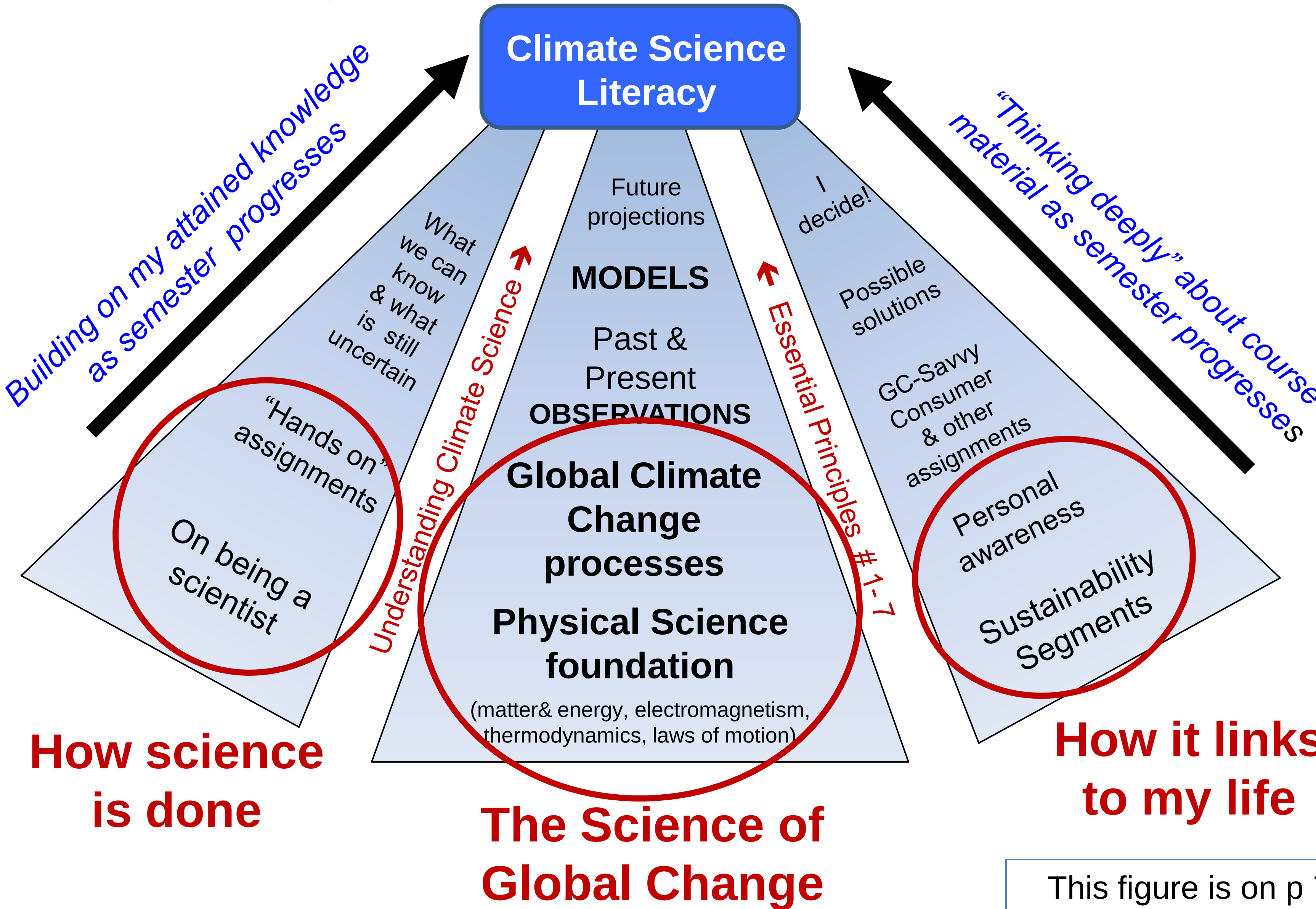
First some important preliminary business . . .

GOAL: Enhanced Understanding Of Global Change Science, How It Operates, & What It Means To Me Personally



This figure is on p 7 of Class Notes

IMPORTANT UPCOMING CLASSES:

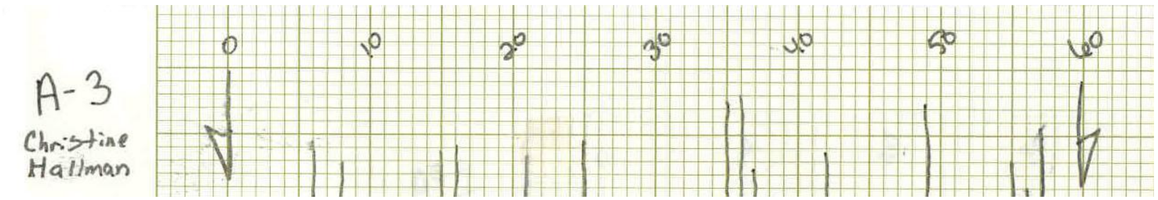
TUESDAY **Oct 5** **TEST #2**		**THURSDAY** **Oct 7** **Group Tree-Ring Activity for I-3: Day 1**
TUESDAY **Oct 12** **Group Tree-Ring Activity for I-3: Day 2** **+ Midterm Exam Mini-Review & Practice**		**THURSDAY** **Oct 14** **MIDTERM EXAM**
TUESDAY **Oct 19** **Topic #10 & G-3** **Group Assignment**		**THURSDAY** **Oct 21** **Topic #11** **RQ-5 due**

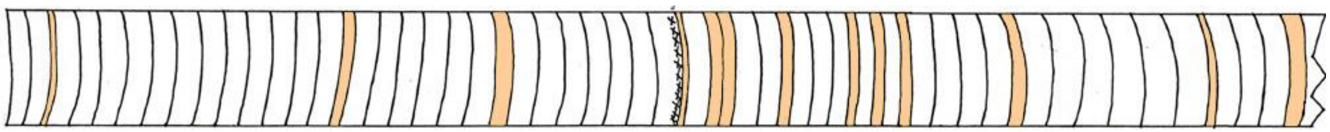
NOTE: If you miss a Group Activity – you will need to make it up by going to a TA office hour -- plus, YOUR GROUP NEEDS YOU!

TEST #2 is NEXT TUESDAY!

advance warning . . .

Question #10 will be a "hands on" question! After a short instructional presentation by Dr H, you will be given a piece of graph paper, a pencil, and a "paper core" and asked to construct a skeleton plot of your core by hand.

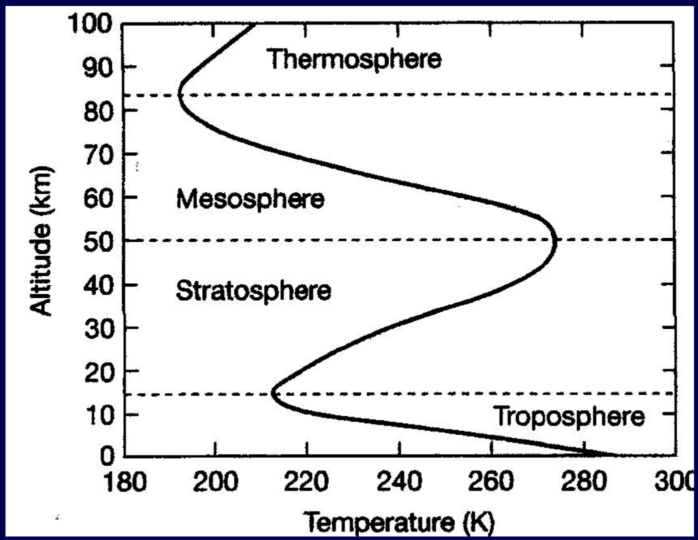




If you produce a proper skeleton plot that pattern matches and crossdates with the other cores in your group, you will get credit for Question #10.

LINK: [Guidelines, Hints & Practice for Question #10]

Just in time for your Test #2 Studying!



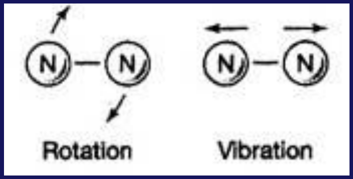
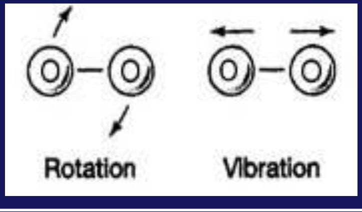
Trust **S**cientists' **M**inds & **Th**oughts

Courtesy of
Last year's class!

WRAP-UP of TOPIC # 8

On Atmospheric Structure & Composition

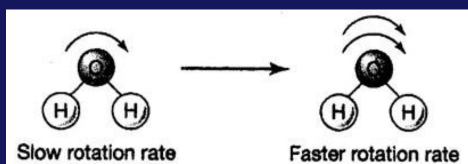
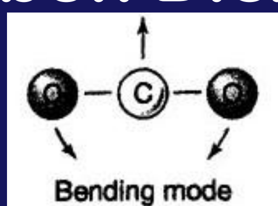
Most Abundant Gases in the Atmosphere

GAS	Symbol	% by volume	% in ppm
Nitrogen 	N_2	78.08	780,000
Oxygen 	O_2	20.95	209,500
Argon	Ar	0.93	9,300

Total = 99.96%

Review p 41

Next Most Abundant Gases:

<table>
<tr><th>GAS</th><th>Sym bol</th><th>% by volume</th><th>% in ppm</th></tr>
<tr><td>Water Vapor

</td><td>H_2O</td><td>0.00001
(South Pole)
to 4.0
(Tropics)</td><td>0.1 - 40,000</td></tr>
<tr><td>Carbon Dioxide

</td><td>CO_2</td><td>0.0390
(and rising!)</td><td>360
(in 1997)
390 !
(in May 2009)</td></tr>
</table>

Greenhouse Gases !

Review p 41

Other Important Greenhouse Gases:

GAS	Symbol	% by volume	% in ppm
Methane	CH_4	0.00017	1.7
Nitrous Oxide	N_2O	0.00003	0.3
Ozone	O_3	0.0000004	0.01
CFCs (Freon-11)	CCl_3F	0.000000026	0.00026
CFCs (Freon-12)	CCl_2F_2	0.000000047	0.00047

Greenhouse Gases!

Review p 41

CFCs (Freon-11 & Freon-12)

* Human-made CFCs (didn't exist in atmosphere prior to 1950s)

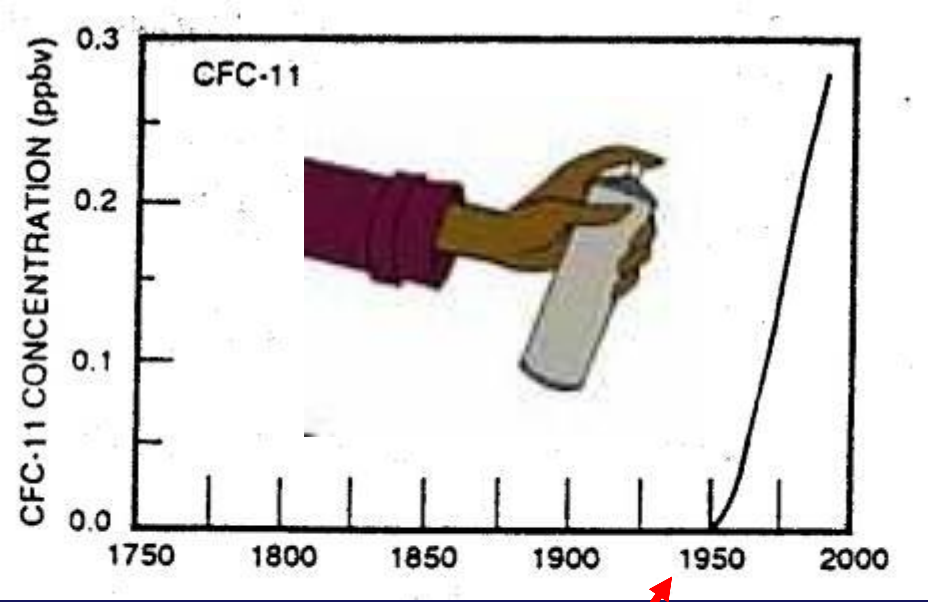
* **Have increased at rates faster than any other greenhouse gas; used in refrigerants, fire retardants, some aerosol propellants & foam blowing agents**

* Absorb at different wavelengths than H_2O and CO_2 (in 8 –12 µm "WINDOW" part of spectrum), hence a single molecule can have great effect *(i.e., "High Global Warming Potential")*

MONTREAL (and subsequent) PROTOCOLS have reduced CFCs!

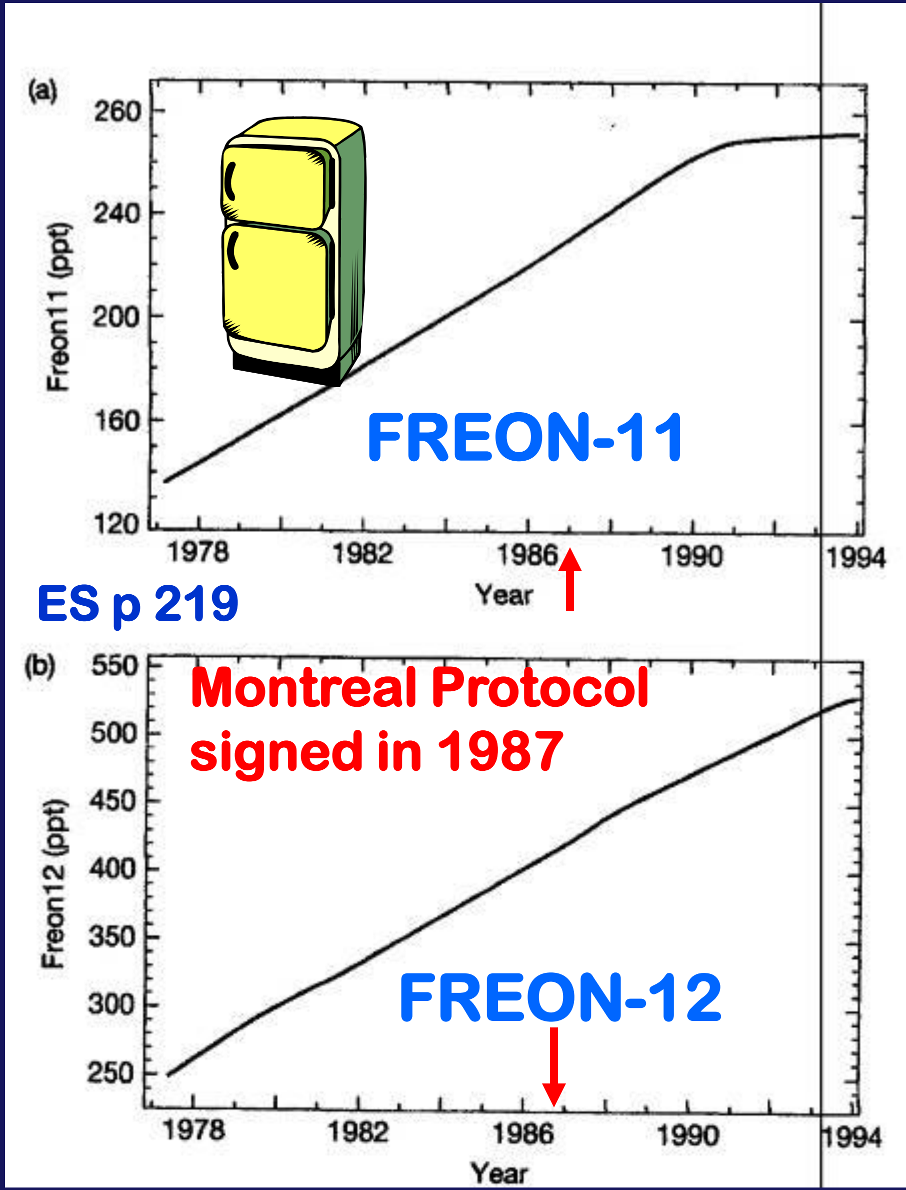
This info is in Table on p 41

CFCs: Trends



Human-made -- didn't exist before 1950!

Now banned . . .



Q1 – Why do you think the concentration of CFC's didn't begin dropping immediately after the Montreal Protocol in 1987?

1. Because it was an international "agreement only" and the nations of the world never followed through.
2. Because it called for only a 50% reduction of CFC's over 10 years and had to be followed by more stringent protocols later.
3. Because CFC's are very stable molecules and don't break down easily once they are in the atmosphere.
4. Both 1 & 2
5. Both 2 + 3

Q1 – Why do you think the concentration of CFC’s didn’t begin dropping immediately after the Montreal Protocol in 1987?

1. Because it was an international “agreement only” and the nations of the world never followed through.
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4. Both 1 & 2
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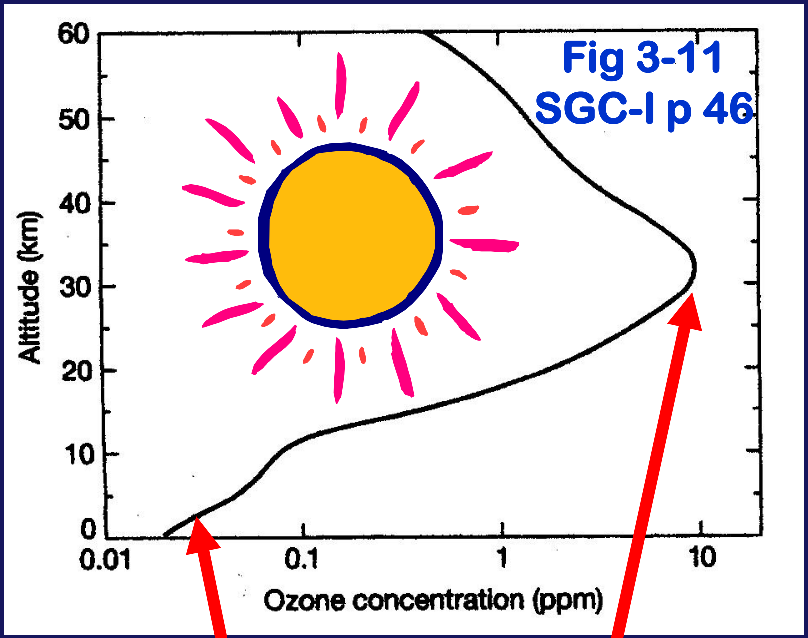
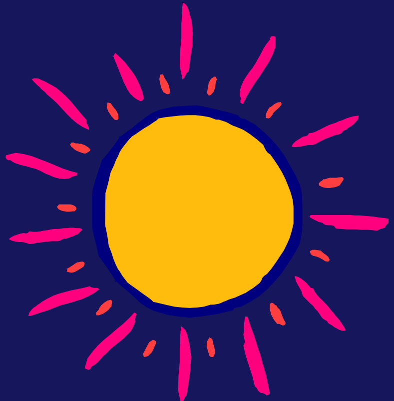
OZONE: Sources



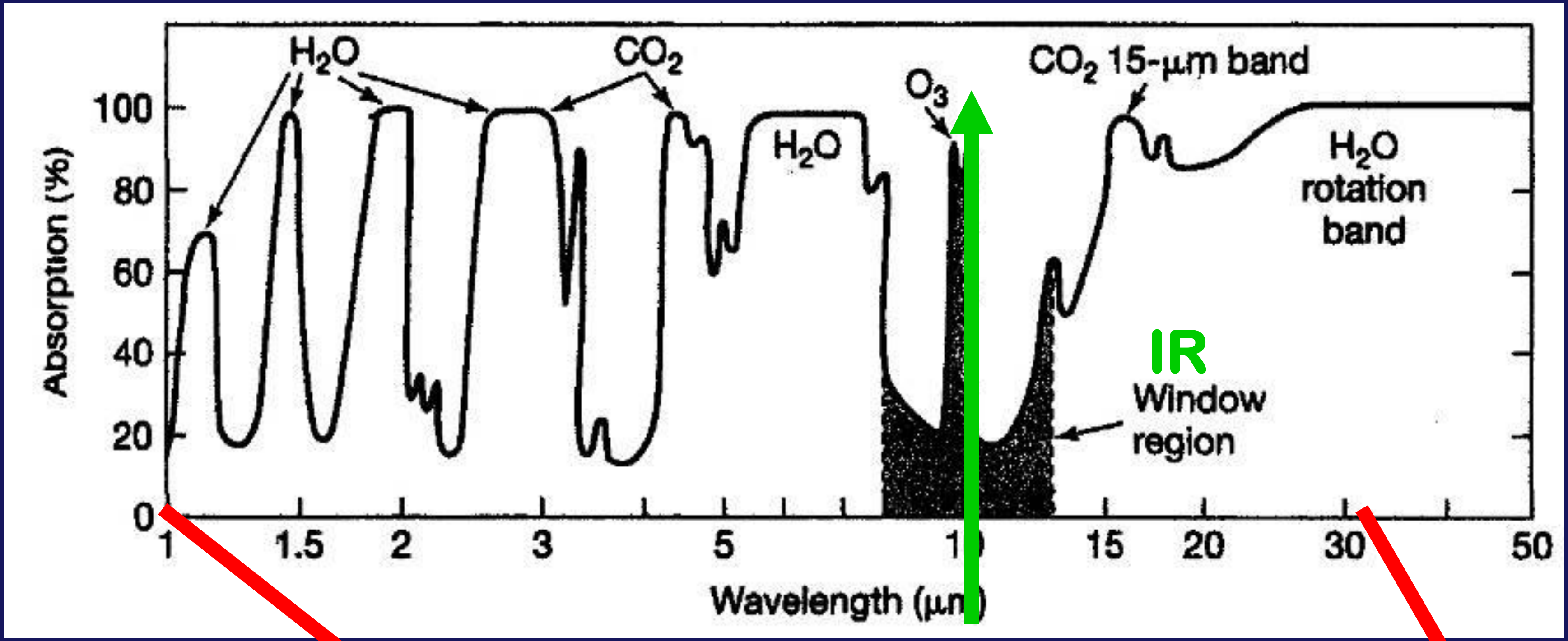


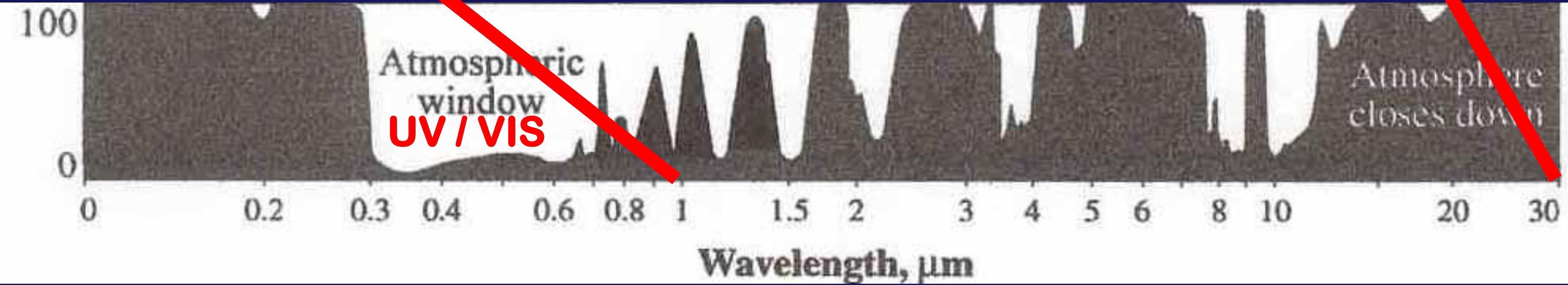
Produced naturally by photochemical reactions in STRATOSPHERIC ozone layer --"good ozone"

Has also *increased* in TROPOSPHERE due to photochemical smog reactions -- "bad ozone" *(more on this later)*

This info is in Table on p 41

O_3 absorbs IR radiation of 9.6 μm, close to wavelength of maximum terrestrial radiation (10 μm)





From p 48 in SGC-I

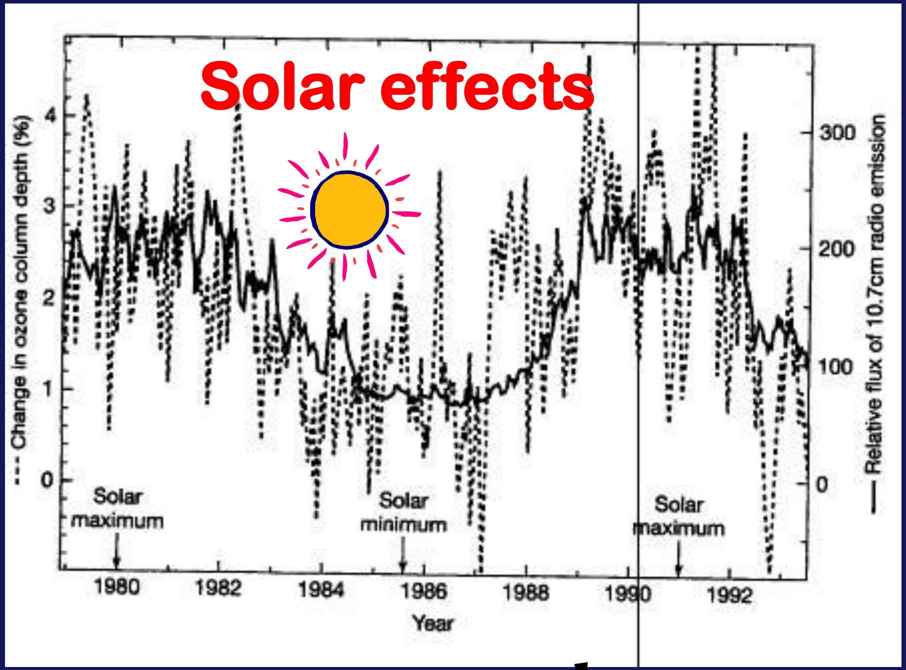
OZONE:
Trends

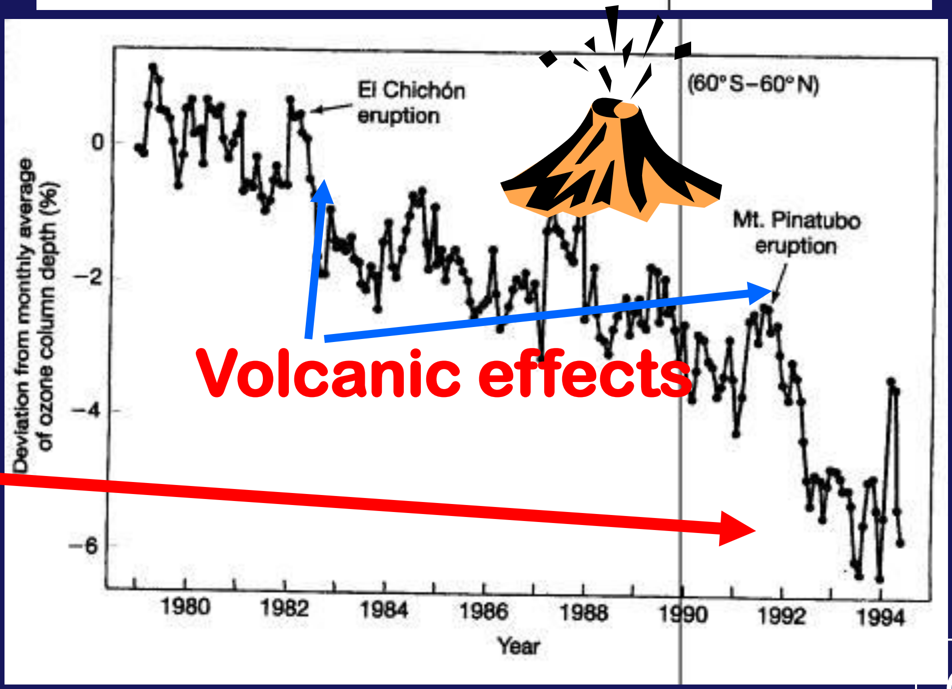
Stratospheric ozone varies by latitude and season:

– is affected by solar radiation, volcanic eruptions & chemical reactions due to CFCs.

Overall, O3 is decreasing in the STRATOSPHERE

More on OZONE later on in the semester





Ozone Layer Damage Has Halted

September 24, 2010

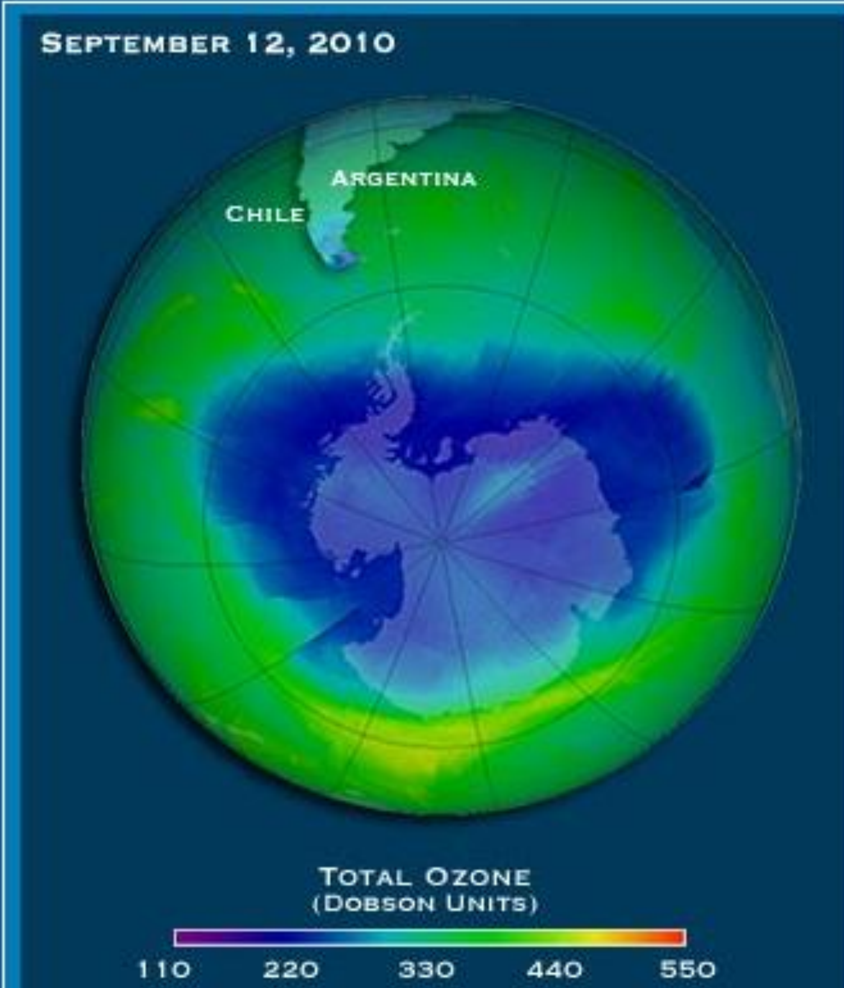
The global agreement to phase out the use of chlorofluorocarbons and other ozone-depleting compounds appears to have finally stopped additional damage to Earth's protective layer of stratospheric ozone.

Scientists say the ozone layer is no longer depleting and should regain its density by about 2048.

The first report in four years by the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol says the ozone "hole" is recovering more quickly than expected.

The ozone provides a filter against harmful ultraviolet rays from the sun, which can cause cataracts and skin cancer.

Photo: NASA



The depth and area of the ozone hole are controlled by the amount of chlorine and bromine in the Antarctic stratosphere.

Two Important Global Change Terms Related to Atmospheric Composition

(They are being introduced now, but we'll discuss them in more detail later)

Radiative Forcing (RF) –
Change in incoming minus outgoing radiation **at the tropopause** due to some factor.

e.g. change due to increasing concentration of carbon dioxide or the output of the Sun.

Global warming potential (GWP) –

An index that measures how much a given mass of greenhouse gas is estimated to contribute to global warming.

GWP depends on:

- the absorption of infrared radiation by a given gas,
- the location of its absorbing wavelengths on the electromagnetic spectrum
- the atmospheric lifetime of the gas

A high GWP correlates with a large infrared absorption and a long atmospheric lifetime.

➔ A gas has the most effect if it absorbs in a "window" of wavelengths where the atmosphere is fairly transparent.

p 42

NOTE:

There are other GHG's (esp. human-made) . . . .

Some examples:

Hydrofluorocarbons (HFCs)
Perfluorocarbons (PFCs)
Sulfur Hexafluoride (SF_6)

Some of these are especially harmful because they have high "Global Warming Potential" (GWP)

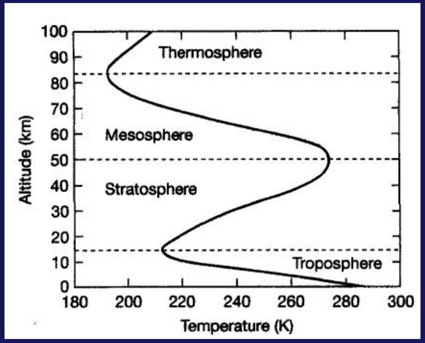
SUMMARY OF KEY CONCEPTS: short version

1. Four gases N_2, O_2, Ar, & CO_2 comprise about 99% of the volume – but “minor” Greenhouse Gases are extremely important.

2. Most of the MASS of the atmosphere is in the bottom few kilometers.

3. Different gases are abundant at certain levels in the atmosphere -- where radiation is absorbed by these gases => vertical temperature profile . . .

4. . . . which leads to the vertical structure of the atmosphere:



Now on to today's topic . . . .

TOPIC # 9
LAWS OF THERMODYNAMICS: Keys to Energy Transfer & Conservation

The Next Piece in the Puzzle to Understand Global Changes

CLASS NOTES:
pp 45-48

OUR QUOTE OF THE DAY . . .

In this house,
we obey the LAWS of
THERMODYNAMICS!

. . . is from 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**

review

Thermal Energy

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

(internal energy)

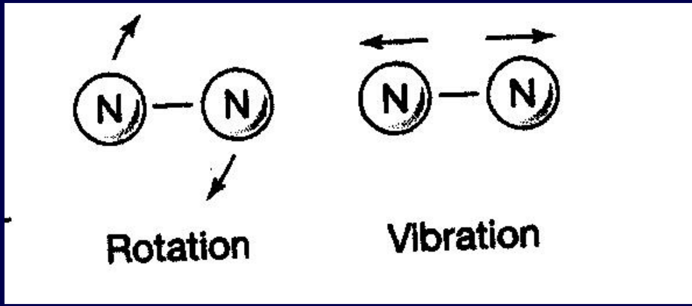
--also: a measure of the quantity of *atomic kinetic & potential energy* contained in every object;

-- also: 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.

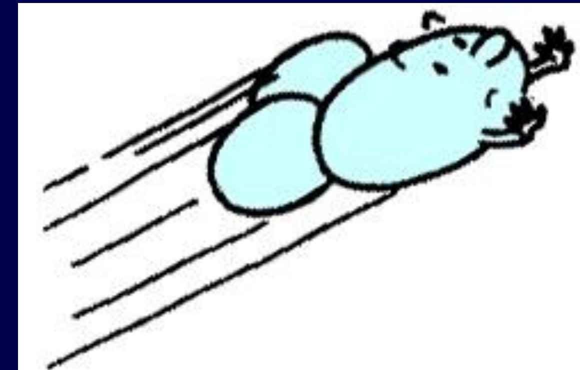
Thermal energy plays a central role in understanding these properties, hence the study of energy can also be called "thermodynamics."

☺

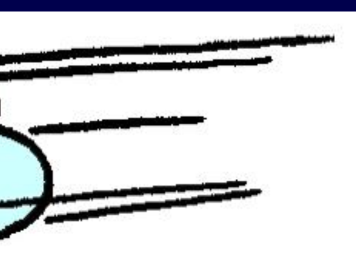
Thermal Energy & Temperature

- ***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).

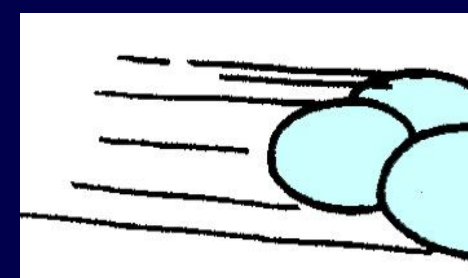
- **Temperature is a measure of the average kinetic energy of each molecule in a body.**

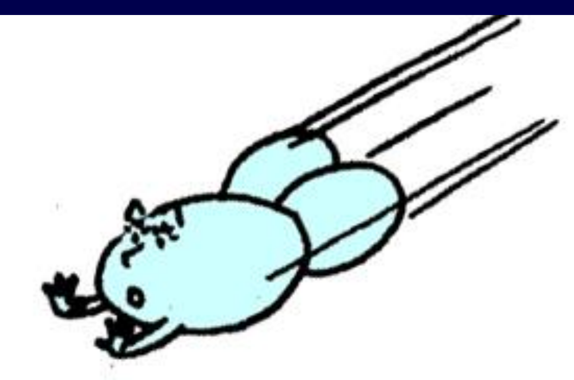


If a body has a high temperature, each of its molecules has, on the average, a large amount of kinetic energy.



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

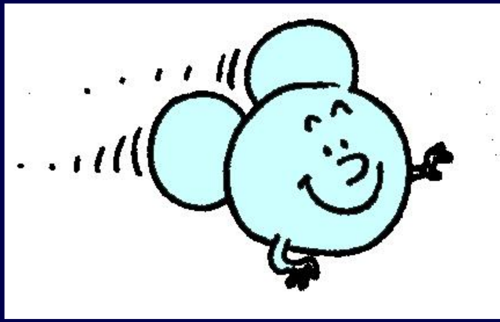




p 45

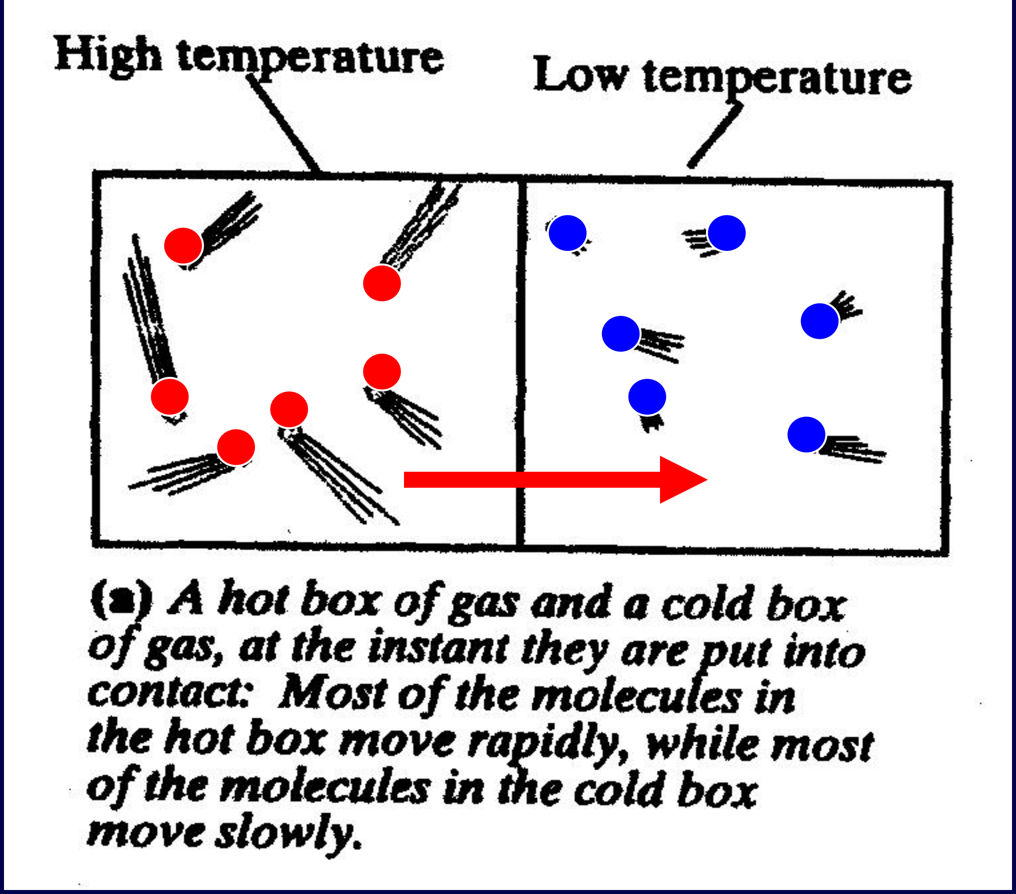
if a body has a low temperature, each molecule on the average has a small amount of kinetic energy.

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



(and if atoms lose all their kinetic energy, they reach the **"absolute zero"** of temperature)

Thermal Energy Flow (Transfer)



In which direction will THERMAL ENERGY be transferred?

Thermal energy flow = HEAT

p 45

Thermal Energy vs. Heat

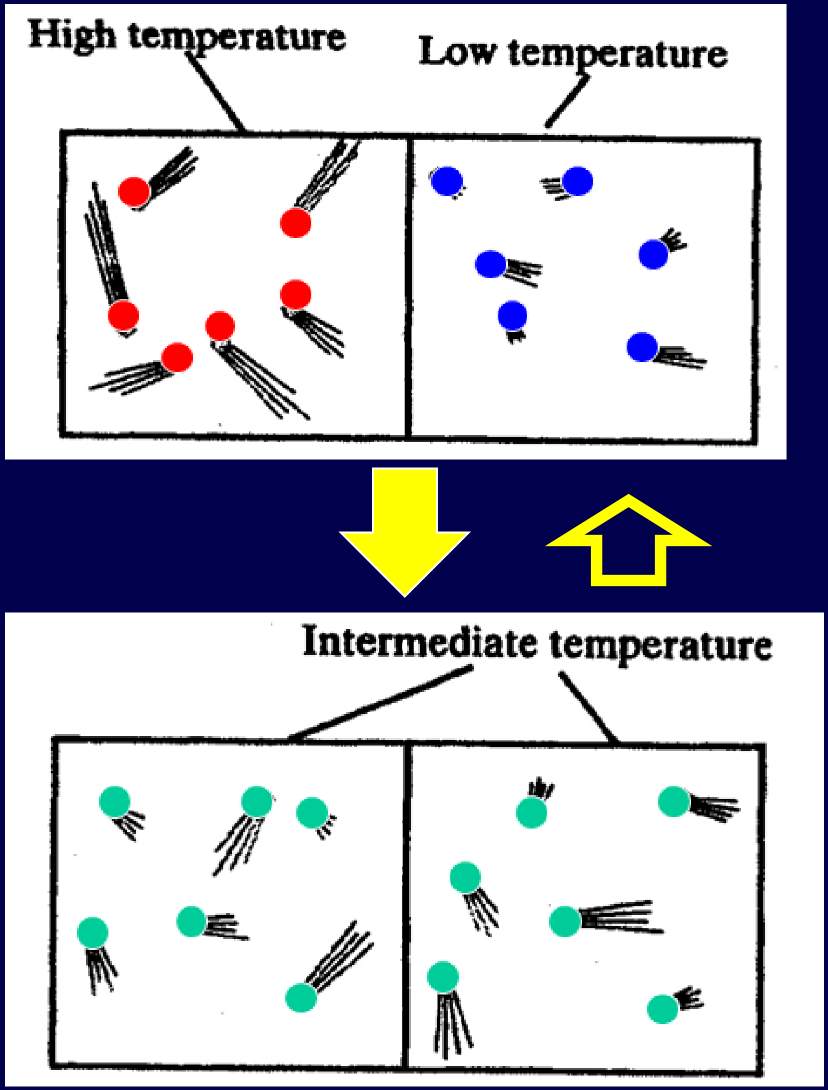
Heat = the thermal energy that is *transferred* from one body to another because of a temperature difference.

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

p 45

Reaches equilibrium



Will not spontaneously return to previous condition!

http://jersey.uoregon.edu/vlab/Thermodynamics/index.html

Skip to p 48

THE LAWS!

"Everything that happens can be described as energy transformations"

(a repeat) Was discussed earlier under ENERGY *(p 22)*

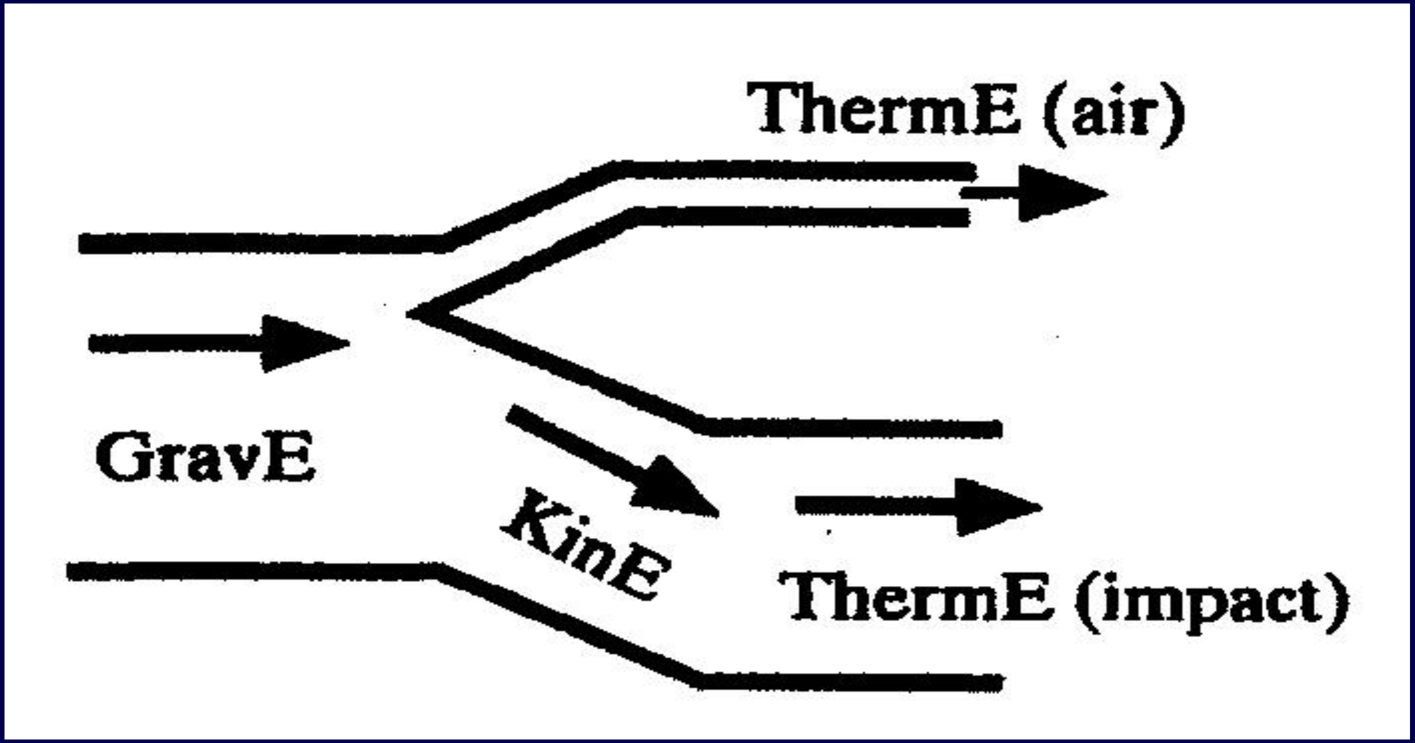
THE FIRST LAW OF THERMODYNAMICS
(stated as the "Law of Conservation of Energy")

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.

Remember this example?

Energy flow for a falling book, with air resistance.



1^{st} Law of Thermodynamics

FIRST LAW OF THERMODYNAMICS

(another way of saying it)

In an isolated system
the total amount of energy
(including heat energy)

is conserved,

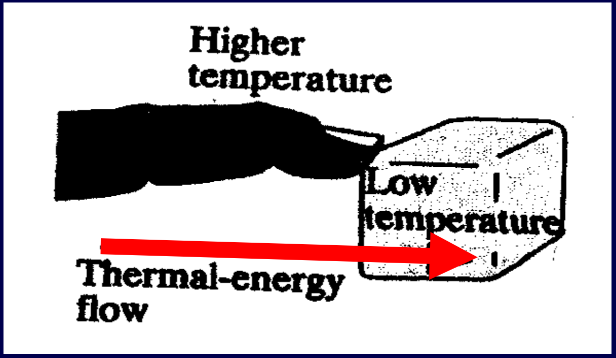
although energy may change from one form to another over and over again.

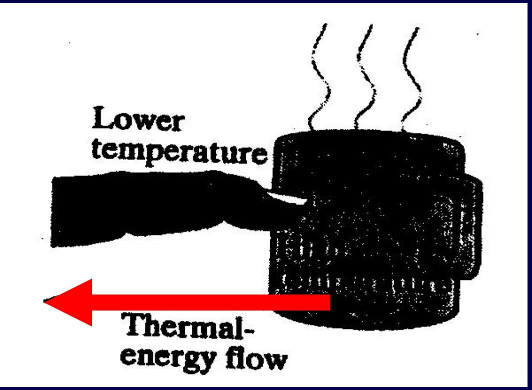
SECOND LAW OF THERMODYNAMICS
(stated as the "Law of Heating")

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

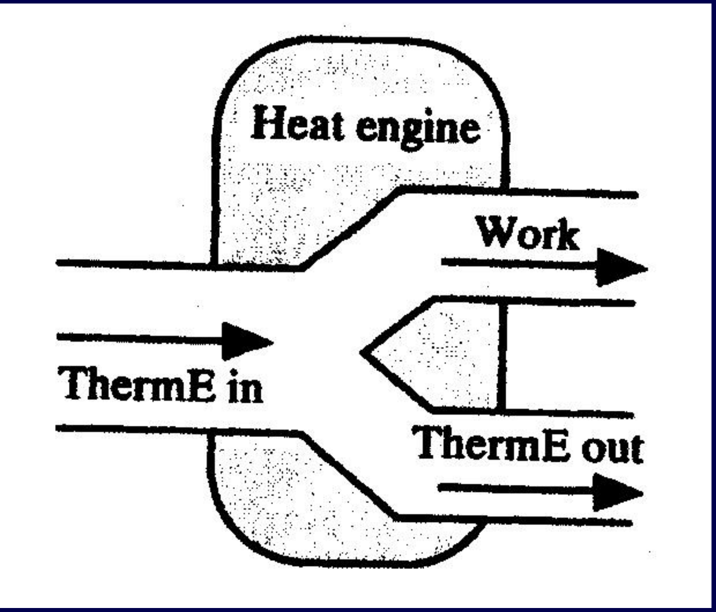
Thermal energy flows spontaneously
(without external assistance)
from a <u>higher</u> temperature object
to a <u>lower</u>-temperature object.

It will not spontaneously flow the other way!





The 2nd Law stated <u>another</u> way:



Energy flow diagram for a heat engine.

←

"2nd Law" = Any process that uses thermal energy as input to do the work must also have thermal energy output (or exhaust)

WHAT TO REMEMBER: heat engines are always less than 100 % efficient! ← **IMPROVED ENERGY EFFICIENCY IS A KEY ASPECT OF GREEN TECHNOLOGIES!**

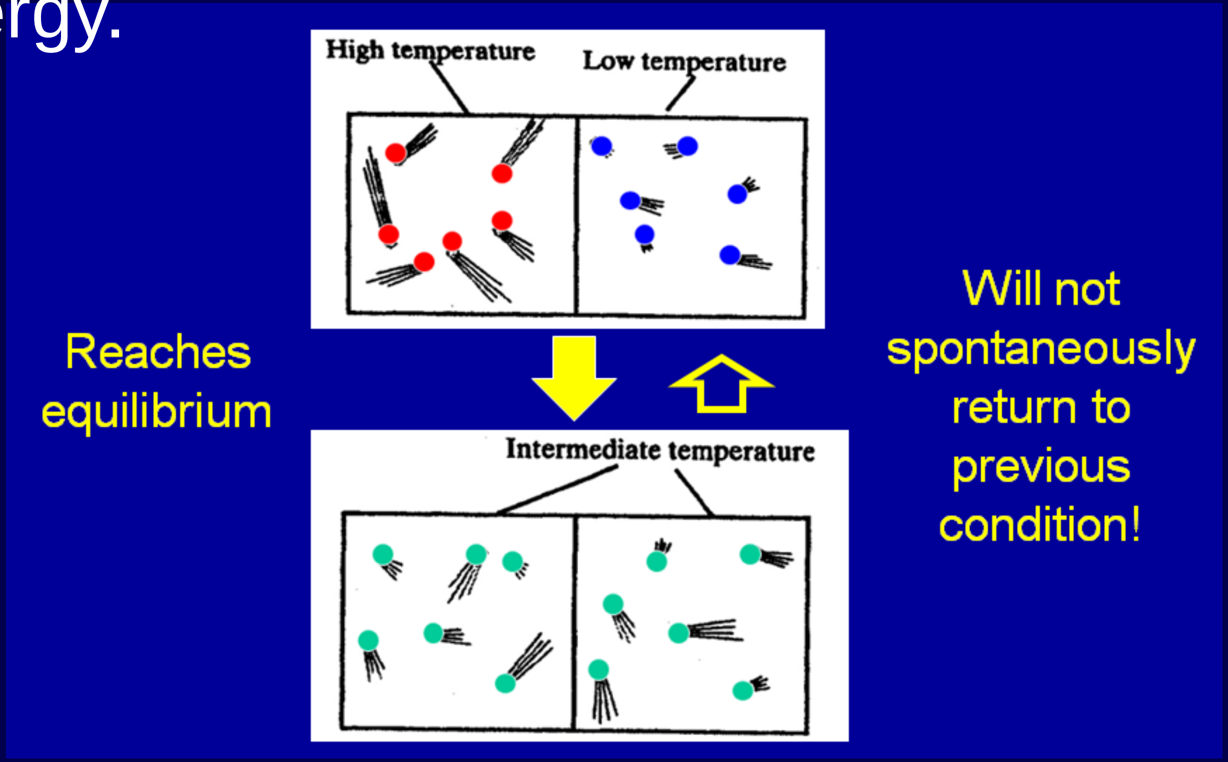
The 2nd Law stated a <u>THIRD</u> way:

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

<u>Entropy</u> = the <u>quantitative measure</u> 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)

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.



CLICKER
SELF TEST
TIME!!!

.....→

Q2 - 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 <u>and</u> Homer to the beer can

Q2 - Which way is heat being transferred?

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

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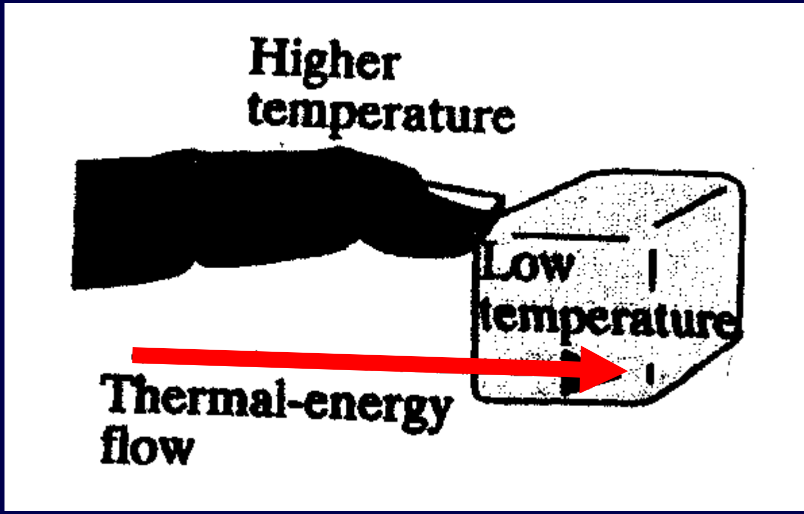
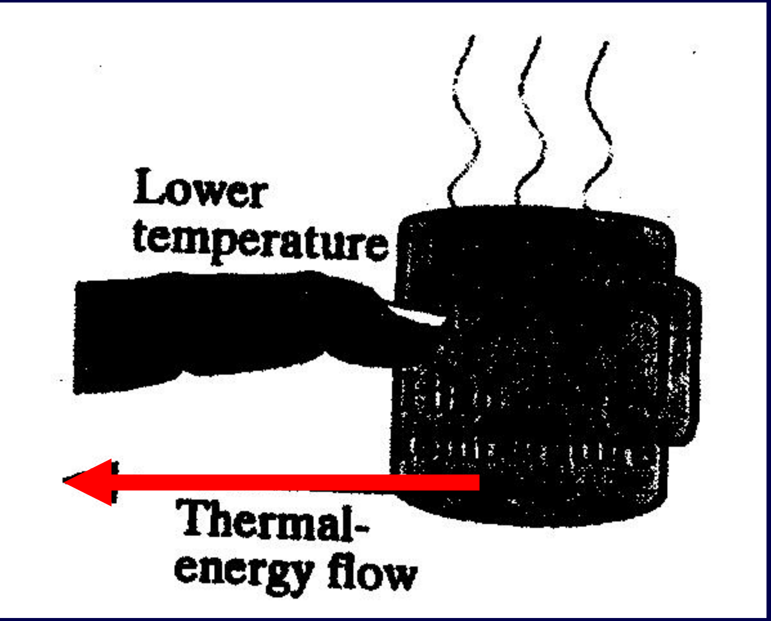
3. From BOTH the beer can to Homer <u>and</u> Homer to the beer can



Explanation for answer to Q2:

The 2nd Law of Thermodynamics!

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



Back to p 45

To prepare for the next few “CLASS SELF TEST” QUESTIONS, some background is needed . . . . .

- Unit of Measure of Thermal Energy
  (i.e., the joule or calorie)
- Specific Heat
- Heat Capacity
- Change of Phase
  (i.e., Latent Energy LE & Sensible Heat (H)
- Heat Transfer

Quick Review: 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)   1 calorie = 4.186 joules

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

Thermal energy calorie
vs
"nutrition" kilocalorie:

"Munch"

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.

p 45

One Other Important Term:

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***.)

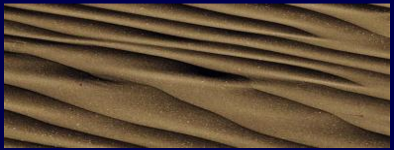
Specific Heat & Heat Capacity for Different Substances

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)
iron	0.105	.440	0.82
silver	0.056	.234	0.59

Note the HEAT <u>CAPACITY</u> differences between higher density substances (like water, iron) vs. the low density substance of AIR.

Q3 - 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?



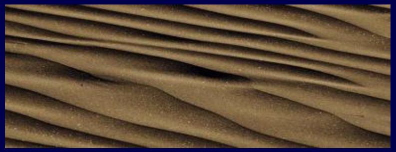
1. AIR
2. WATER
3. SAND

HINT: the greater the heat capacity, the longer it will take to heat up the substance.

To answer, check out the heat capacities in the table on p 45 of Class Notes.

Q3 - 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. AIR
2. WATER
3. SAND

Explanation:

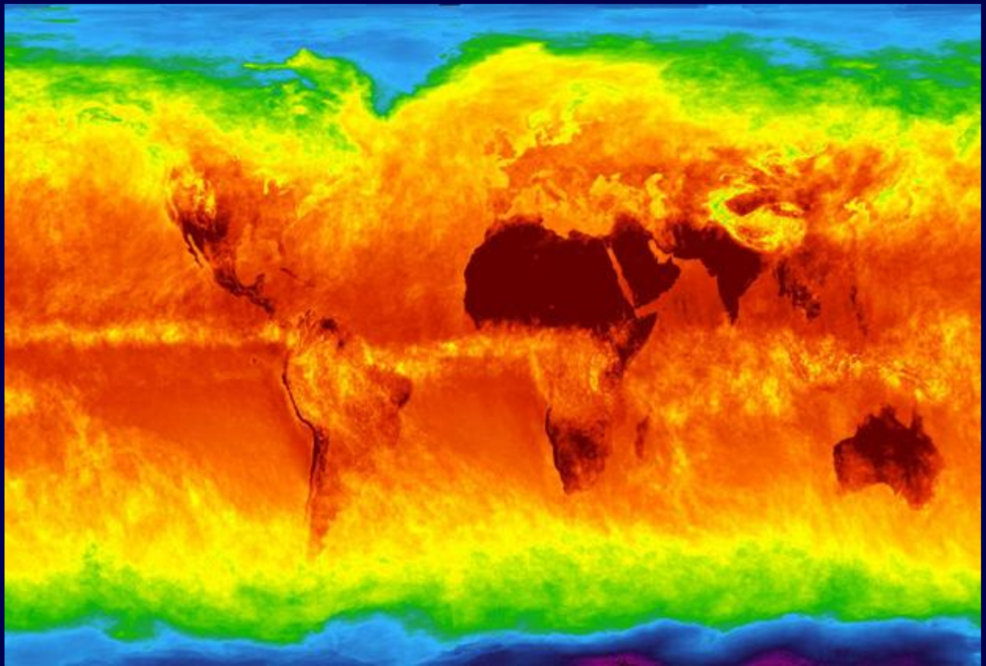
The lower the heat capacity, the quicker the response to a transfer of heat into the substance!

Q4 – As global warming is occurring we will be able to detect it FIRST where?

1 = the ocean temperature

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

3 = actually, they will both heat up at the same rate



Map of global surface temperatures

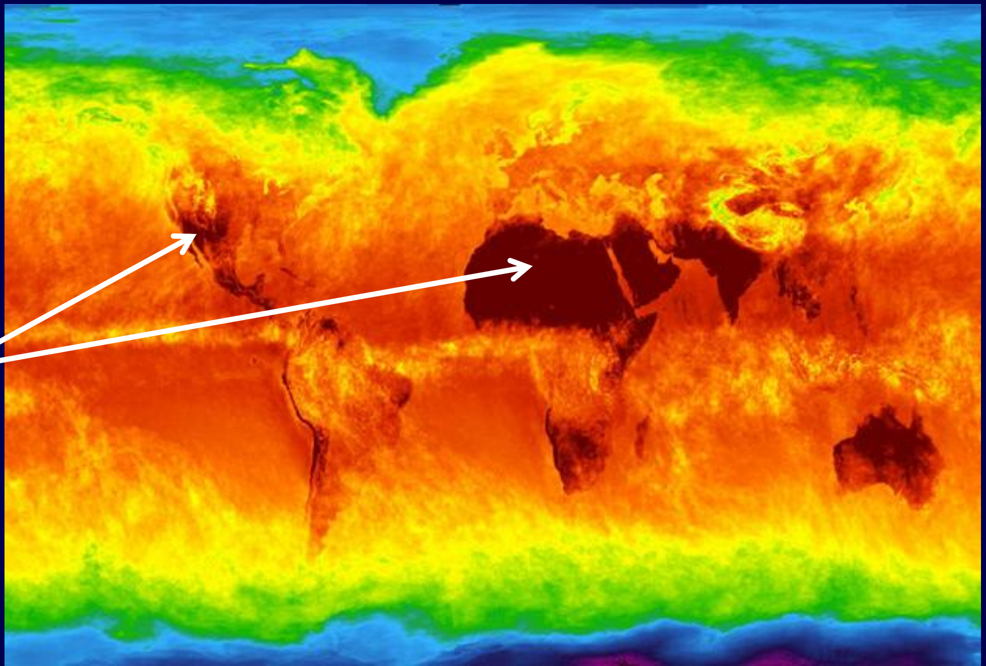
Q4 – As global warming is occurring we will be able to detect it FIRST where?

1 = the ocean temperature

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

3 = actually, they will both heat up at the same rate

Note where the hottest temperatures occur



☺

Q5 - Why will he burn his tongue, even if the pie 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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Q6 - 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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One last quick review point . . . .

Heat generally causes ***EXPANSION*** of a substance.

WHY?

When the temperature of the substance increases:

-- the molecules jiggle faster
-- more energetic collisions occur between the molecules
-- molecules are forced to move farther apart
-- thereby expanding the substance and making it LESS DENSE.

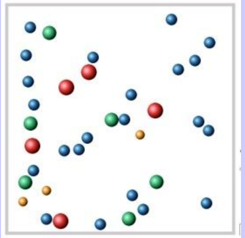
p 46

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

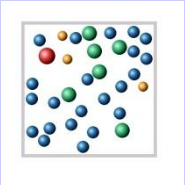
Likewise, cold air is more dense than hot air & tends to SINK

These thermal differences play an important role in driving ATMOSPHERIC CIRCULATION, WEATHER & GLOBAL CLIMATE PATTERNS . . . . .

HOT



COLD

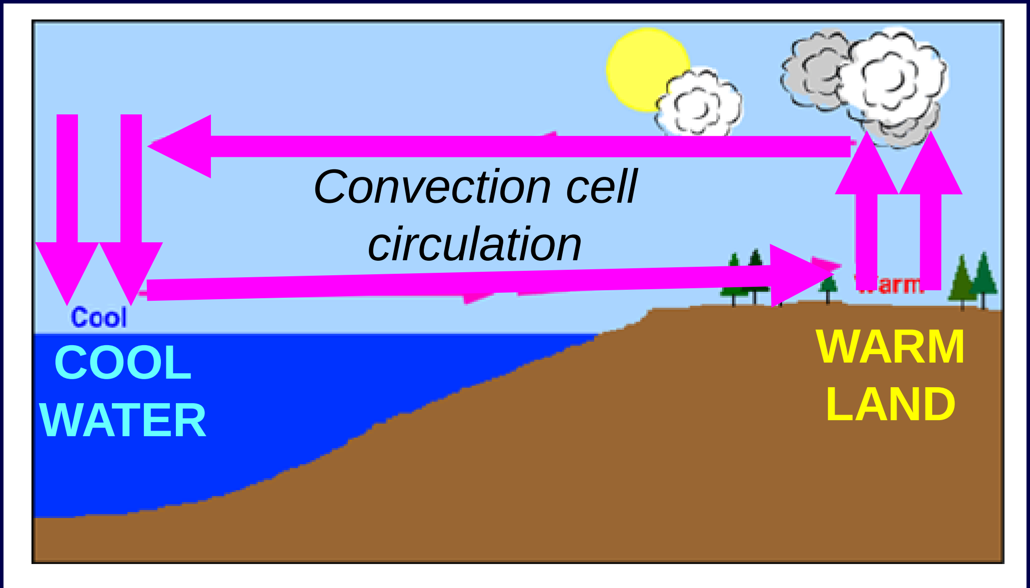


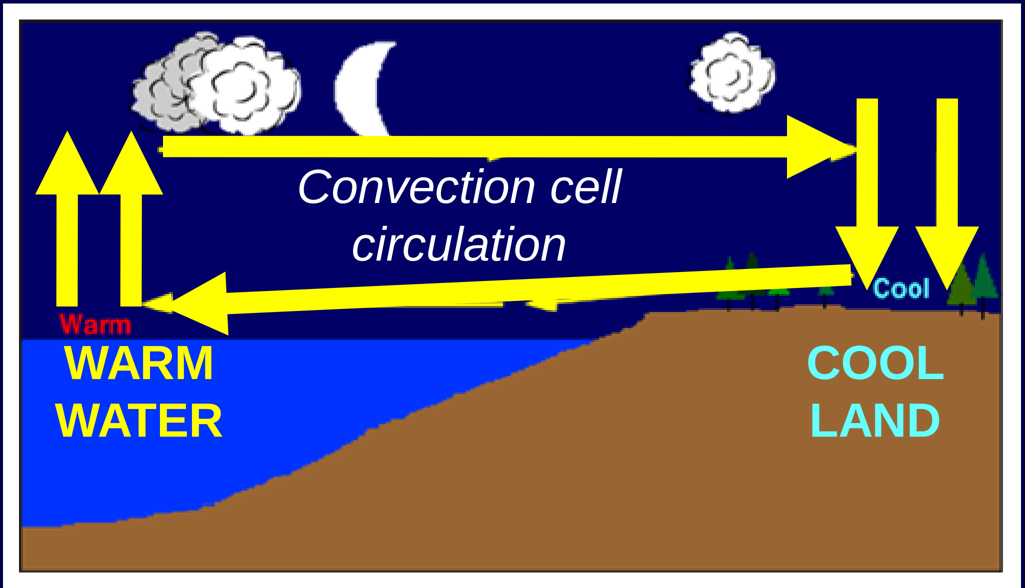
Example: **Sea Breeze & Land Breeze**

Thermally driven density differences of air

+ differences in the specific heat / heat capacity of LAND vs. WATER

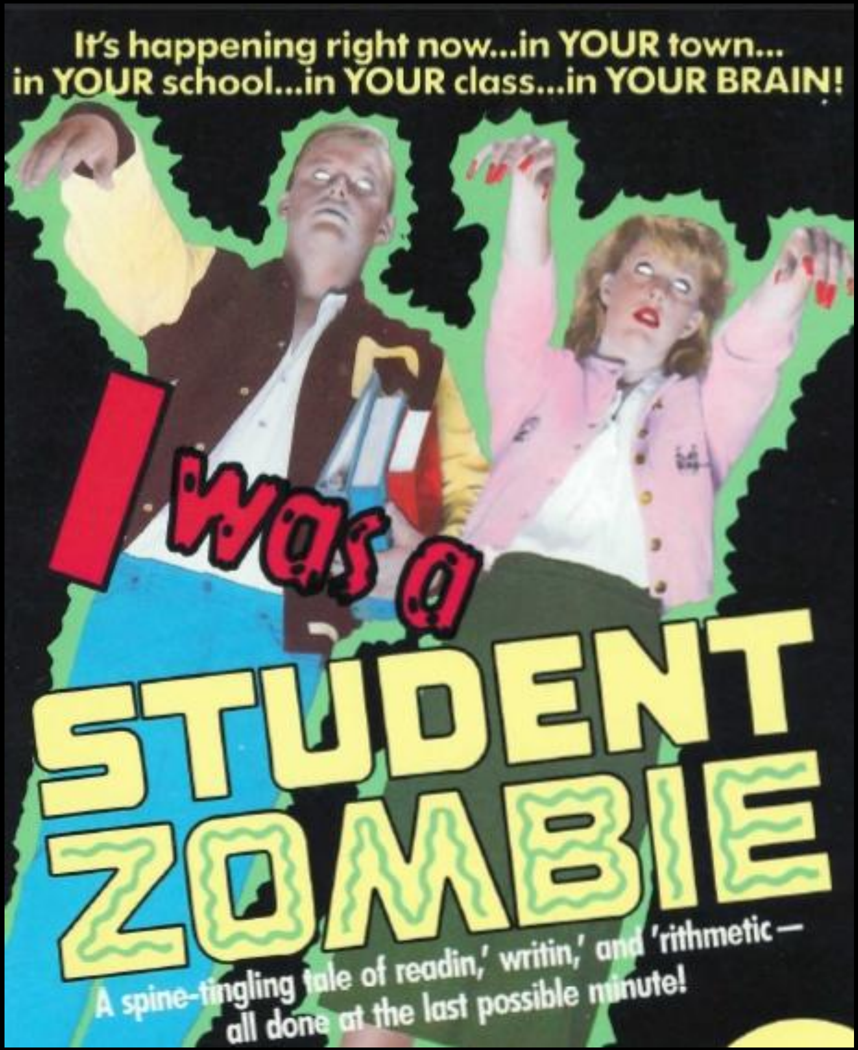
➔ atmospheric circulation





On large continental scale = MONSOON CIRCULATION!

Got all that Homer?



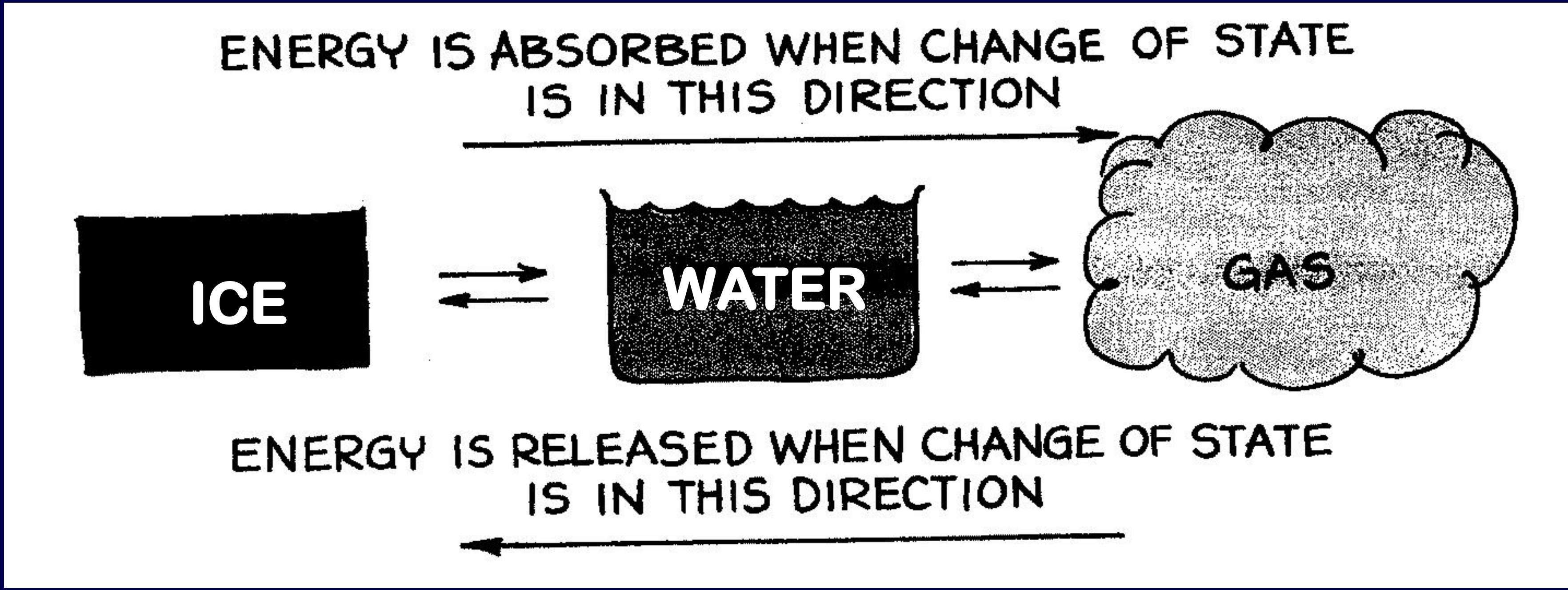
ZOMBIE BREAK !

Ready for some more SCIENCE Homer?

(Homer gives his brain a pep talk)

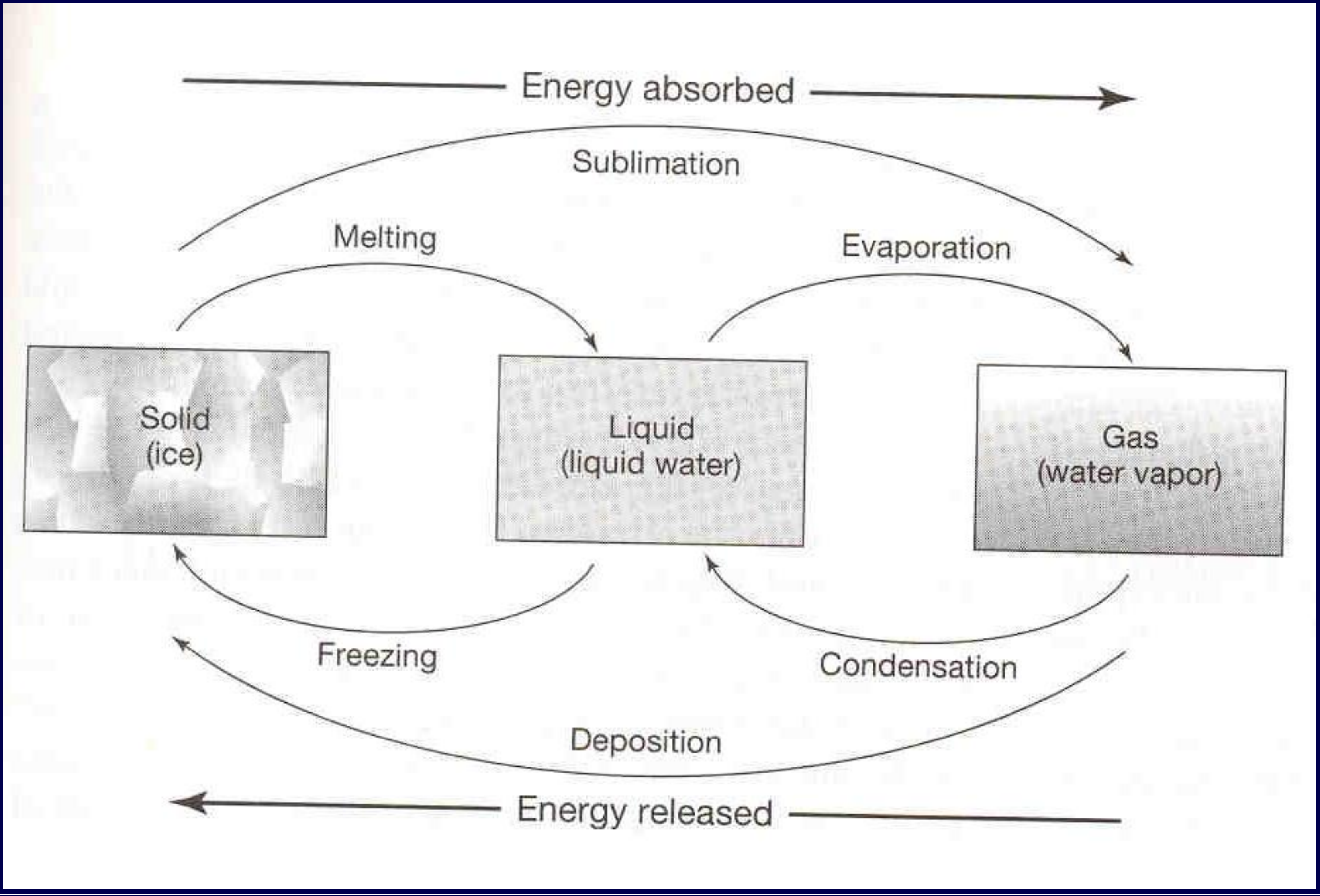
THERMAL ENERGY & PHASE CHANGES IN H_2O

Energy stored as LATENT ENERGY
(energy is "hidden" & not sensed)



Energy released as SENSIBLE HEAT
(i.e. the warmth can be "sensed")

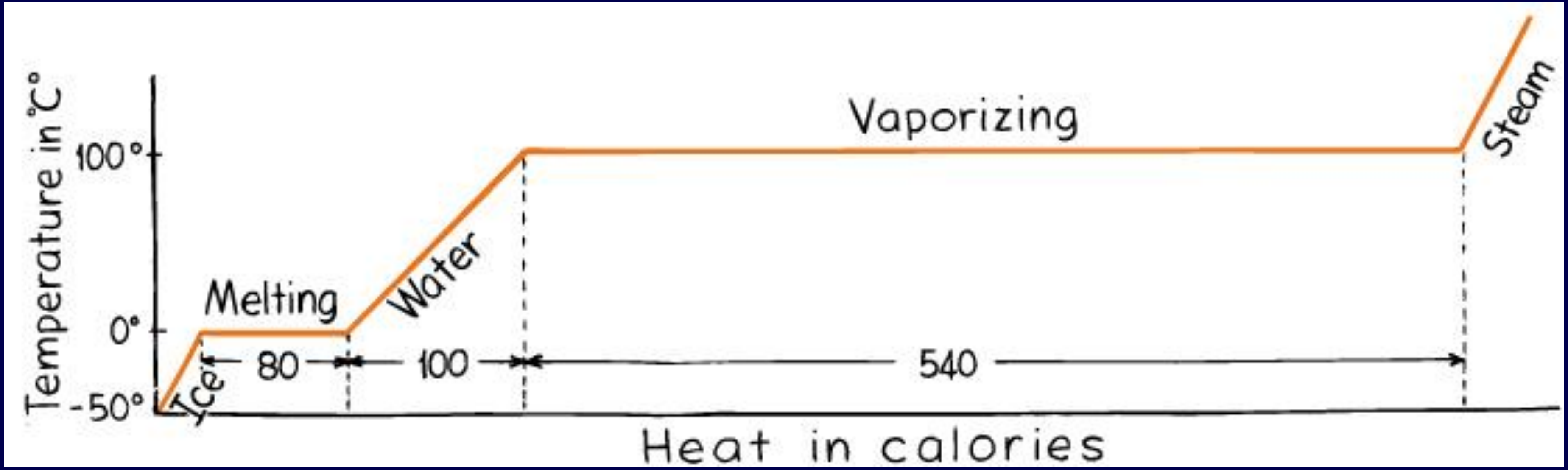
PHASE CHANGES (another view)



This is in your textbook: Fig 4-23 p 76 in SGC- I text

THOUGHT QUESTION:

In this graph, what's happening to the energy in the portions where the graph is <u>horizontal</u>?



HINT: it has to do with

SENSIBLE HEAT (H)

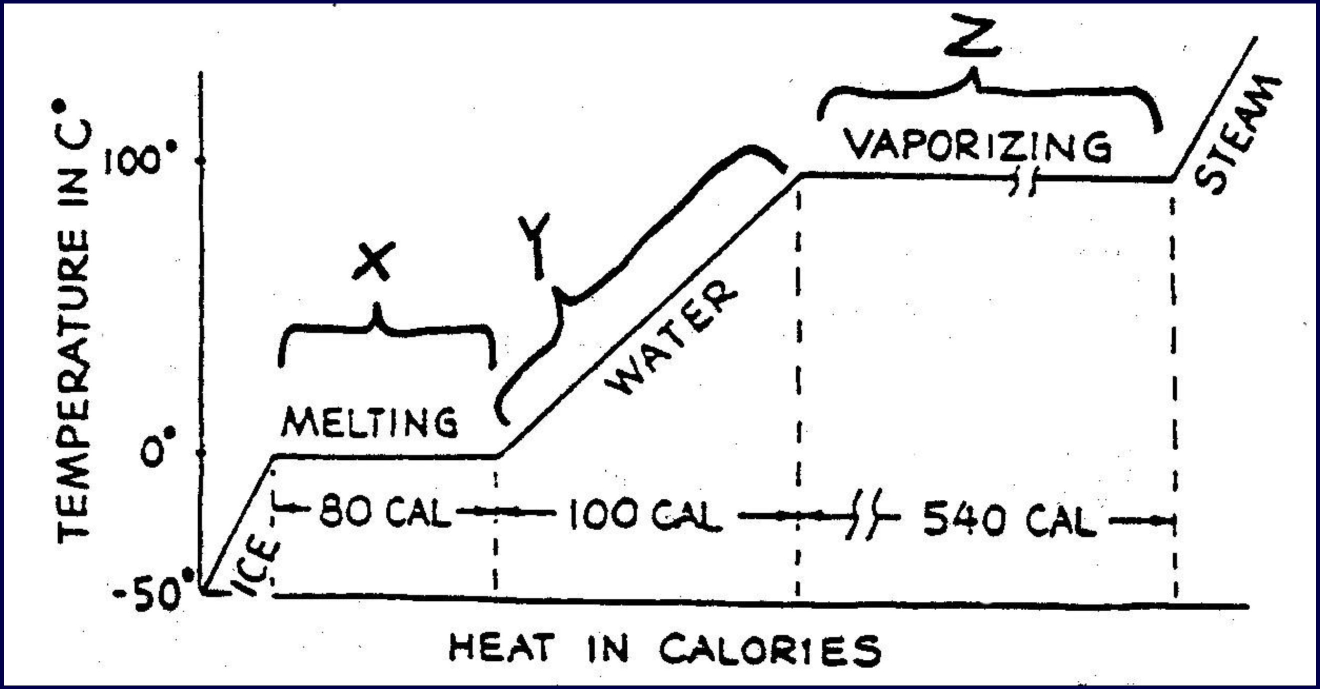
&

LATENT HEAT (LATENT ENERGY) LE

REVIEW / BACKGROUND:

SENSIBLE = the energy can be SENSED
(e.g., with a thermometer,
by the environment, etc.)

LATENT (means "HIDDEN") = the
energy is there, but it is <u>NOT
SENSED</u> by the environment,
a thermometer . . . or YOU!



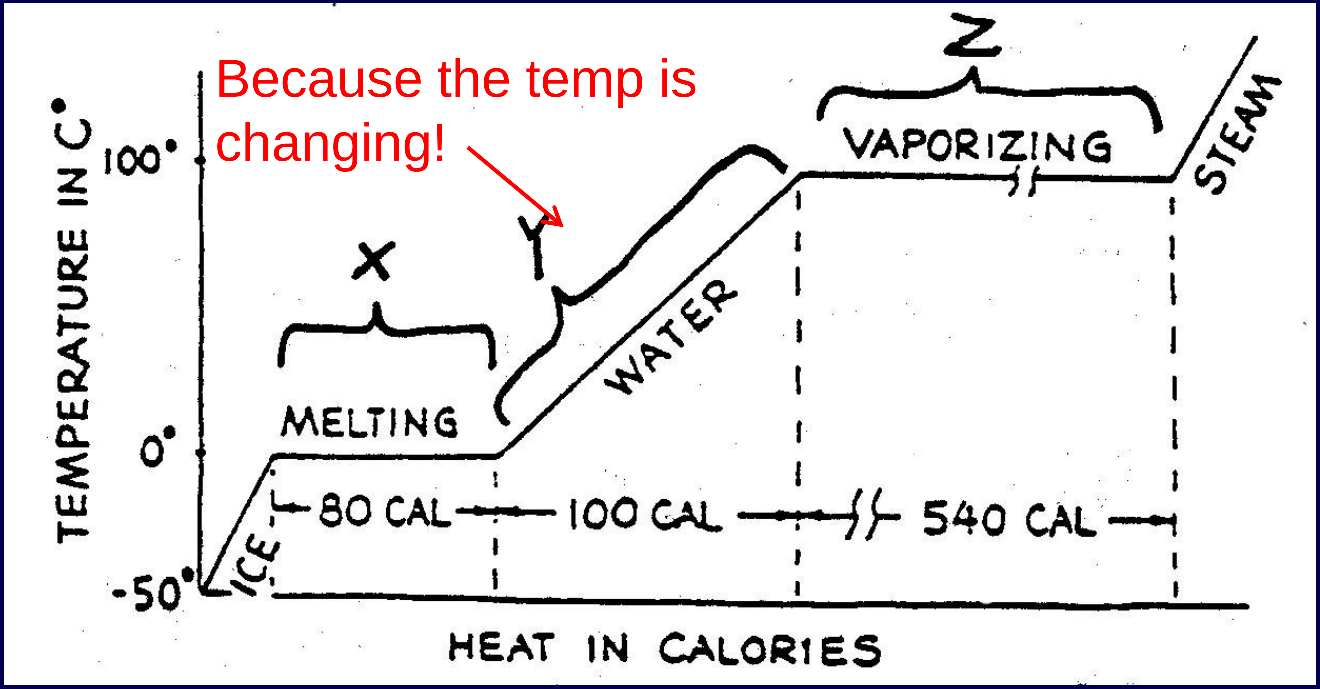
Q7 -- Which segment or segments of the graph represent(s) **SENSIBLE HEAT (H)** ?

1 = X & Z

3 = Y only

2 = X only

4 = Z only



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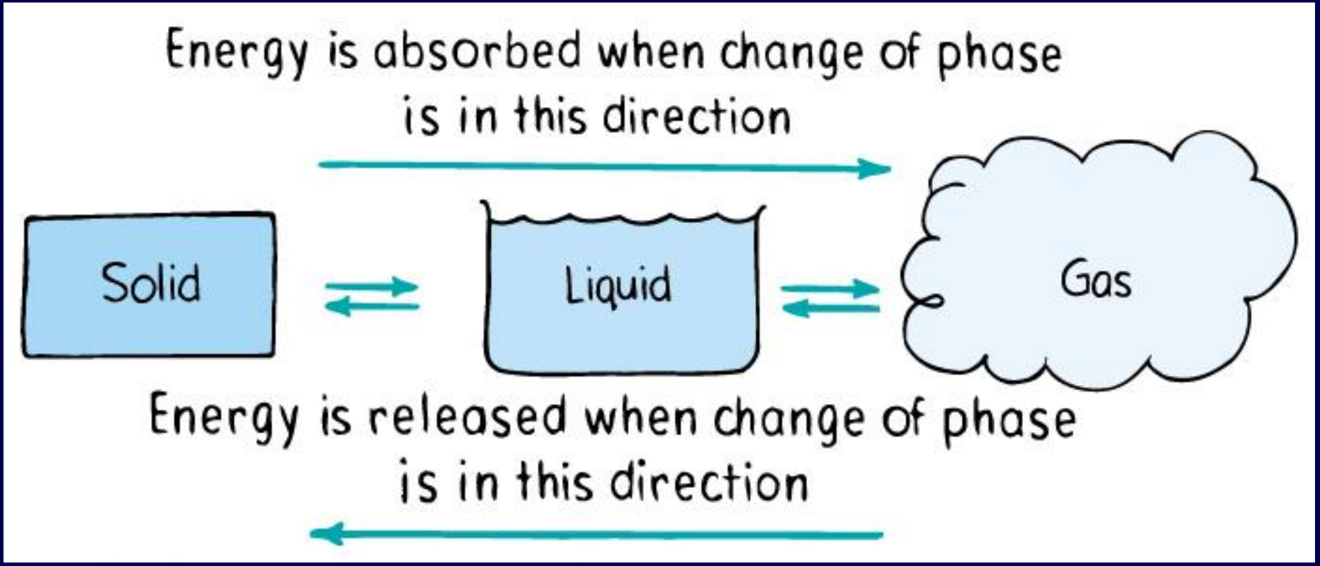
Q8 - In a phase change from ice to water or water to water vapor, <u>WHAT</u> is absorbing the energy?

1 = the surrounding environment

2 = the H_2O molecules

3 = both the environment & the H_2O



p 46

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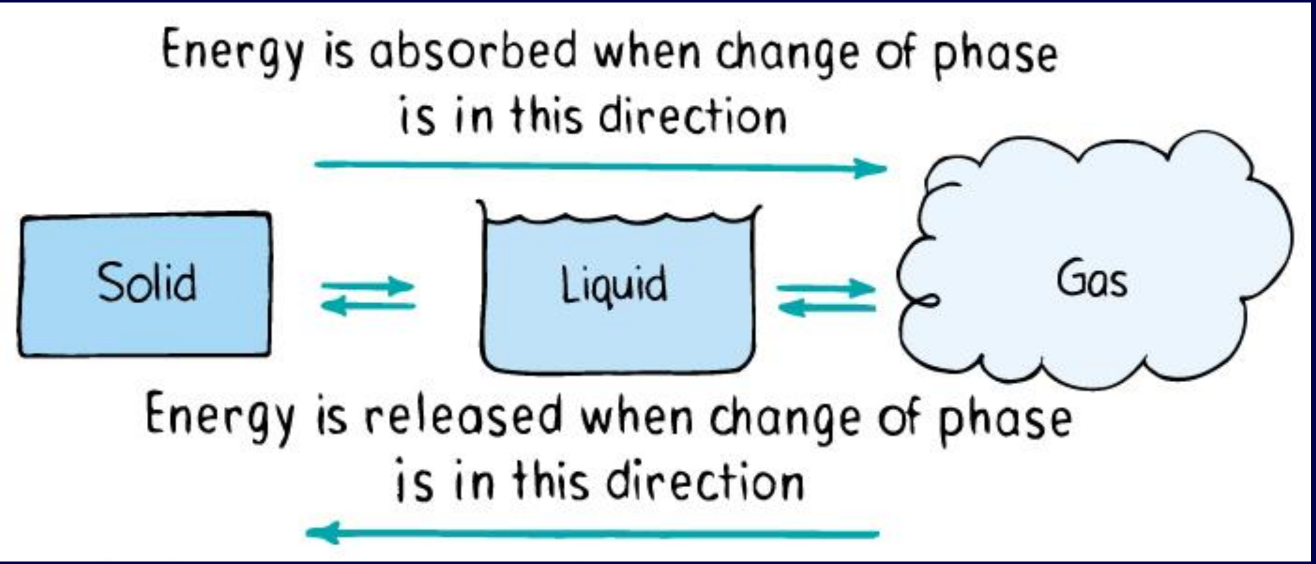

p 46

Q9 - In a phase change from water vapor to liquid water or liquid water to ice, TO WHERE is the energy being released?

1 = into the surrounding environment

2 = into the H_2O molecules

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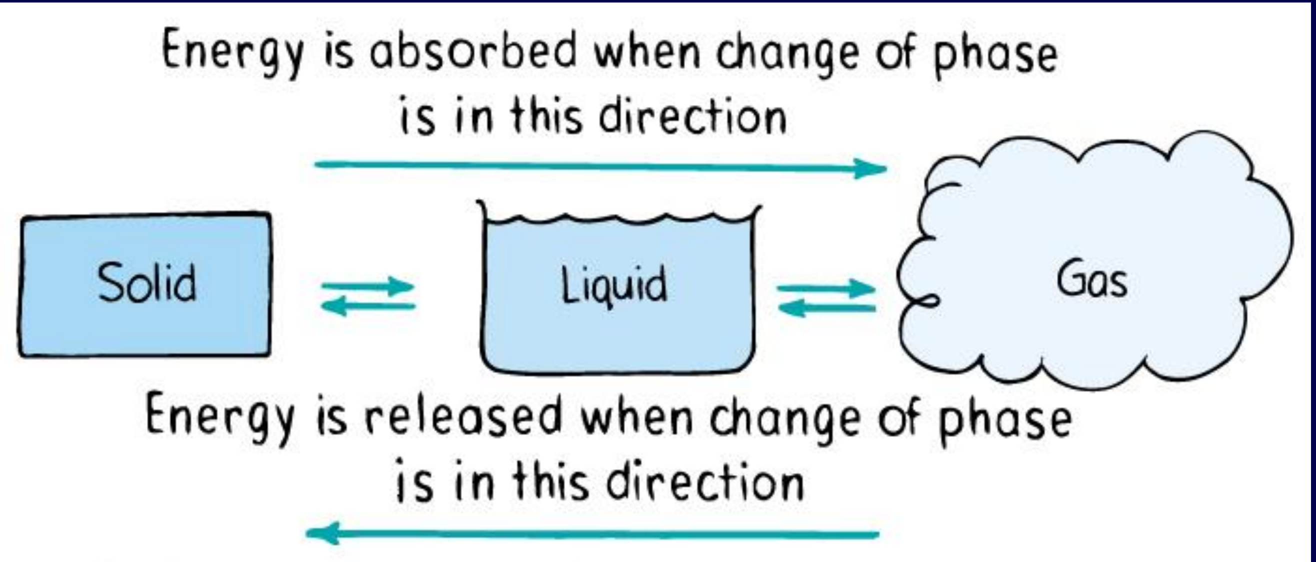

p 46

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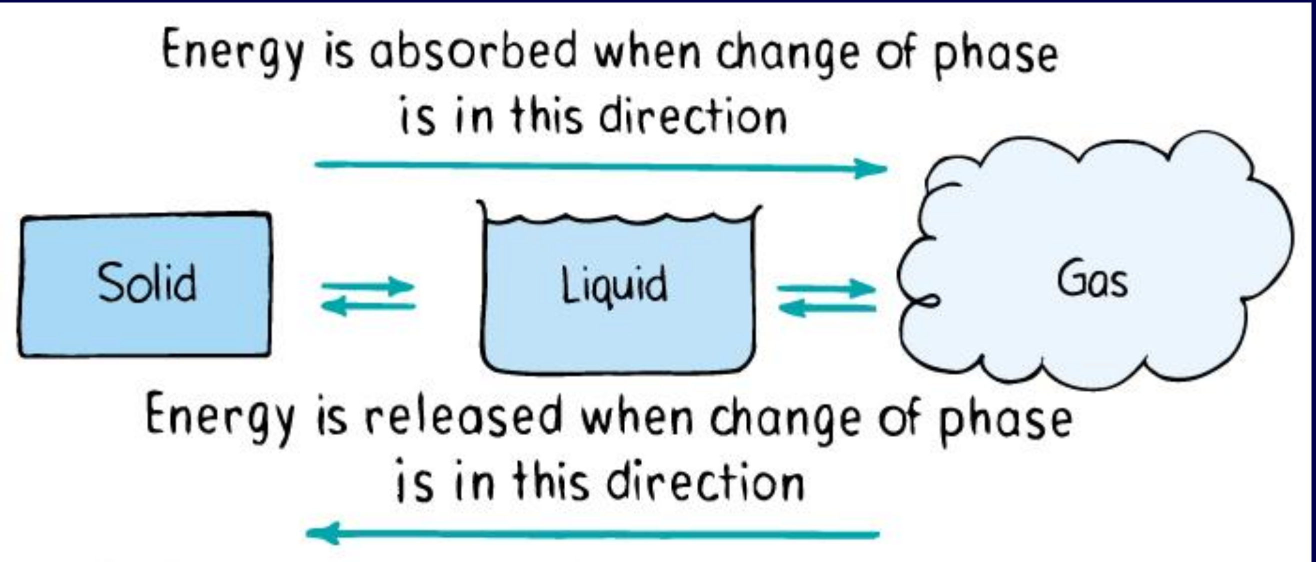
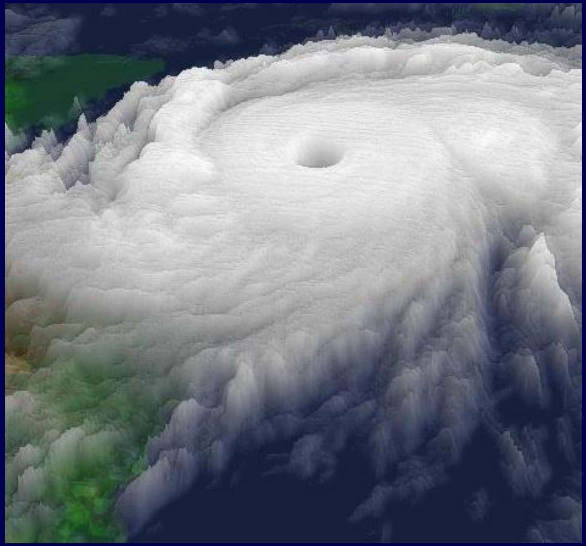
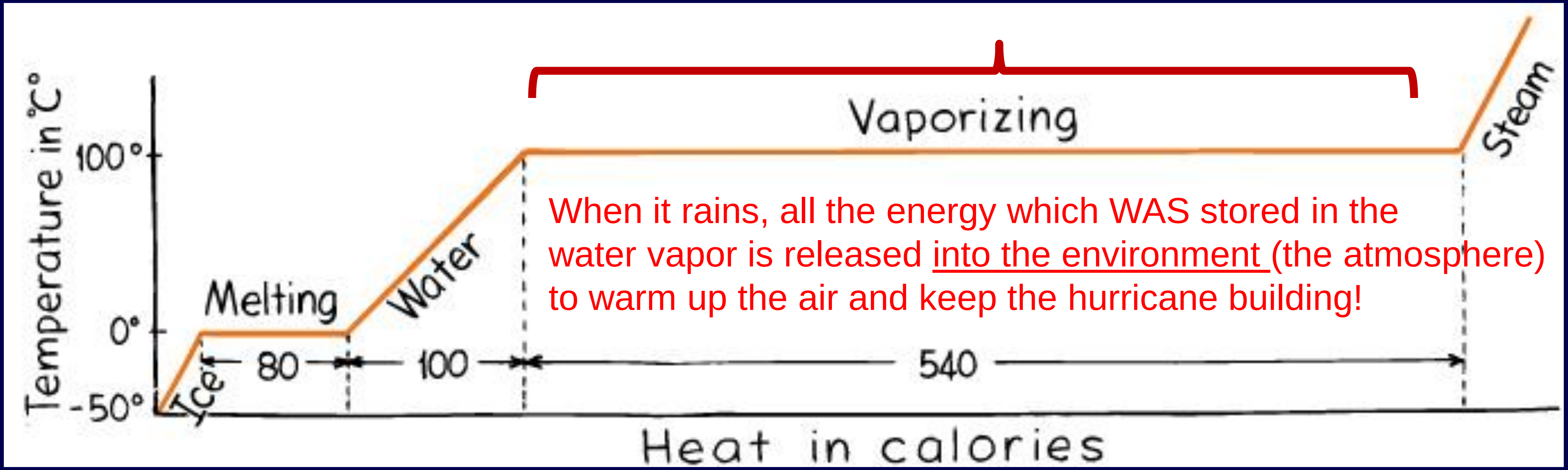


p 46

This is what drives tropical storms & HURRICANES!!





THERMAL ENERGY TRANSFER

(aka "Heat Transfer")

CONDUCTION = passage of thermal energy through a body **without large-scale movement** of matter within the body. Most effective in SOLIDS.

CONVECTION = passage of thermal energy through a fluid (liquid or gas) **by means of large-scale movements** of material within the fluid, as in a convection cell. Most effective in GASES & LIQUIDS.

RADIATION = the transfer of thermal energy by ***electromagnetic radiation*****.** The only one of the three mechanisms of heat transfer that does not require atoms or molecules to facilitate the transfer process, i.e., **does not even need MATTER as a medium to transfer energy!**

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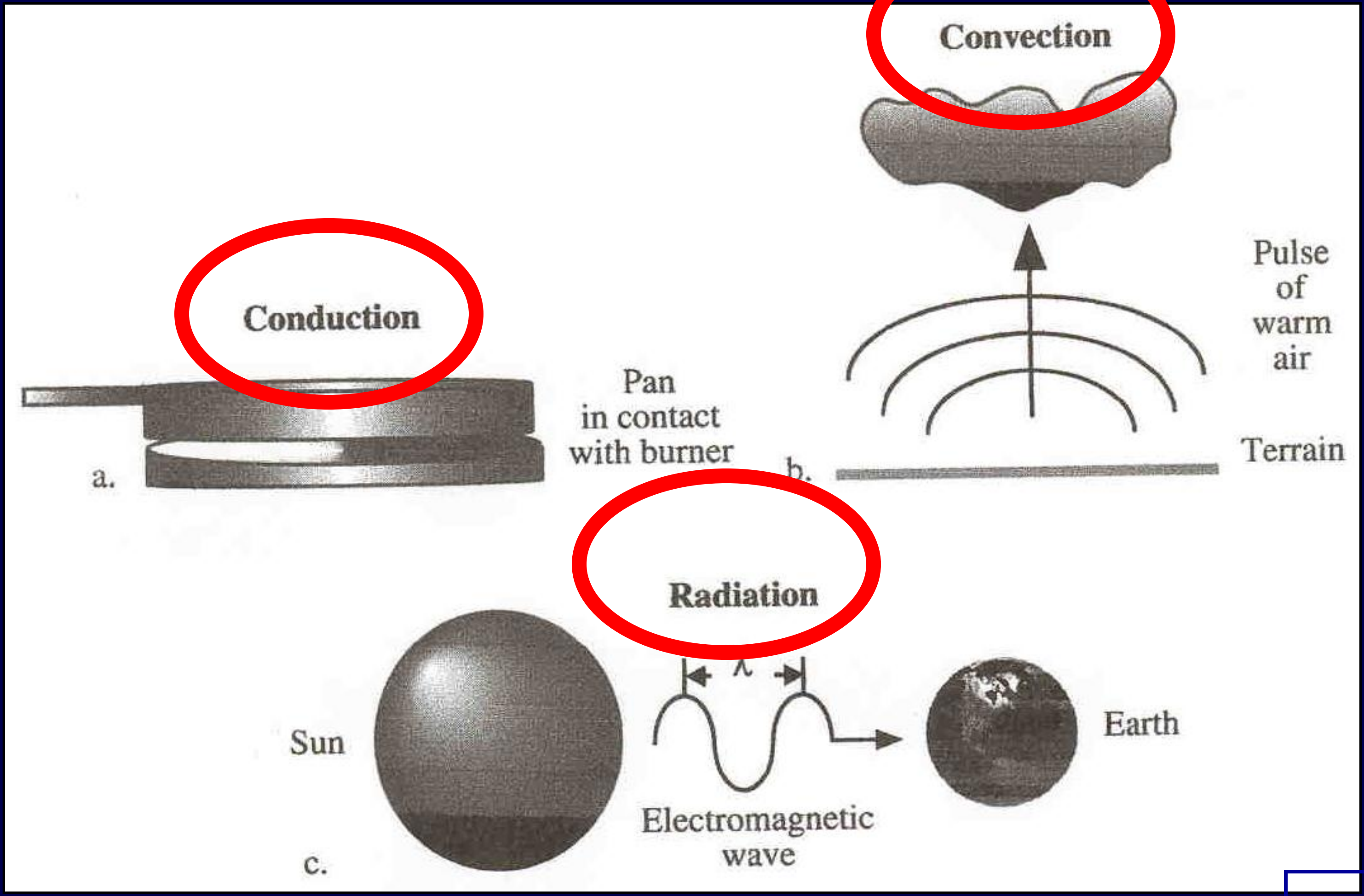
HEAT TRANSFER = the process by which thermal energy moves from one place to another



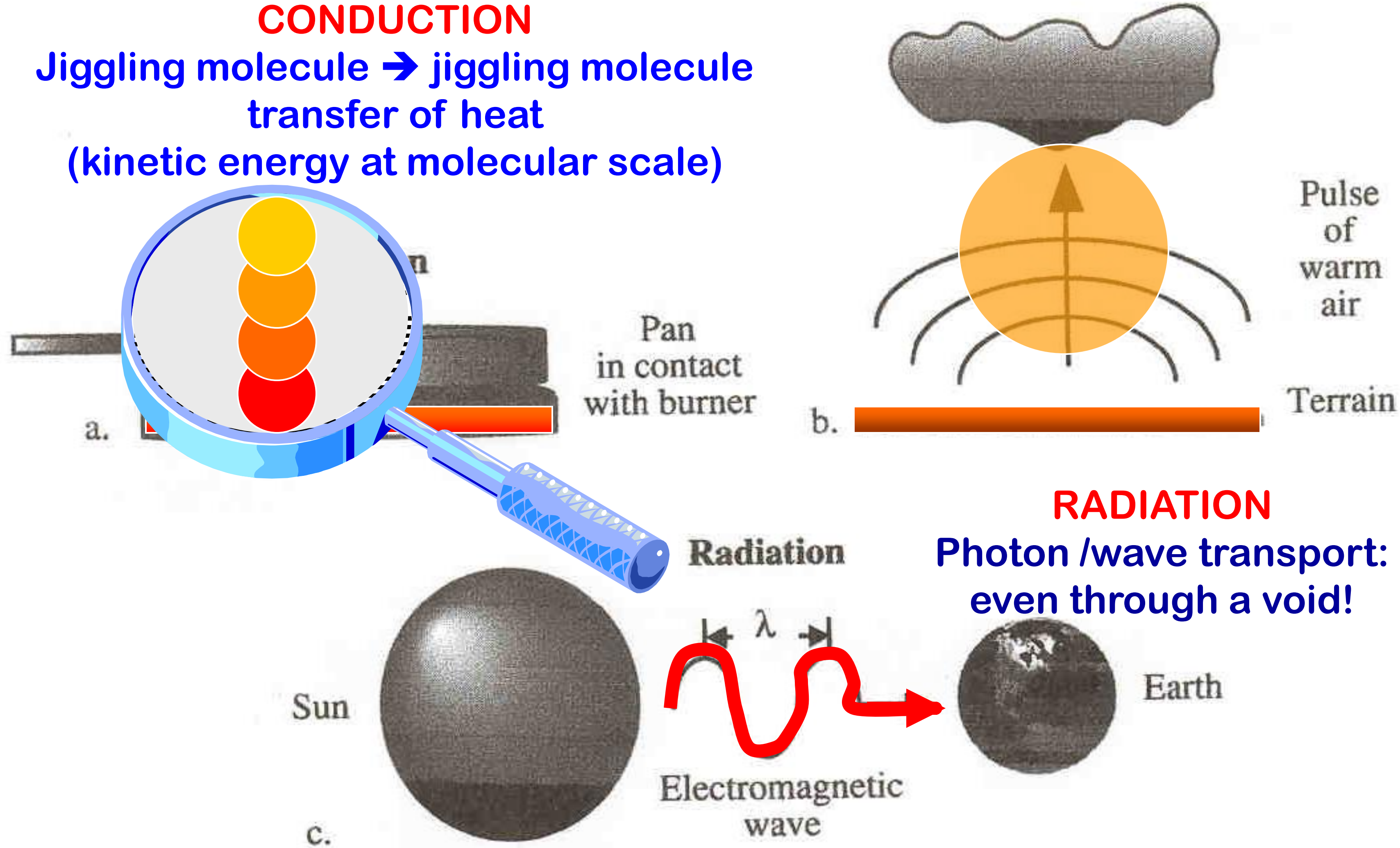
CONVECTION

Mass of warm air or liquid heats, expands, rises

CONDUCTION

Jiggling molecule → jiggling molecule transfer of heat

(kinetic energy at molecular scale)



RADIATION

Photon /wave transport: even through a void!

Electromagnetic Radiation
(a KEY POINT about it!)

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.).

SNOOZING?

How about some practice questions

for TEST #2, Homer?

Q10 - Which if the following is a **correct** statement about the Radiation Law represented by this equation: $\mathbf{E = \sigma T^4}$

1. This equation, referred to as the **Stefan-Boltzmann Law**, can be used to compute how much radiant **energy** (or energy flux) a body -- such as the Earth -- will emit, if the body's **temperature** is known.

2. This equation, referred to as **Wein's Law** states that the **hotter** the temperature of a body, the **longer** the **wavelength** of maximum emission of radiation

3. This equation, referred to as the **Planck function**, can be used to determine what the shape of a **blackbody** curve will be for a body of **wavelength** $= \sigma$

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Q11 -The “**Goldilocks Problem**” refers to the question: “Why is Venus too hot, Mars too cold, and Earth’s temperature just right!” Your textbook explains that . . .

1. Earth's temperature is "just right" because Earth has a **greenhouse effect** and Venus and Mars do not.

2. Earth's temperature is "just right" due to: (a) **the inverse-square law** (the Earth being just the right distance from the Sun), (b) the **greenhouse effect,** and (c) **the Earth’s reflectivity** – all working together

3. Earth's temperature is "just right" because the Earth radiates like a black body and is just the right distance from the Sun – Mars is too close & Venus too far.

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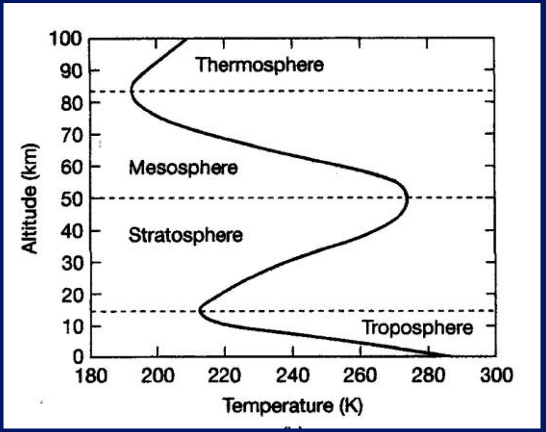
Q 12 The atmospheric layer of **the troposphere** is important to global climate change because:



1. it is the layer that is heated up **primarily** by gases that can absorb high-energy **shortwave radiation** coming in directly from the Sun

2. it is the layer in which **temperature INCREASES with altitude** in the atmosphere

3. it is the layer with a high concentration of **ozone** that absorbs harmful **ultraviolet radiation**.

4. it is the layer in which most of the absorption by **greenhouse gases** occurs in the atmosphere

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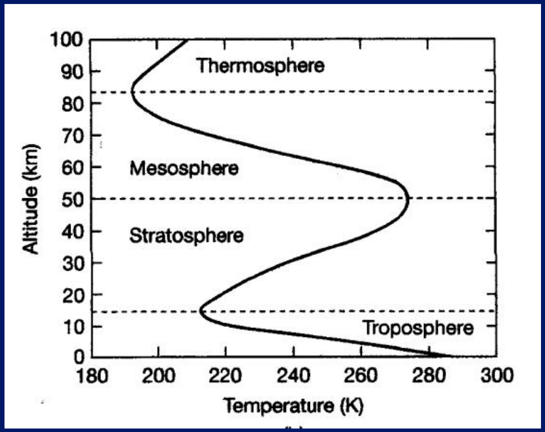

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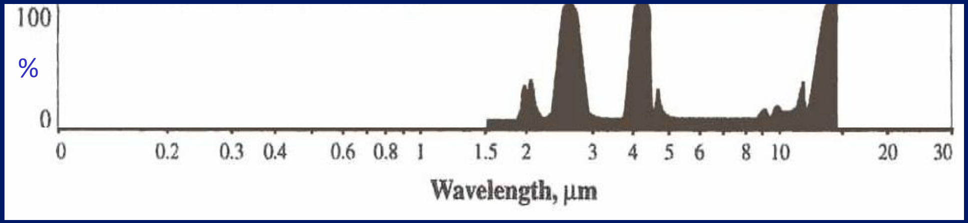
Q13 - Which of the following is a correct statement about this absorption curve:



1. the curve represents absorption by a gas that can absorb both **visible light** and **infrared radiation**

2. **t**he curve represent absorption by a gas that is likely to be a **Greenhouse Gas.**

3. **t**he curve represents absorption by a gas that protects the Earth from **ultraviolet (UV) radiation**

4. **t**he curve represents absorption by a gas that can absorb **ultraviolet, infrared,** & **visible** light wavelengths of radiation.

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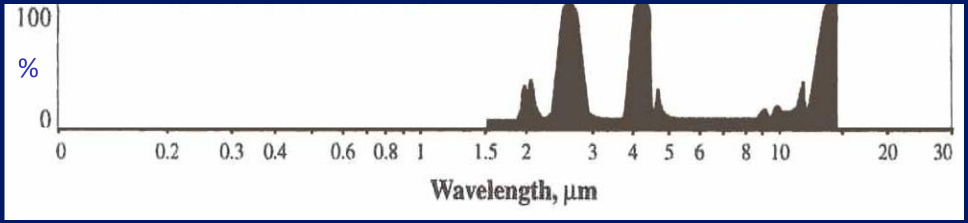

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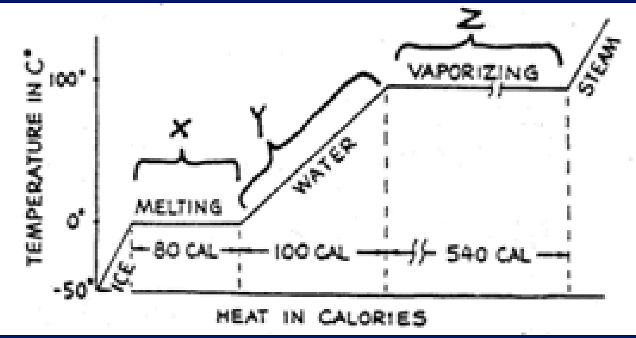
Q14 – Which choice best explains what the graph is illustrating about the energy involved in <u>phase changes (changes of state)</u> in H_2O.



1. **Portion X** of the graph indicates that it takes **<u>much more energy</u>** to create a **phase change from <u>ice to liquid</u>** than it does from liquid to vapor.

2. **Portion Y** of the graph indicates that 100 calories of energy are being added to one gram of H_2O **without changing the temperature** of the H_2O at all. This process produces a **phase change** from ice to vapor.

3. **Portions X and Z** of the graph indicate that **during phase changes**, the calories of energy being added to a gram of H_2O, **do not change the temperature of the H_2O .**

4. **Portion Z** of the graph indicates that as soon as the temperature of H_2O reaches 100 º C, it immediately starts cooling off and condenses into a liquid.

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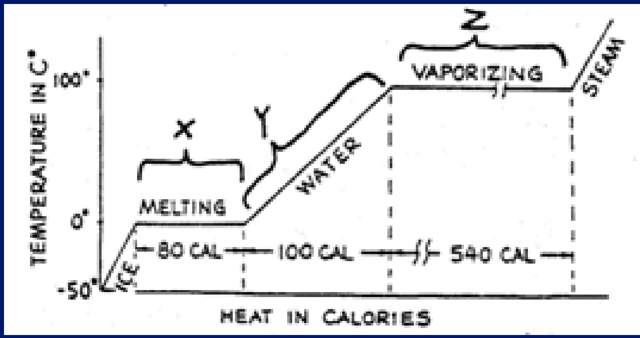

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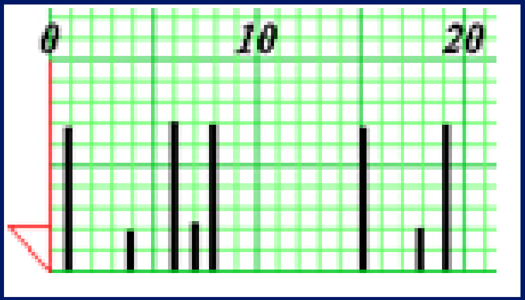
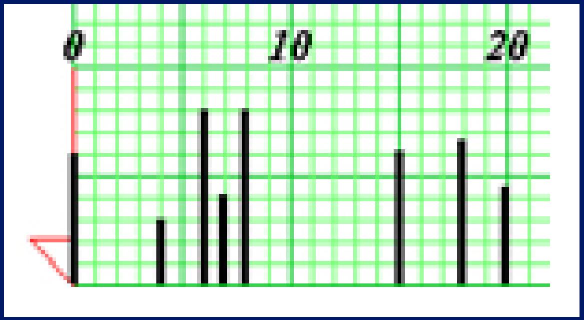
Q15. Which of the skeleton plots below is the <u>best match</u> for this tree-ring core?

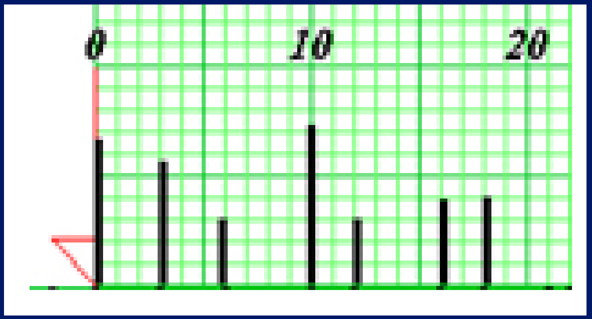
1.



2.



3.



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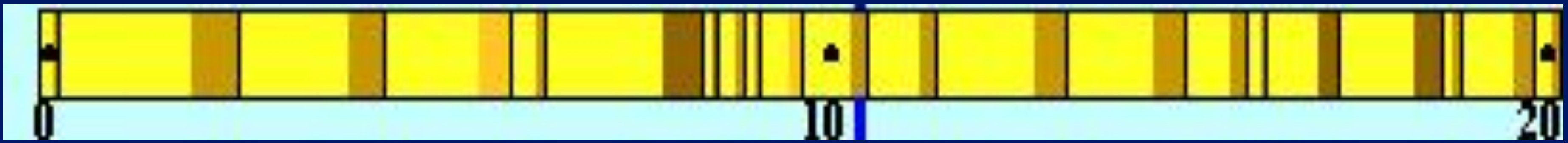

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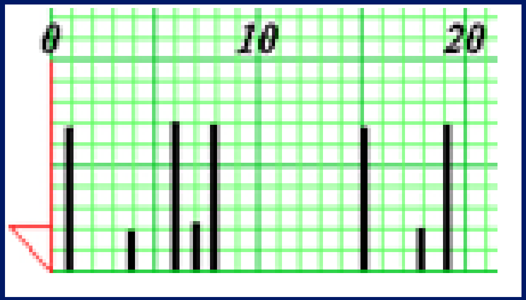

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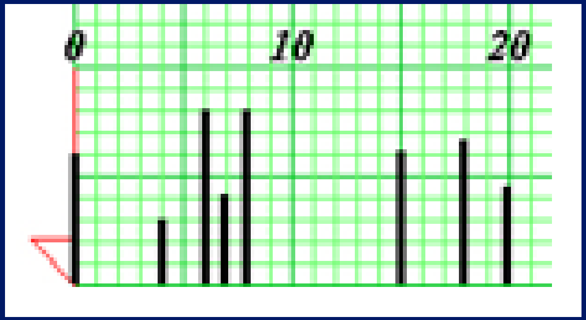

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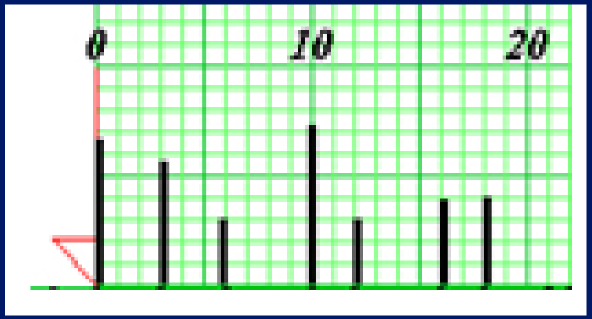

Can I go now????

YES!!

STUDY HARD

FOR TEST #2 !!!