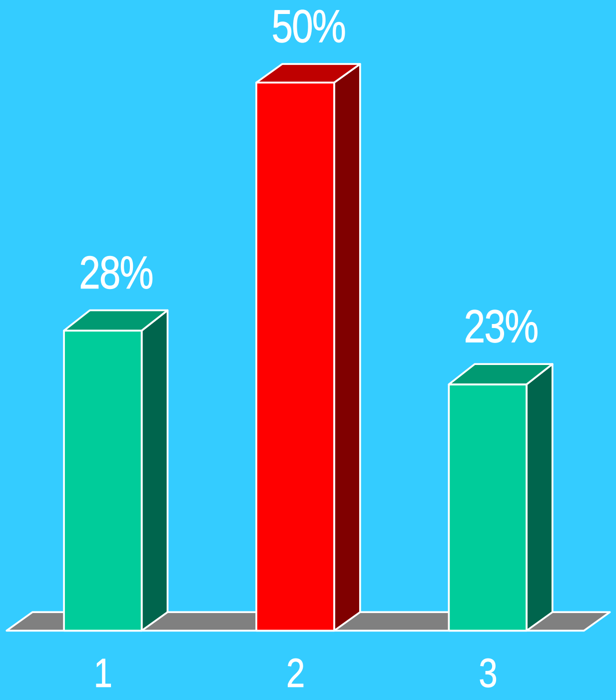


1. The surrounding environment
2. The H_2O molecules
3. Both the environment & the H_2O molecules

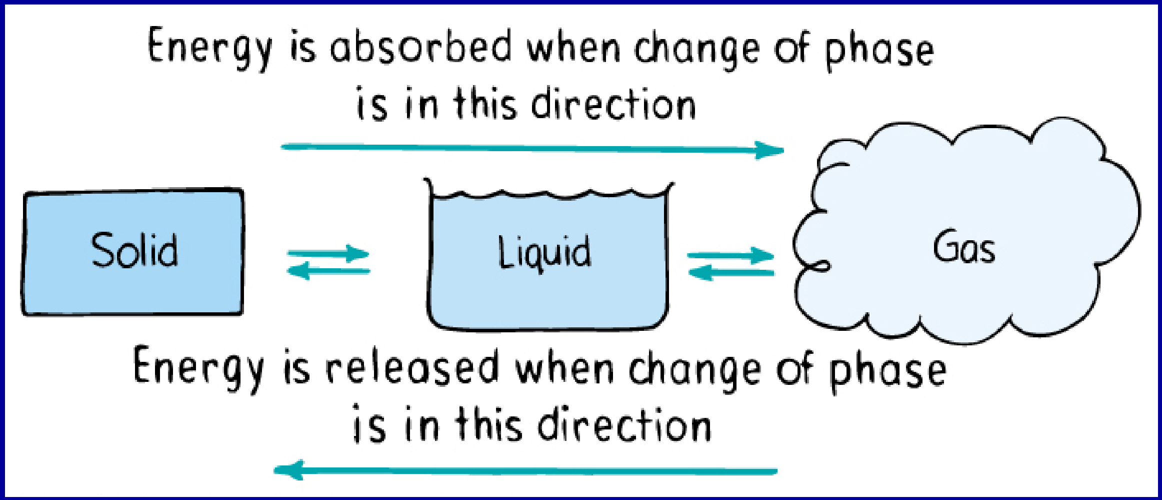


Q8 = In a phase change from water vapor to water or water to ice, TO WHERE is the energy being released?

1 = into the surrounding environment

2 = into the H_2O molecules

3 = into both the environment & the H_2O



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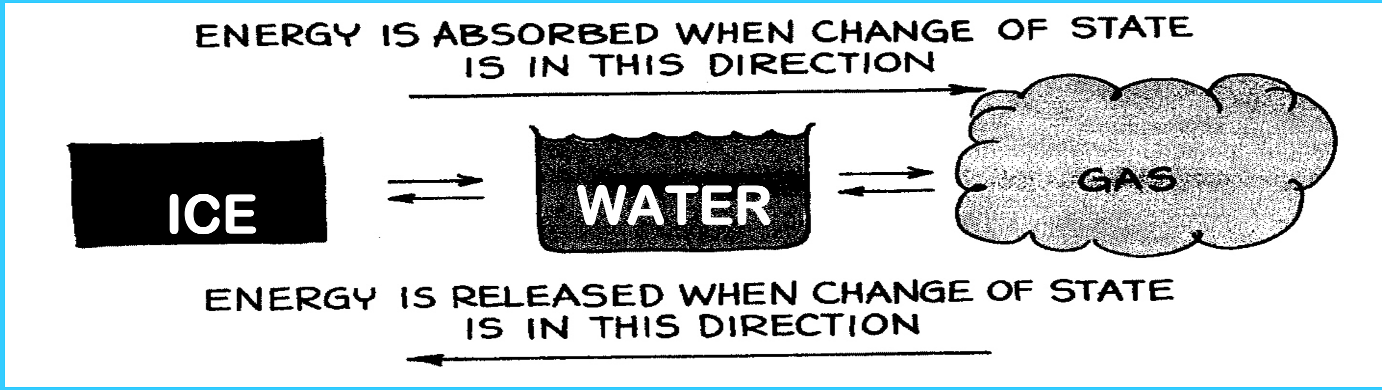

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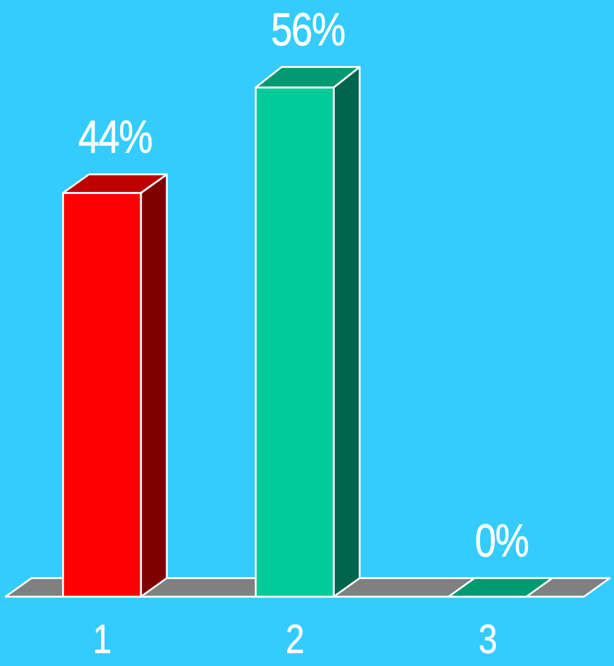
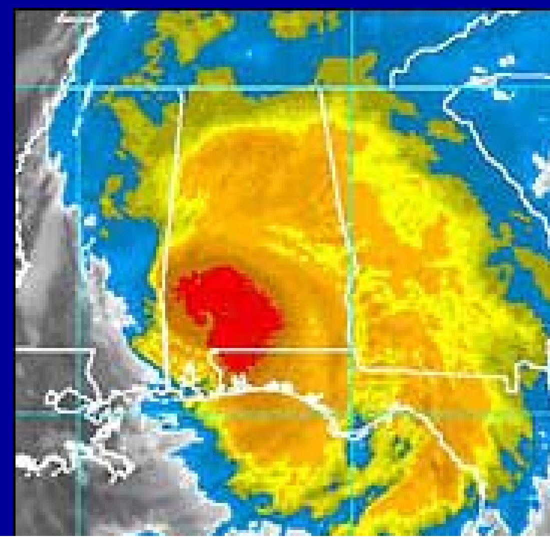
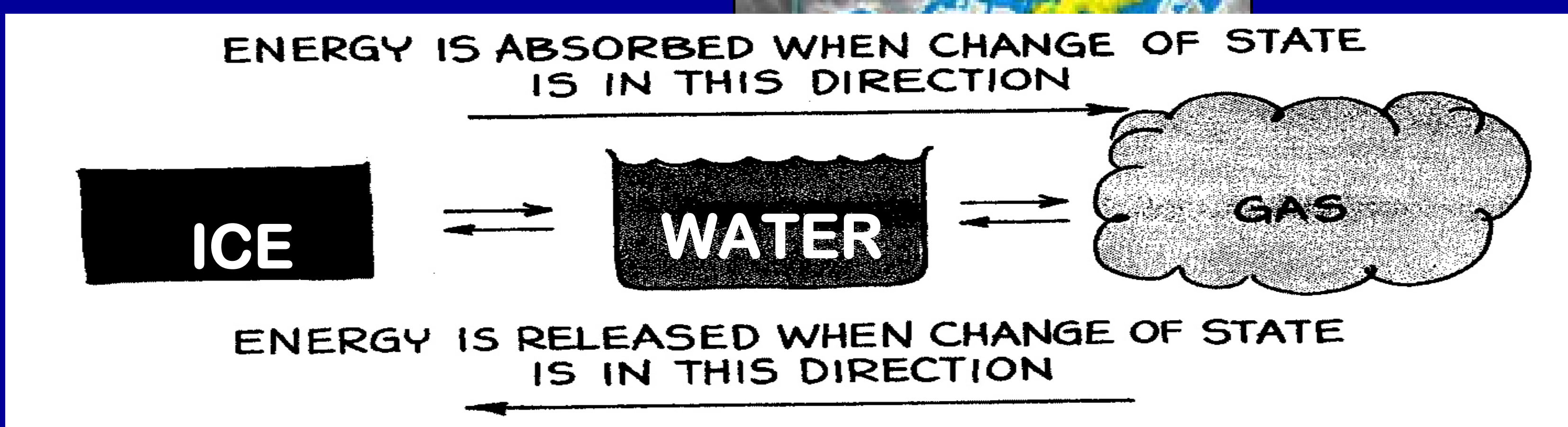
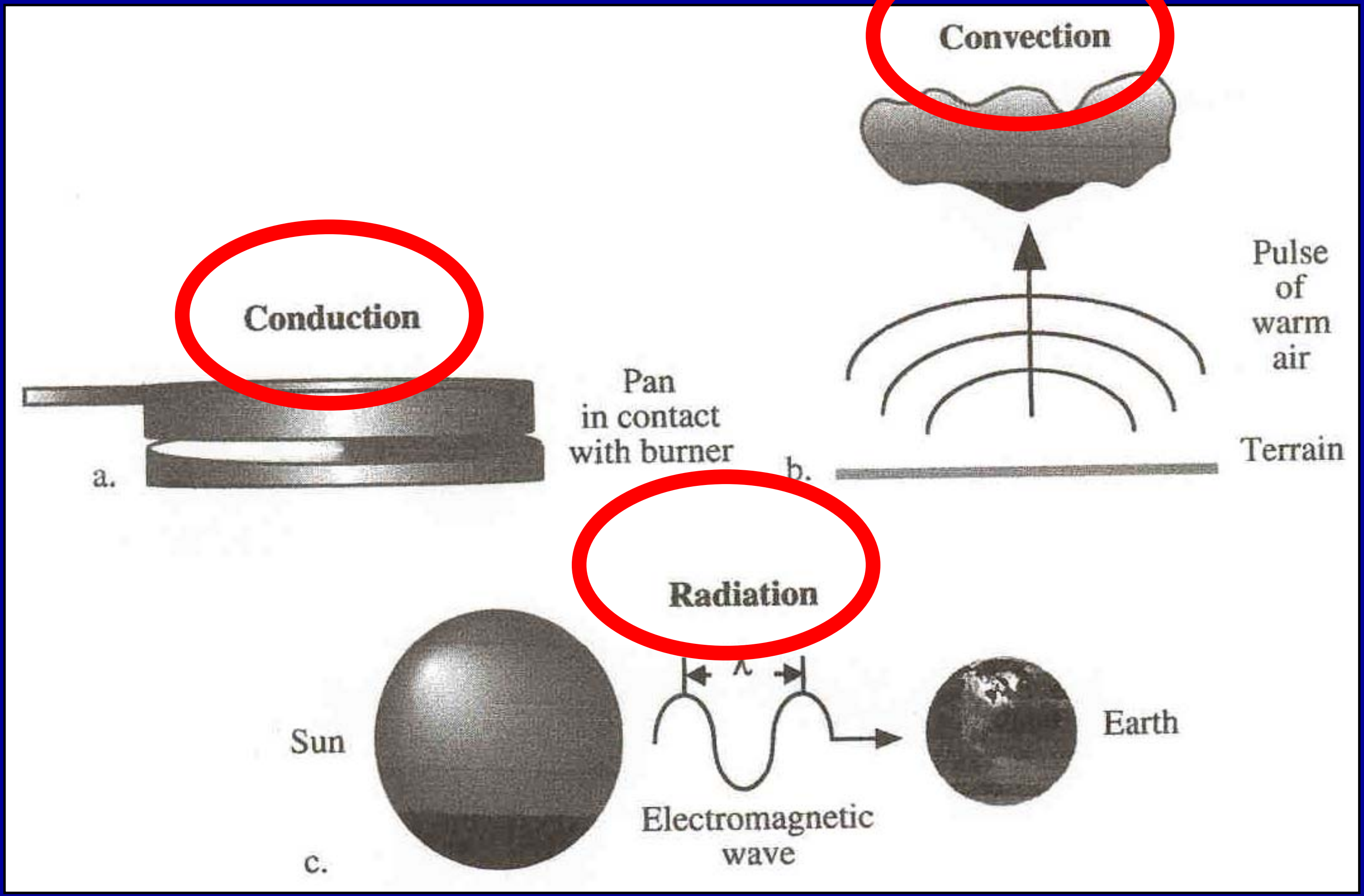


WHAT DRIVES HURRICANES LIKE KATRINA??





HEAT TRANSFER = the process by which thermal energy moves from one place to another



Electromagnetic Radiation

Electromagnetic energy (radiation) is not heat energy.

It does not become heat (jiggling molecules) until it strikes an object, is absorbed by the object and sets the molecules in the object in motion, thereby heating up the object.

KEY CONCEPT:

The sun's energy comes in as radiant (electromagnetic) energy, and is converted to measurable heat only after it is absorbed (e.g., by the surface of the earth, a gas in the atmosphere, etc.).

ENERGY TRANSFORMATIONS & the Laws of Thermodynamics

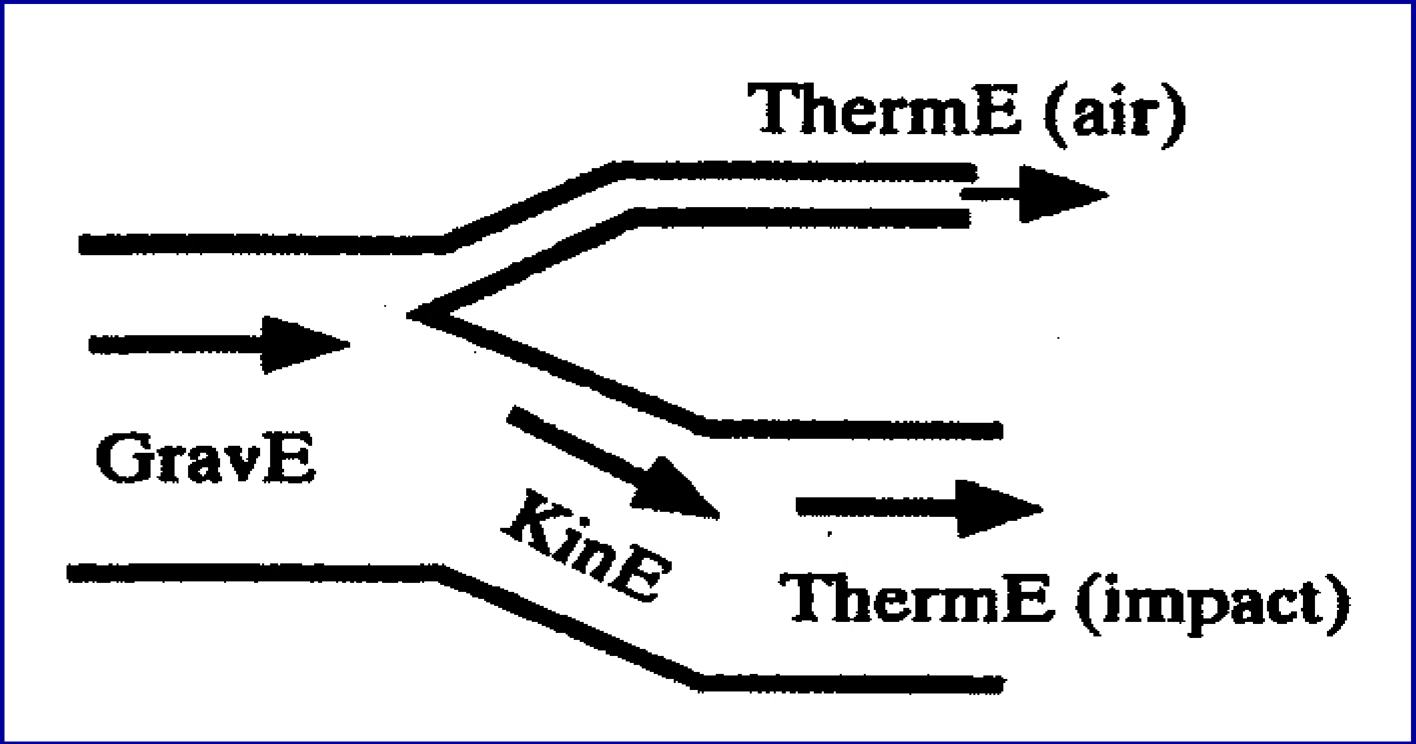
"Everything that happens can be described as energy transformations"

THE FIRST LAW OF THERMODYNAMICS
(stated as the "Law of Conservation of Energy")

The total energy of all the participants in any process must remain unchanged throughout the process. There are no known exceptions.

Energy can be transformed (changed from one form to another), but the total amount always remains the same.

1^{st} Law of Thermodynamics



Energy flow for a falling book, with air resistance.

FIRST LAW OF THERMODYNAMICS

(another way of saying it)

In an isolated system
the <u>total amount of energy</u>
(including heat energy)

is <u>conserved</u>,

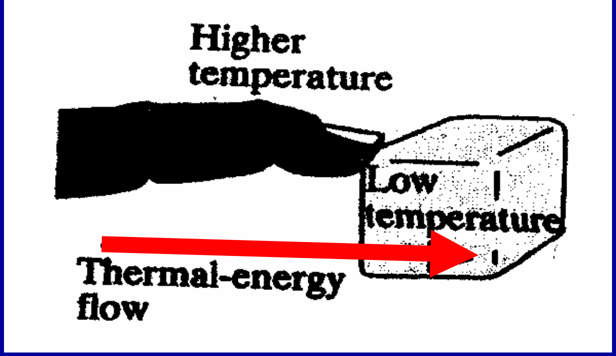
although energy may change from one form to another over and over again.

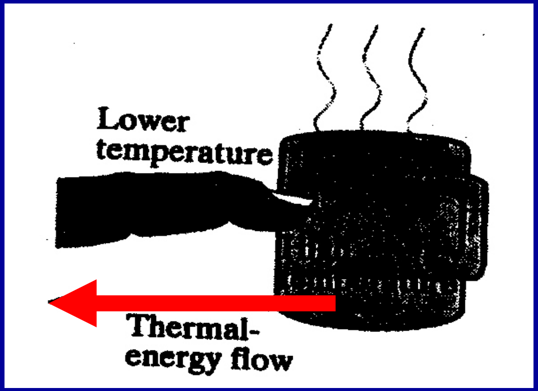
SECOND LAW OF THERMODYNAMICS
(stated as the "Law of Heating")

Heat will not flow spontaneously from a cold to a hot body.

Thermal energy flows spontaneously (without external assistance) from a <u>higher</u> temperature object to a <u>lower</u>-temperature object.

It will not spontaneously flow the other way!



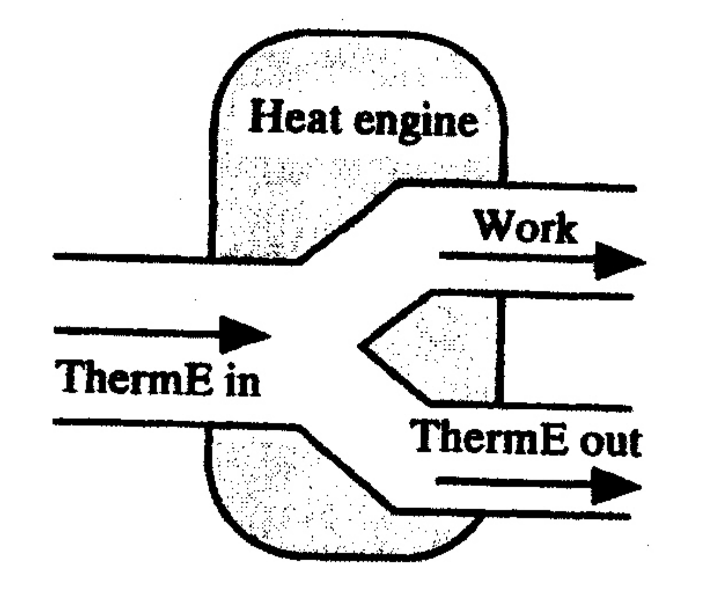


*The **2nd Law of Thermodynamics** says that:*

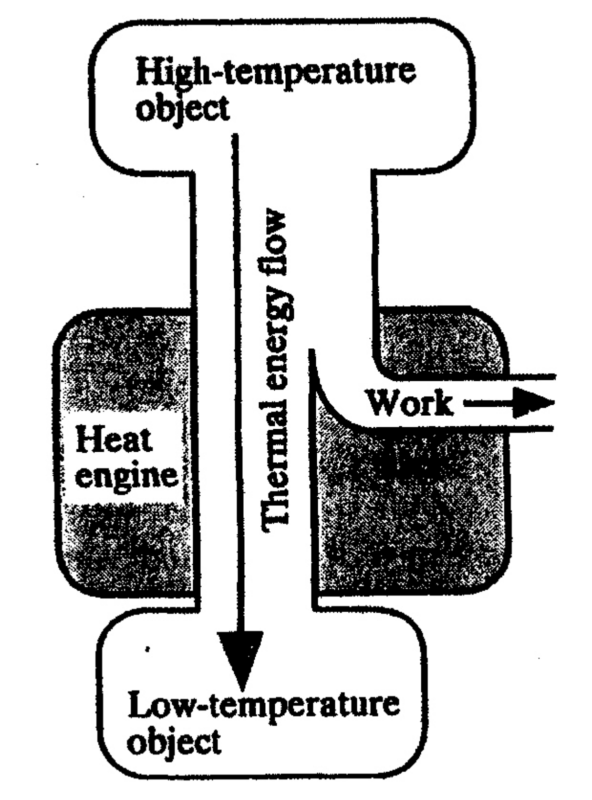
Energy of all kinds in our material world disperses or dissipates if it is not hindered from doing so!

Entropy = the quantitative measure of this kind of spontaneous dissipating process:

i.e., how much energy has flowed
from being constricted or concentrated
to being more widely spread out
(at the temperature of the process)

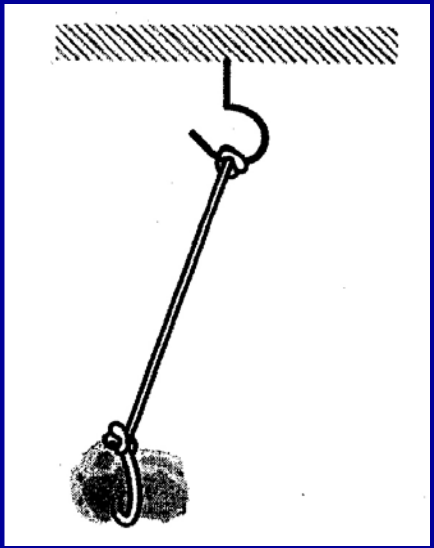


<=== Energy flow diagram for a heat engine. heat engines consume thermal energy and turn part of it into work, which could then produce any form of energy.



Heat engines use a portion of the thermal energy that flows naturally from a high to a low temperature and convert it to work. ====>

Irreversibility: Once a system creates thermal energy, that system will never by itself (spontaneously) be able to return to its previous condition. There is an irreversibility about any process that creates thermal energy.



Energy quality: "things run down"
A rock swinging on a string tied to some fixed point overhead. The rock "dies down" illustrating the irreversibility of natural processes implied by the second law of thermodynamics.

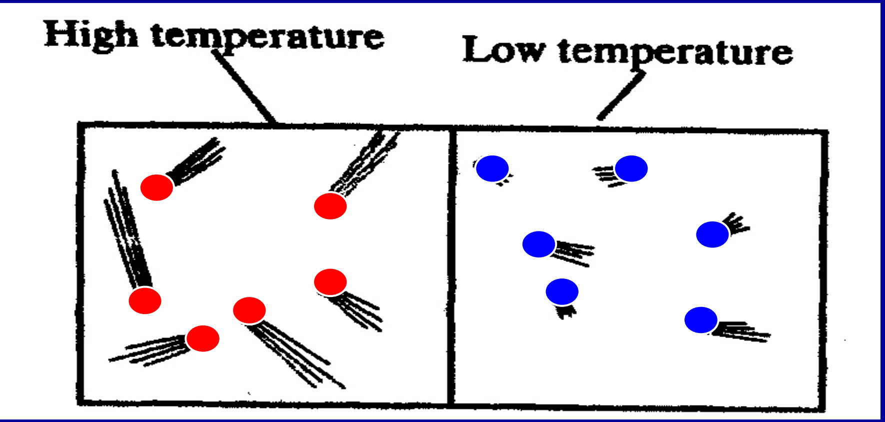
ENTRY example:

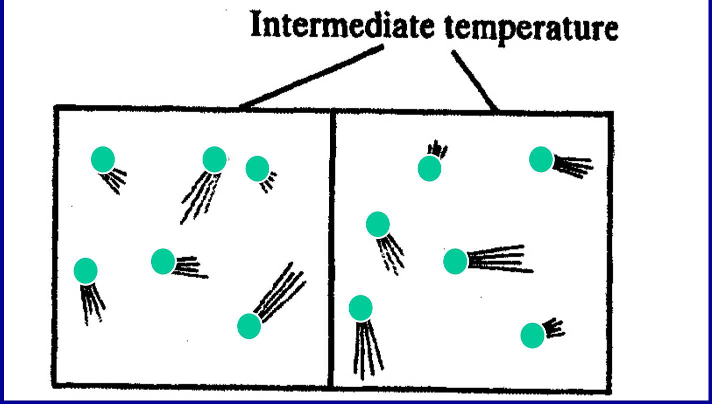
(at the molecular level)

When a box of hot gas and cold gas are allowed to mix,

eventually the faster molecules striking the slower molecules spread out some of their energy to the slower molecules,

leading to a wider range of speed and an intermediate temperature in the box.





SECOND LAW OF THERMODYNAMICS (stated as the "Law of Increasing Entropy")

The second law of thermodynamics is a powerful aid to help us understand why the world works as it does

-- why hot pans cool down,
-- why our bodies stay warm even in the cold,
-- why gasoline makes engines run.

The second law of thermodynamics says that **energy of all kinds in our material world disperses or dissipates if it is not hindered from doing so.**