WRAP UP:

TOPIC #7
Atmospheric Structure
& Composition

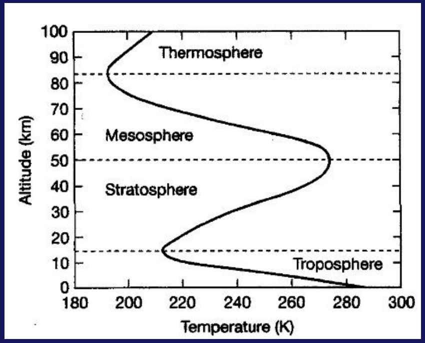
SUMMARY OF KEY CONCEPTS: short version

1. Four gases N_2, O_2, Ar, & CO_2 comprise about 99% of the volume – but "minor" trace Greenhouse Gases are extremely important. **Which of the 4 is a GHG?**

2. Most of the MASS of the atmosphere is in the bottom few kilometers (i.e. the Toposphere!)

3. Different gases are abundant at certain levels in the atmosphere. The effect of radiation absorbed by these gases is seen in the vertical temperature profile

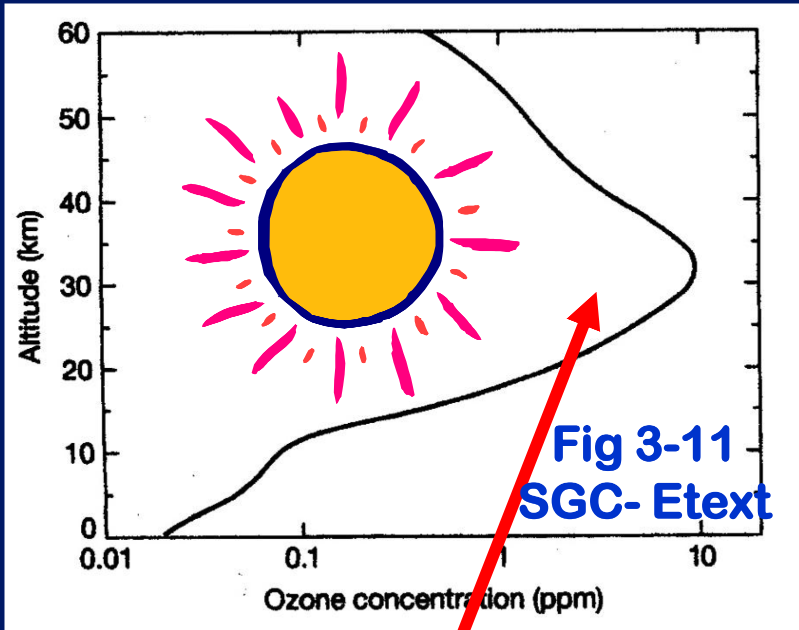
4. . . . which leads to the vertical structure of the atmosphere:

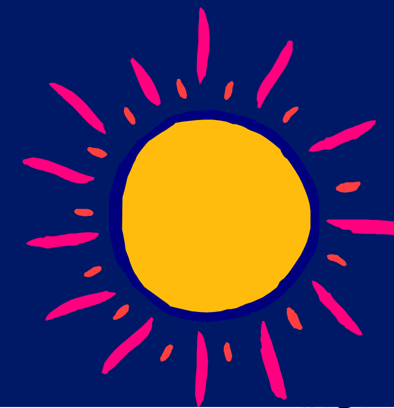


Name that GAS!!!

MYSTERY GHG # 7 was OZONE . . .

OZONE: Sources



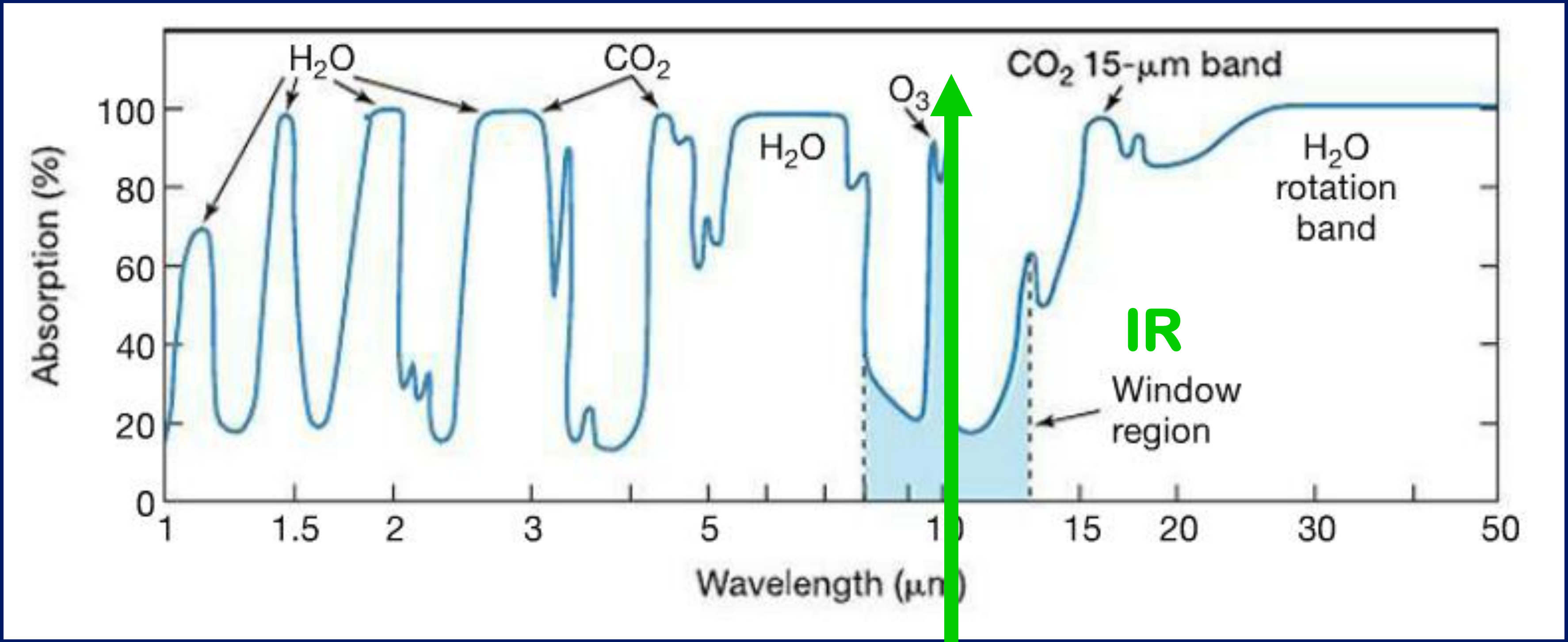


Produced naturally in photochemical reactions in STRATOSPHERIC ozone layer --"good ozone"

Has *increased* in TROPOSPHERE due to photochemical smog reactions -- "bad ozone"

☺ Table on p 40

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



CHAPTER 3 in E-text Fig 3.13

Therefore . . . .

OZONE has a HIGH <u>Global Warming Potential</u>

OZONE has a HIGH Global Warming Potential:

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**

The highest GWPs are linked to gases with:

-- a large infrared absorption ability, and

-- a long atmospheric lifetime.

GLOBAL WARMING POTENTIAL (GWP) of other GHG's

LIFETIME AND GLOBAL WARMING POTENTIAL OF HUMAN-GENERATED GREENHOUSE GASES

Gas	CO_2	CH_4	N_2O	CFC-11	CFC-12	HCFC-22
Lifetime years	Multiple	12	114	45	100	12
Global warming potential calculated over . . .						
20 years	1	72	289	6,730	11,000	5,160
100 years	1	25	298	4,750	10,900	1,810
500 years	1	8	153	1,620	5,200	549

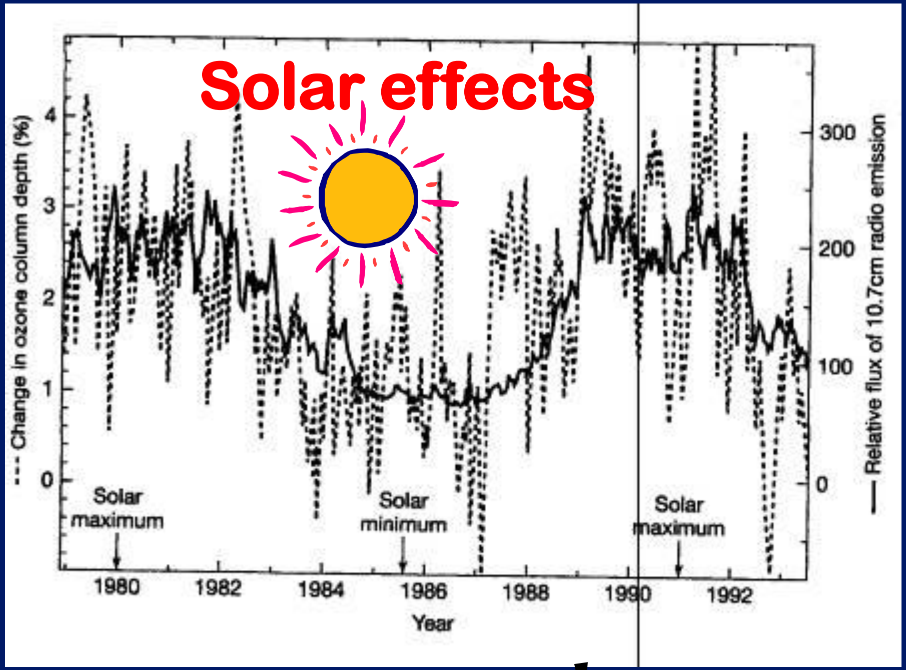
"If you have an equal mass of CO_2 and CH_4, the methane will trap 72 times more heat than the carbon dioxide over the next 20 years"

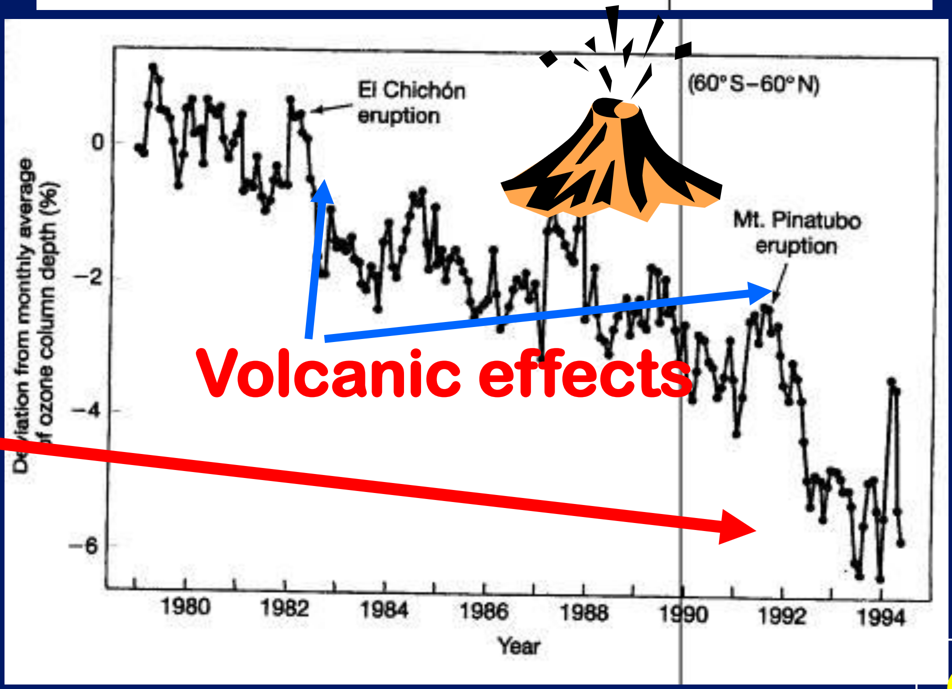
See pp 29-29 in *Dire Predictions*

OZONE:
Trends

•Stratospheric ozone varies by latitude and season -- is affected by:

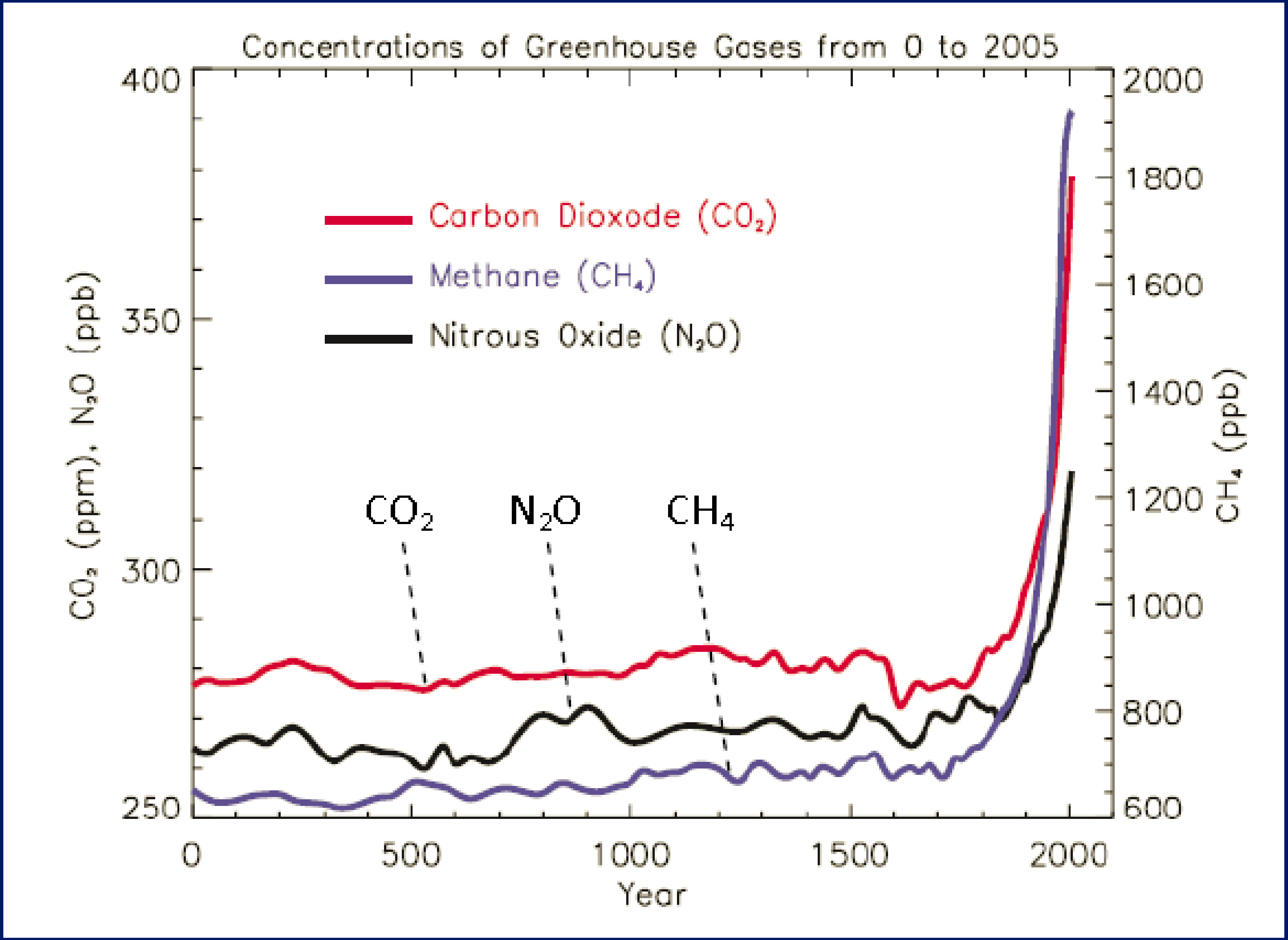
-- SOLAR radiation
-- VOLCANIC eruptions
-- chemical reactions due to CFCs.



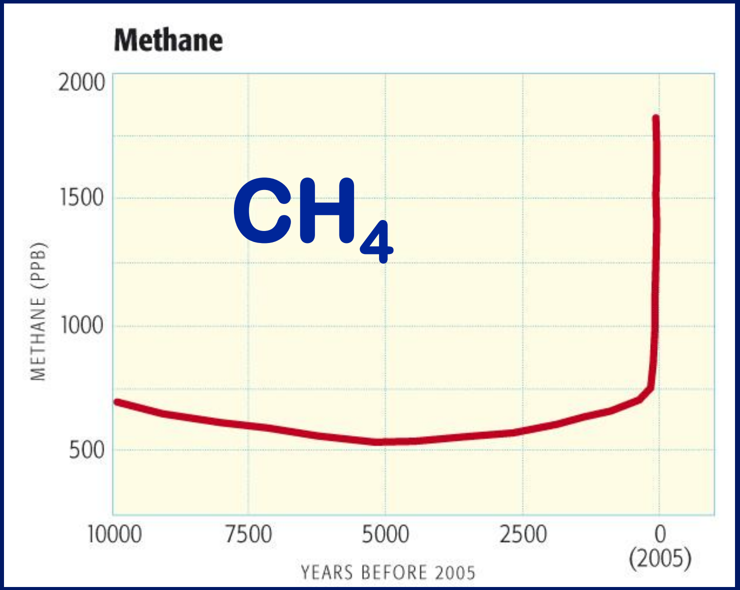


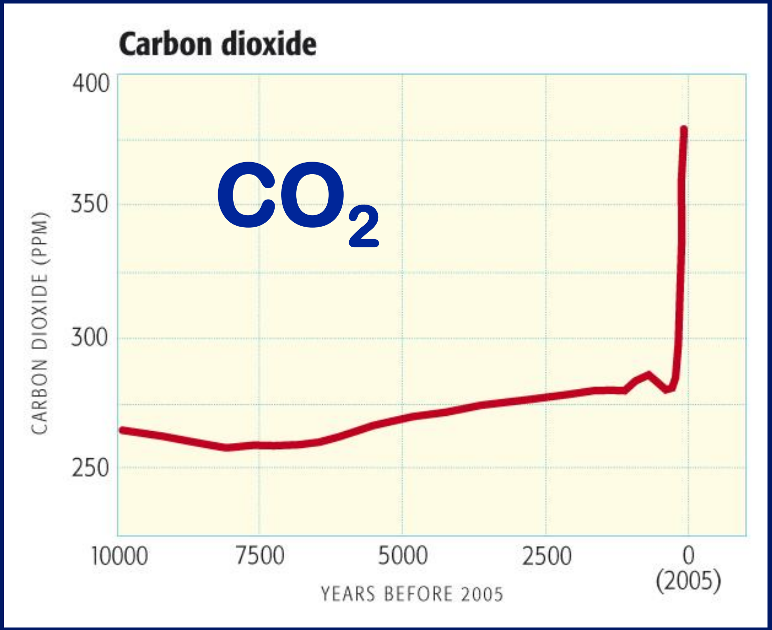
Overall, O3 is decreasing in the STRATOSPHERE

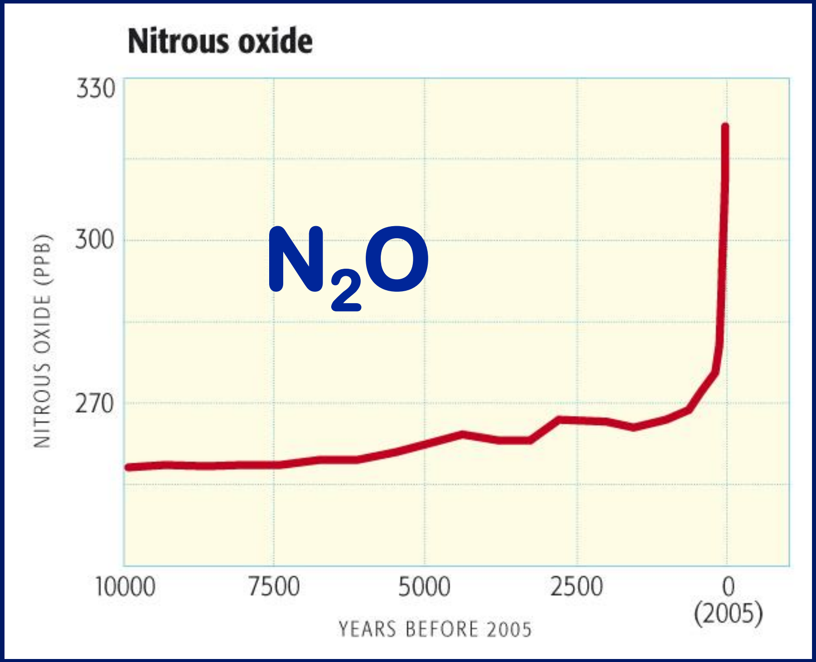
Much more on OZONE later on in the semester!!


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO₂)
Methane (CH₄)
Nitrous Oxide (N₂O)
CO₂
N₂O
CH₄
CO₂ (ppm), N₂O (ppb)
CH₄ (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000

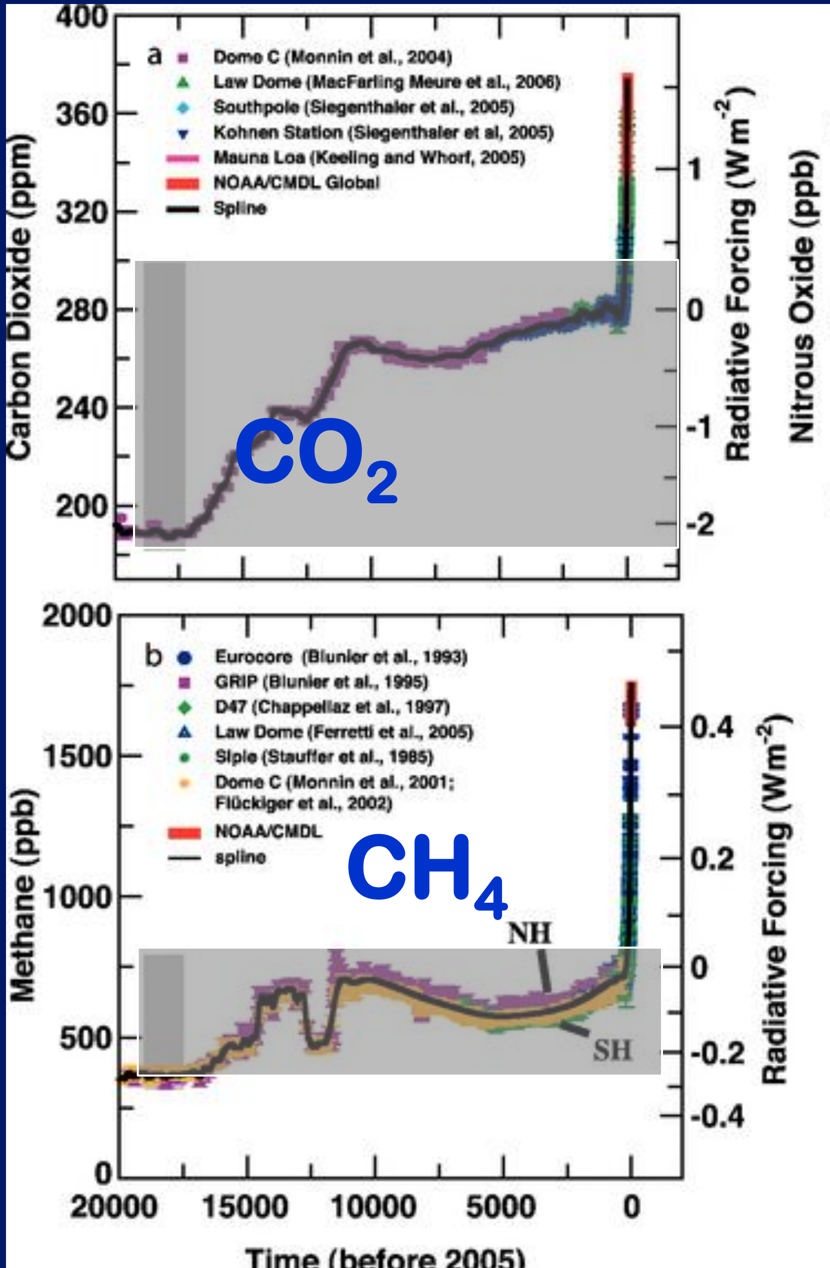
Updated figures from **Dire Predictions** p 33

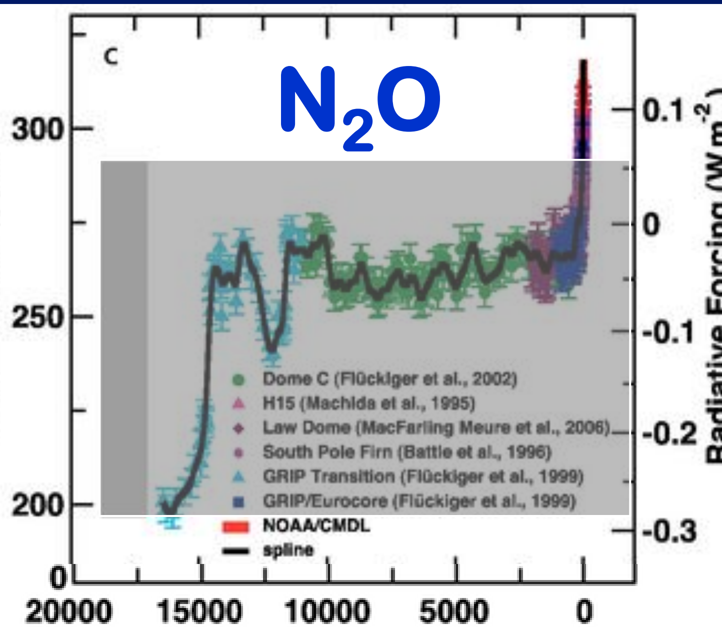






The grey bars show the ranges of ***natural variability*** *for the* ***past 650,000 years!***





These graphs go WAY back in time: 20,000 years ago!

Now on to today’s topic . . . .

TOPIC # 8
LAWS OF THERMODYNAMICS & MOTION: Keys to Energy Transfer & Conservation

The Next Piece in the Puzzle to Understand Global Changes

Featuring . . . .

CLASS NOTES:
pp 43-49

OUR QUOTE OF THE DAY . . .

In this house,
we obey the LAWS of
THERMODYNAMICS!

. . . is from HOMER SIMPSON

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."

☺

Forms of Energy - Review

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

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

review

Thermal Energy

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

the kinetic energy of the molecules in the substance!

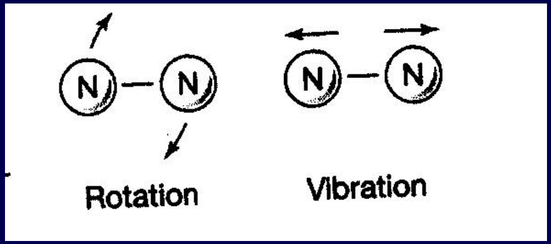
"Internal Energy"

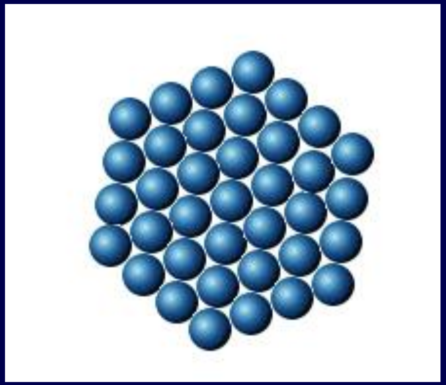
-- specifically: a measure of the quantity of *atomic kinetic & potential energy* contained in every object

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.

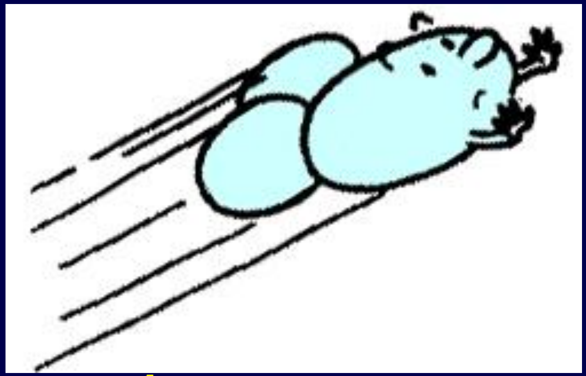




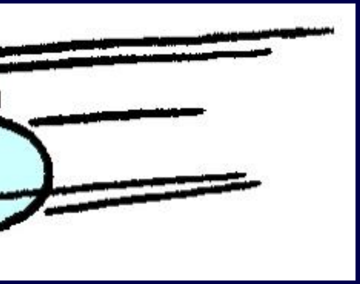
Thermal Energy & Temperature

- ***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).

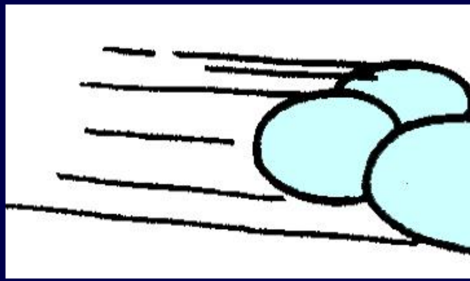
- **Temperature is a measure of the average kinetic energy of each molecule in a body.**

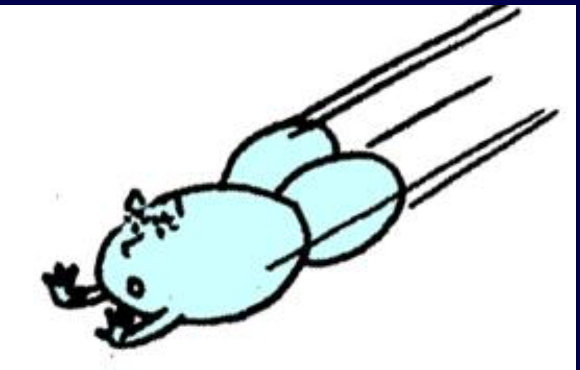


If a body has a high temperature, each of its molecules has, on the average, a large amount of kinetic energy.



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

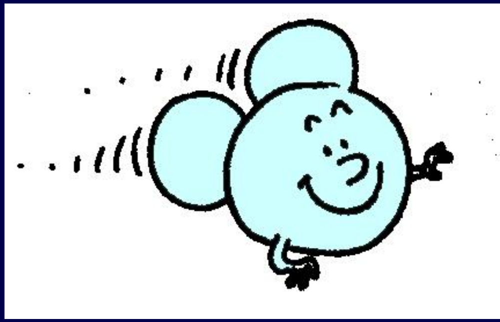




p 43

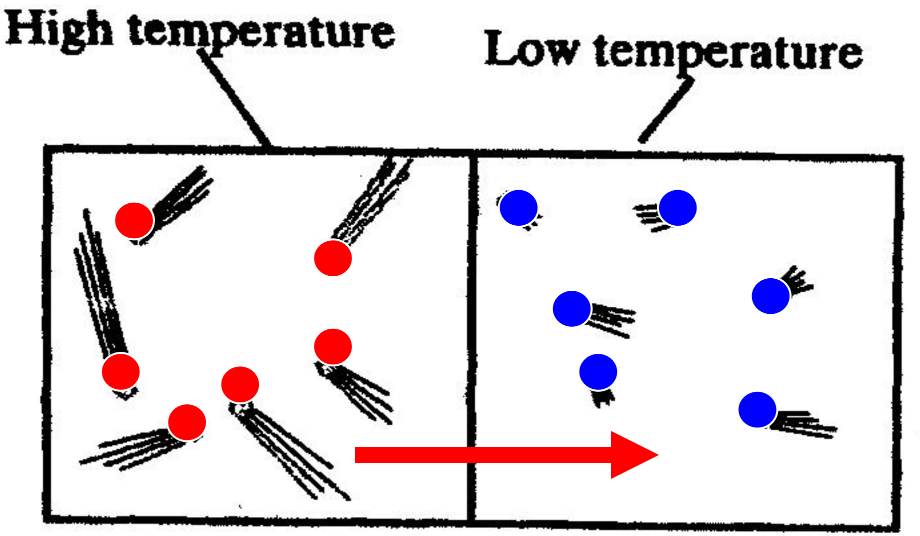
if a body has a low temperature, each molecule on the average has a small amount of kinetic energy.

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)



(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?

Thermal energy flow = HEAT

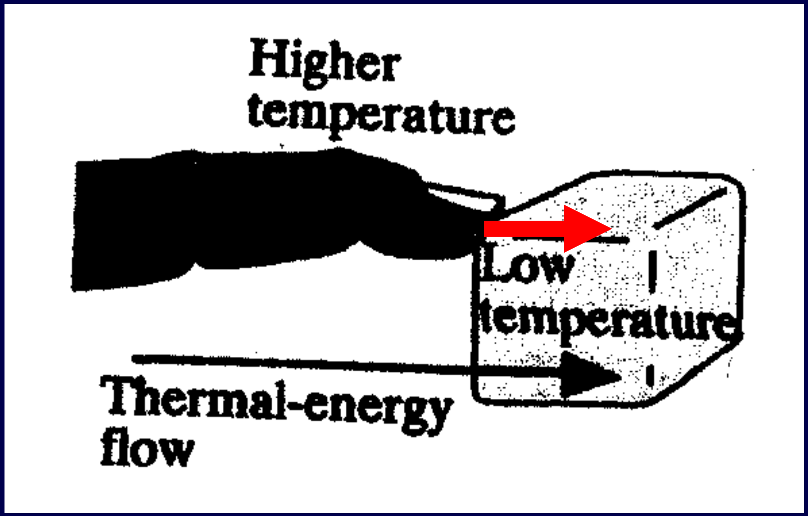
p 43

Thermal Energy vs. Heat

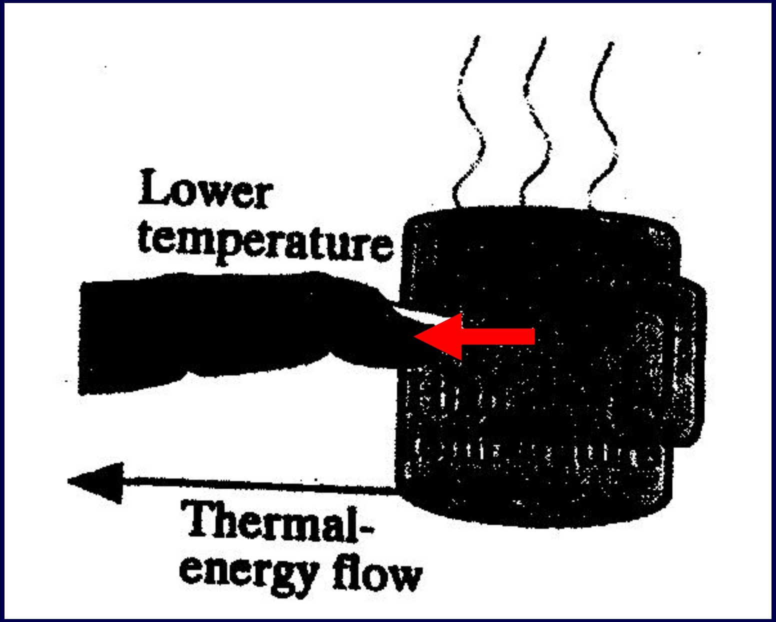
Heat = the thermal energy that is *transferred* from one body to another because of a temperature difference.

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

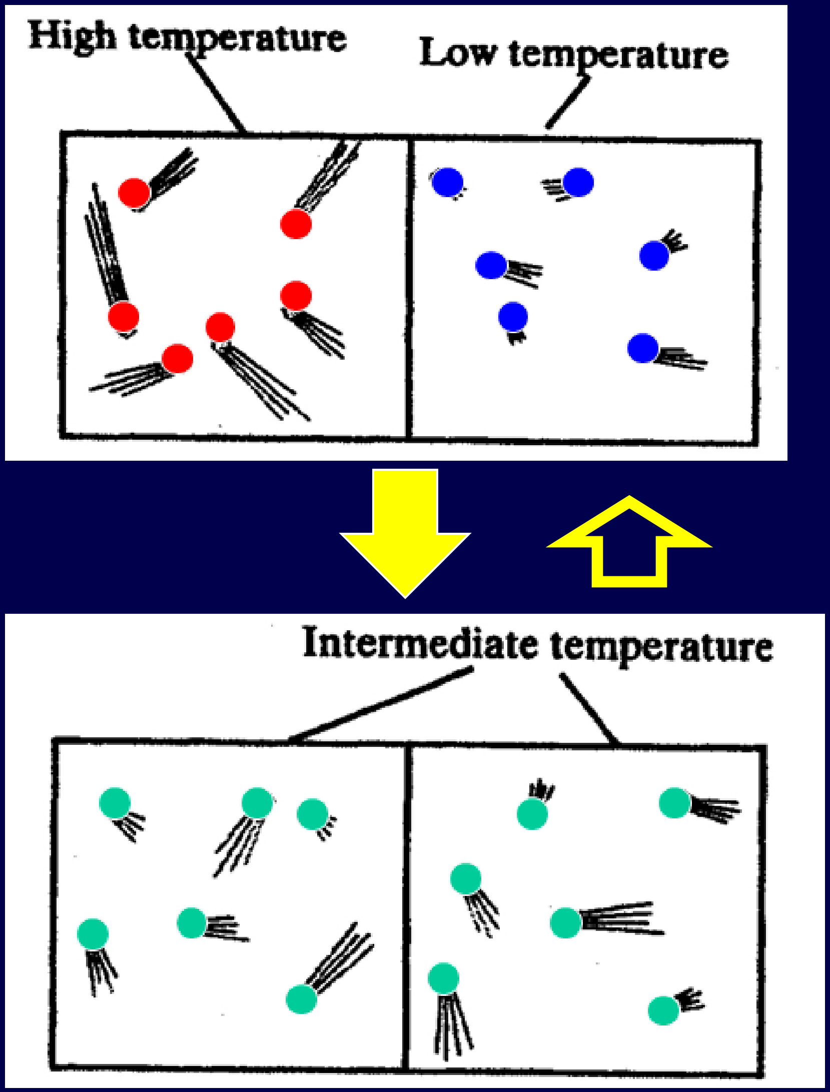
Higher T → Lower T



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



Reaches equilibrium



Will not spontaneously return to previous condition!

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

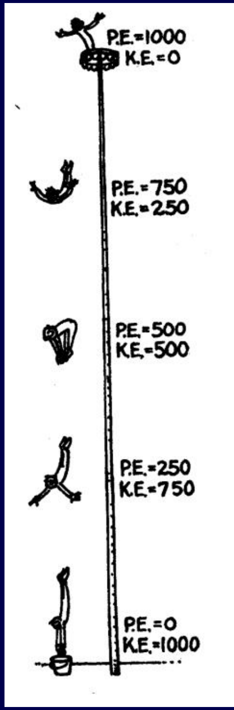
Skip to p 44

THE LAWS!

"Everything that happens can be described as energy transformations"

(a repeat quote)

Was discussed earlier under ENERGY *(p 24)*



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.

Whoops! Homer just dropped his Global Change textbook . . .

The falling book illustrates

The 1st Law of Thermodynamics

which is also known as

The Law of Conservation of Energy

HOW???

p 44

Gravitational Potential Energy (GravE)

Has potential energy due to its elevated position

Kinetic Energy (KinE)

Converts to energy of motion as it falls

Also jiggles the air molecules as it falls through the air

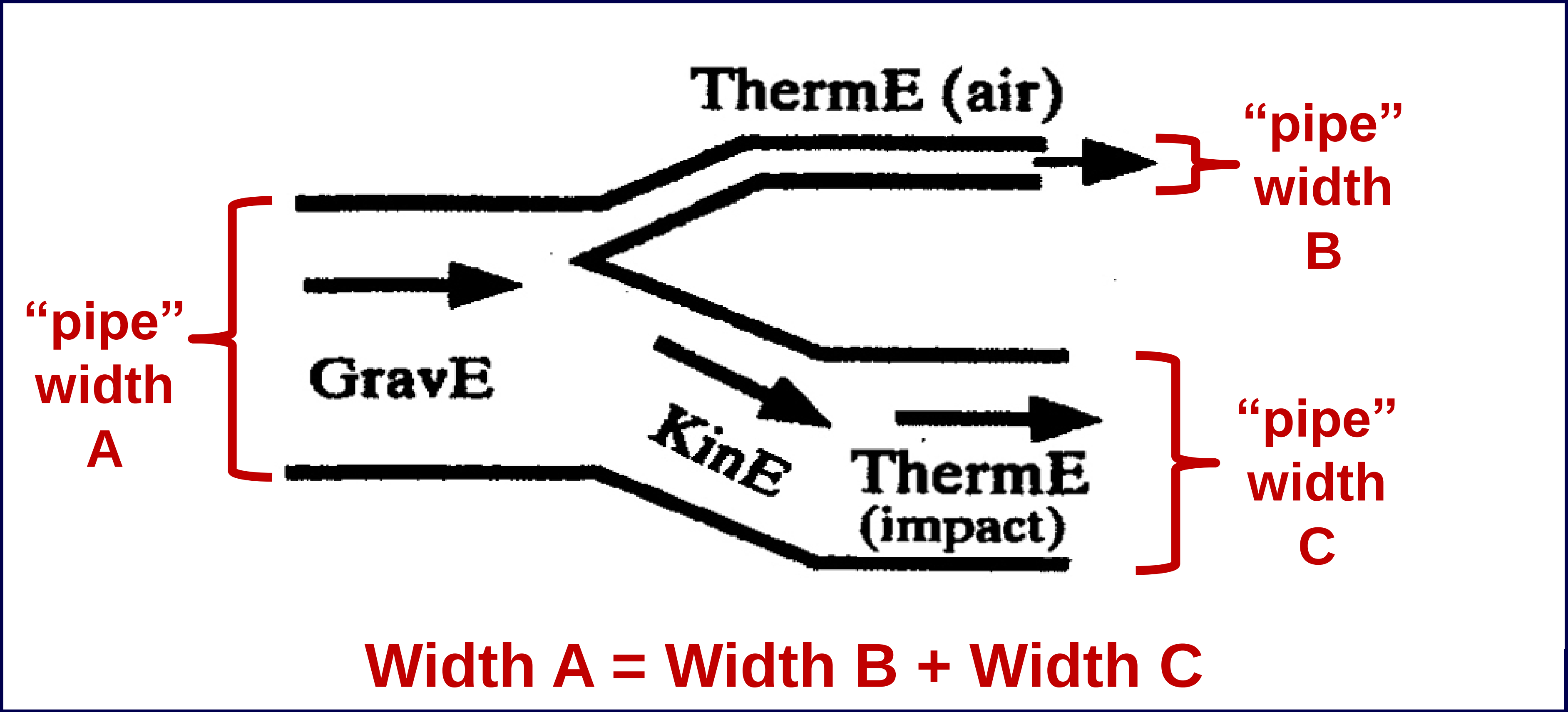
Thermal Energy (ThermE)

Converts to thermal energy on impact by jiggling the molecules of the floor it hits ➔ slight increase in temperature

p 44

An "Energy Flow Diagram"

Energy flow for a falling book, with air resistance.



1st Law of Thermodynamics!

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.

. . . but

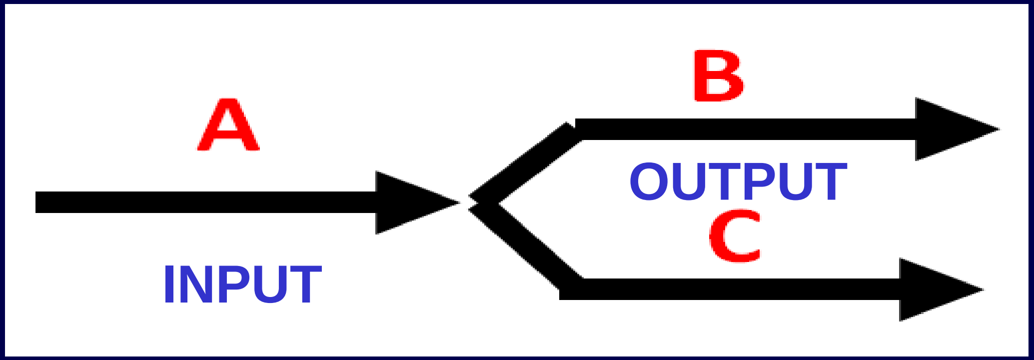
Although energy may not be destroyed, it *can* become **INEFFICIENT**
-- i.e., so that it is not easily used or available to do work!

Efficiency = work done / energy used

Review p 24

How would you draw an energy flow diagram for a LIGHT BULB?

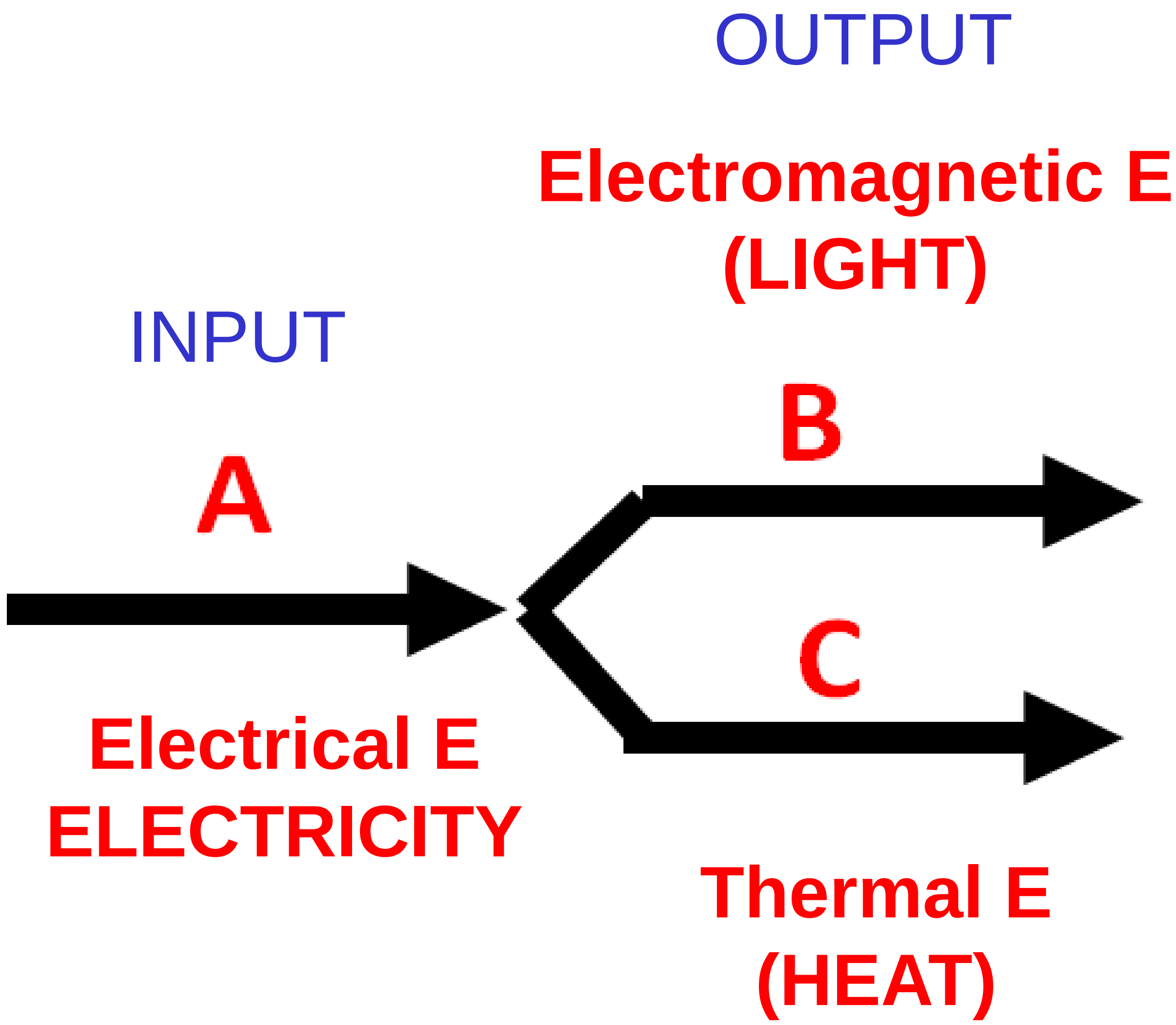
Here is a simplified and unlabeled ENERGY FLOW DIAGRAM for a <u>generic</u> LIGHT BULB.



(the width of the "pipes" has <u>not</u> been adjusted to show the relative amounts of energy in each type of energy flow.)

Which pipe is which?

Choices: (**electromagnetic energy)** *<u>light</u>*
(**electrical energy**) *<u>electricity</u>*
(**thermal energy**). *<u>heat</u>*

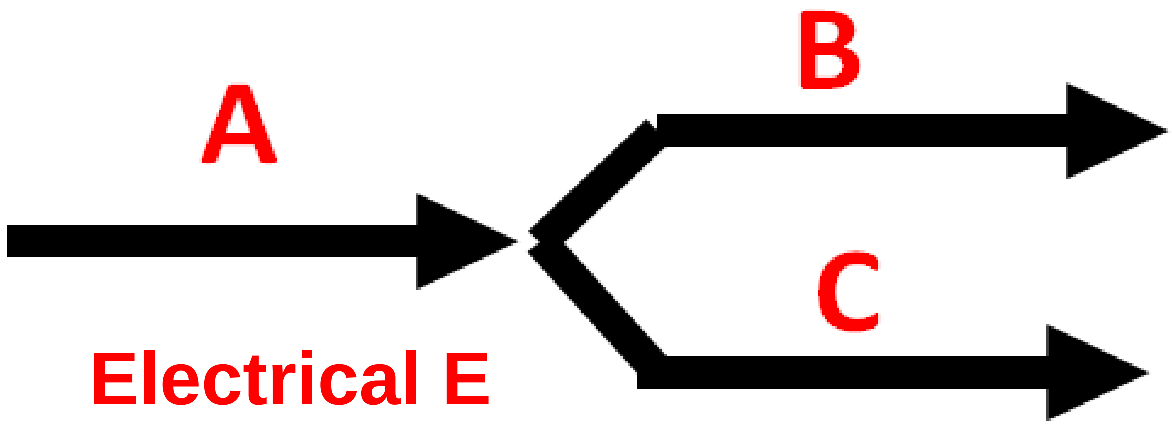

OUTPUT
Electromagnetic E
(LIGHT)
INPUT
B
A
C
Electrical E
ELECTRICITY
Thermal E
(HEAT)

Also correct . . . .

OUTPUT

Thermal E (HEAT)

INPUT



You can re-arrange the OUTPUT pipes!

Electrical E ELECTRICITY

Electromagnetic E (LIGHT)

IN A FEW SLIDES WE'LL TALK ABOUT HOW YOU WOULD YOU DRAW THE PIPE WIDTHS . . .

But first . . .

THE
SECOND LAW OF
THERMODYNAMICS

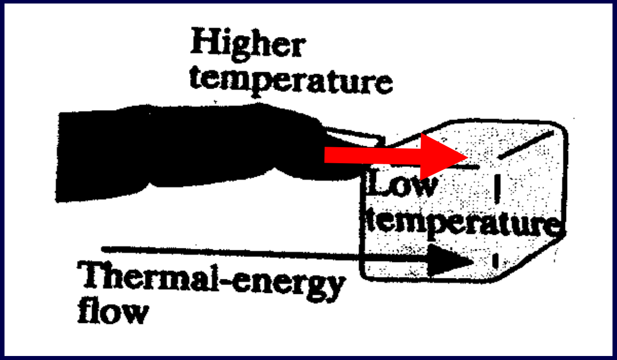
SECOND LAW OF THERMODYNAMICS
(stated as the "Law of Heating")

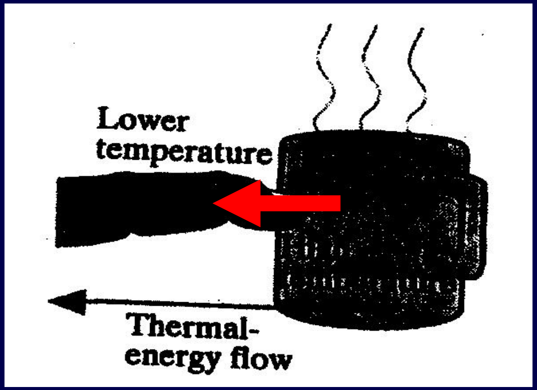
Heat will not flow spontaneously from a cold to a hot body.

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

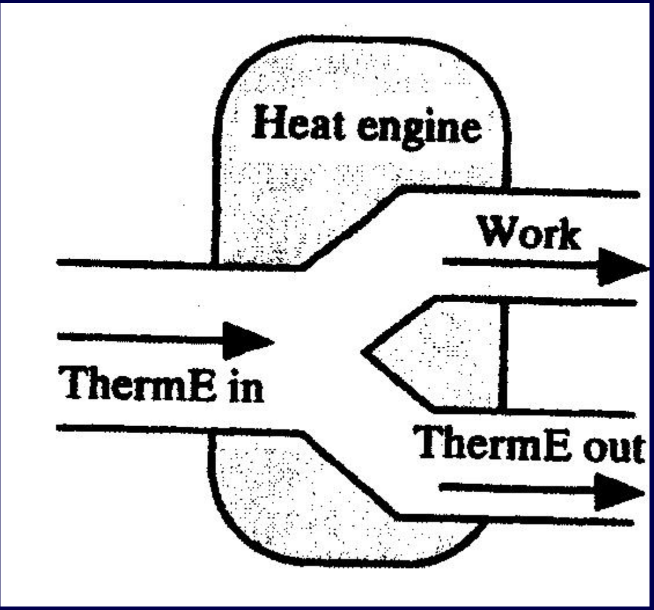
It will not spontaneously flow the other way!

Example from p 43 ➔





The 2nd Law stated another 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!**

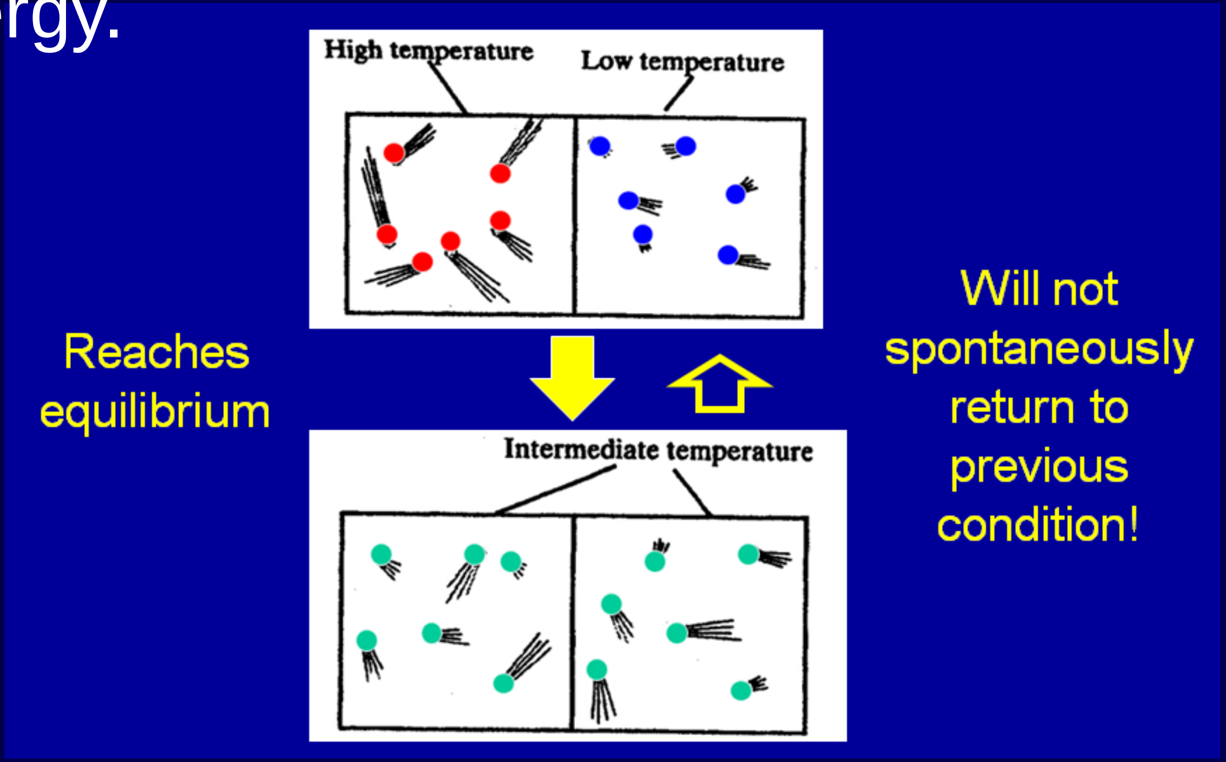
The 2nd Law stated a THIRD way:

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)

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.



Got all that Homer?

boring . . . . !

CLICKER SELF-TEST TIME!!! . . . .→

Channel 28

Q1 - 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 warmer beer belly

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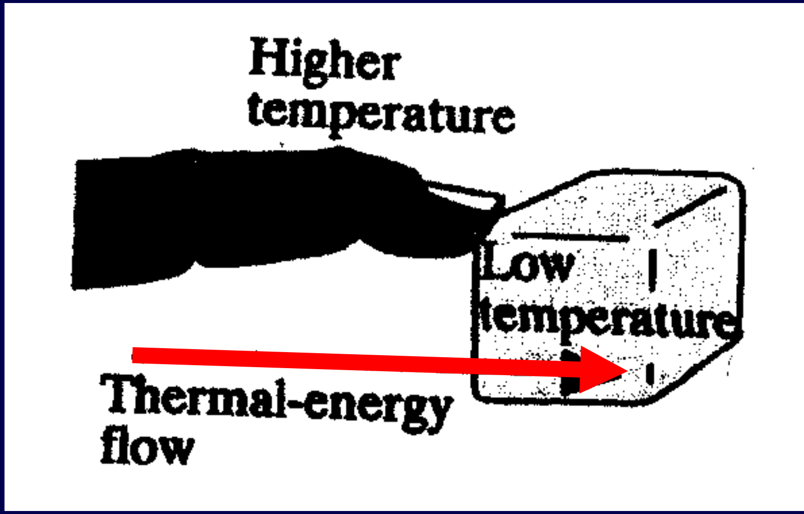
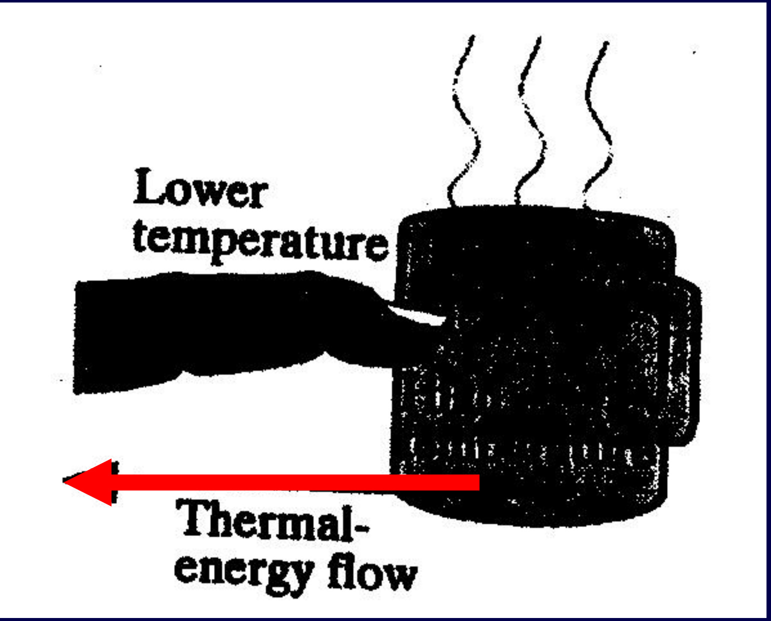
3. From BOTH the beer can to Homer <u>and</u> Homer to the beer can

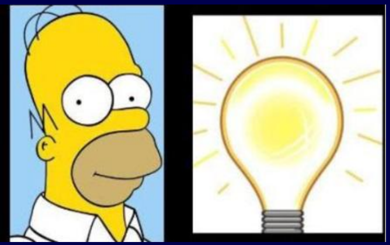


Explanation for answer to Q2:

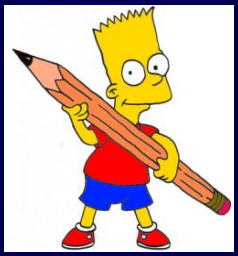
The 2nd Law of Thermodynamics!

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

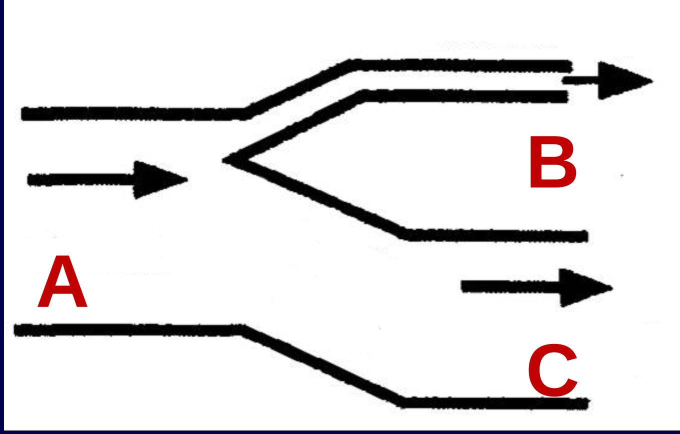




Homer doesn’t want to give up his incandescent light bulbs but they are very inefficient and lose 90% or their energy as heat!

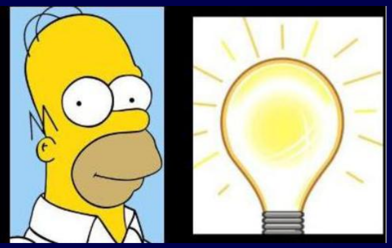


So Bart drew Homer this ➔ energy flow diagram for the bulb with different pipe widths!

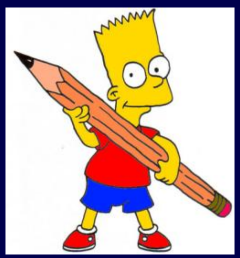


Q3. Select the # with the correct labels for Bart’s diagram:

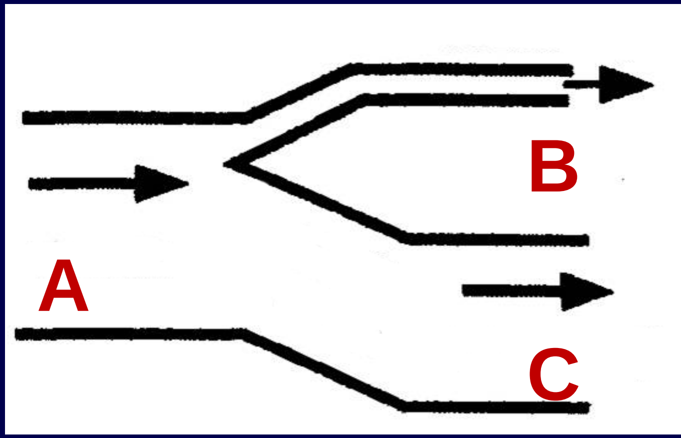
1. A = Electrical E B = Thermal E C = Light E
2. A = Light E B = Thermal E C = Electrical E
3. A = Electrical B = Light E C = Thermal E
4. A = Thermal E B = Electrical E C = Light E



Homer doesn’t want to give up his incandescent light bulbs but they are very inefficient and lose 90% or their energy as heat!



So Bart drew Homer this → energy flow diagram for the bulb with different pipe widths!



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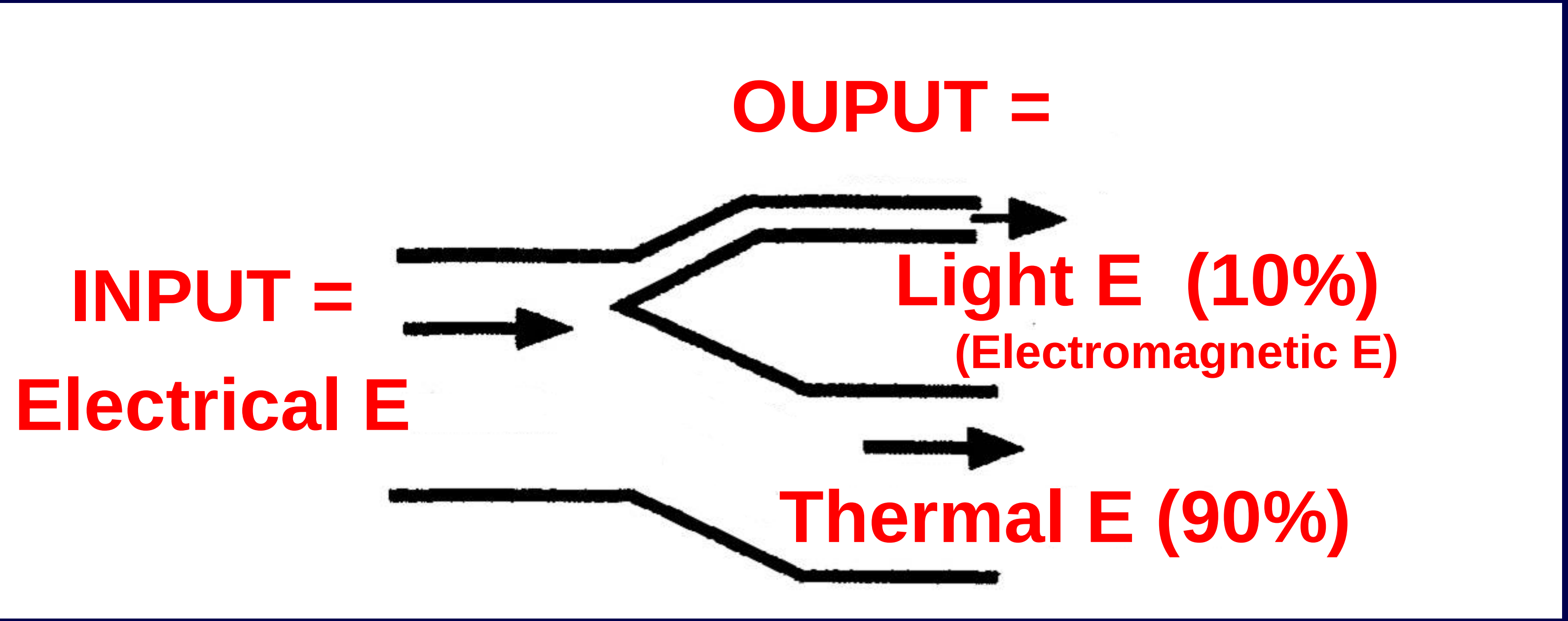
2. A = Light E B = Thermal E C = Electrical E
3. A = Electrical B = Light E C = Thermal E
4. A = Thermal E B = Electrical E C = Light E

Here it is labeled:



Q4. **Which of the LAWS we've just covered is <u>MOST CLOSELY</u> related to the following statement about energy resources:**

"When the Earth's energy resources are used,
energy is degraded from highly useful forms,
such as oil, to less useful forms such as thermal energy."

1. The Law of Conservation of Energy *(one way of stating it):*
"energy cannot be destroyed but it can be conserved."

2. The 1st Law of Thermodynamics *(one way of stating it):*
"energy cannot be created, but it can be destroyed and disappear from the system."

3. The 2nd Law of Thermodynamics *(one way of stating it):*
"heat engines are always less than 100% efficient at using thermal energy to do work."

Q4. **Which of the LAWS we've just covered is <u>MOST CLOSELY</u> related to the following statement about energy resources:**

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3. The 2nd Law of Thermodynamics *(one way of stating it):* "heat engines are always less than 100% efficient at using thermal energy to do work."

Can I go now????

NO!

It's time for a Sustainability Segment!

A LINKING TO LIFE VIDEO . . .

http://www.pbs.org/moyers/journal/09212007/watch3.html

MORE ABOUT <u>THERMAL</u> ENERGY:

First, some more 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

p 45

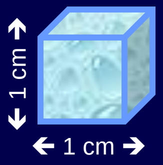
Quick Review: Thermal Energy Units

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

“Low Joule Cola”

Label from a soda bottle purchased in Europe

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

. . . or about the mass of 1 small paper clip!)

review

REMINDER: 1 calorie is NOT the same as our everyday language use of the term “calorie” in “nutrition” discussions:

“nutrition calorie” = kilocalorie!

“Munch”

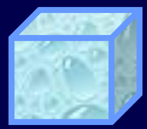
1 “calorie” in nutrition context = 1000 calories or a kilocalorie (Kcal)

review

Key Term:

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

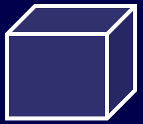
Specific heat =
1.00 calorie



1 g
of water

vs.

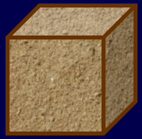
Specific heat =
0.24 calorie



1 g
of air

vs.

Specific heat =
0.20 calorie



1 g
of sand

p 45

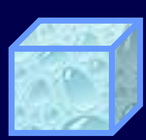
One Other Key Term:

Heat Capacity = **specific heat x mass (density) of a substance for a given <u>VOLUME</u>.**

(Density is measured in grams per cubic centimeter.)

Heat capacity represents the capacity of a substance to absorb heat in relation to its ***<u>volume</u>*** and ***<u>density</u>***.

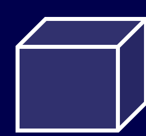
Heat capacity =
1.00
calorie / cubic cm



1 cubic cm
of water

vs.

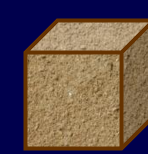
Heat capacity =
0.00024 – .00034
calorie / cubic cm



1 cubic cm
of air

vs.

Heat capacity =
0.1 – 0.6 *higher if wet*
calorie / cubic cm



1 cubic cm
of sand

p 45

Specific Heat & Heat Capacity for Different Substances

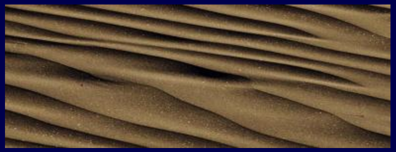
Substance	Specific Heat		Heat Capacity
	cal	*joules*	
water	1.00	4.186	1.00
air	0.24	1.005	0.00024 - 0.00034
concrete	0.21	.879	0.50
sand	0.20	.837	0.10 - 0.60 (higher if wet)
iron	0.105	.440	0.82
silver	0.056	.234	0.59

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

MORE CLICKER Q's➔

Q5 - 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?



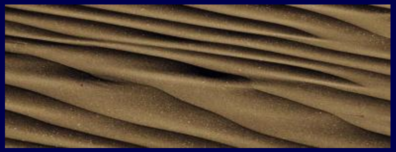
1. AIR
2. WATER
3. SAND

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

Q5 - 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:

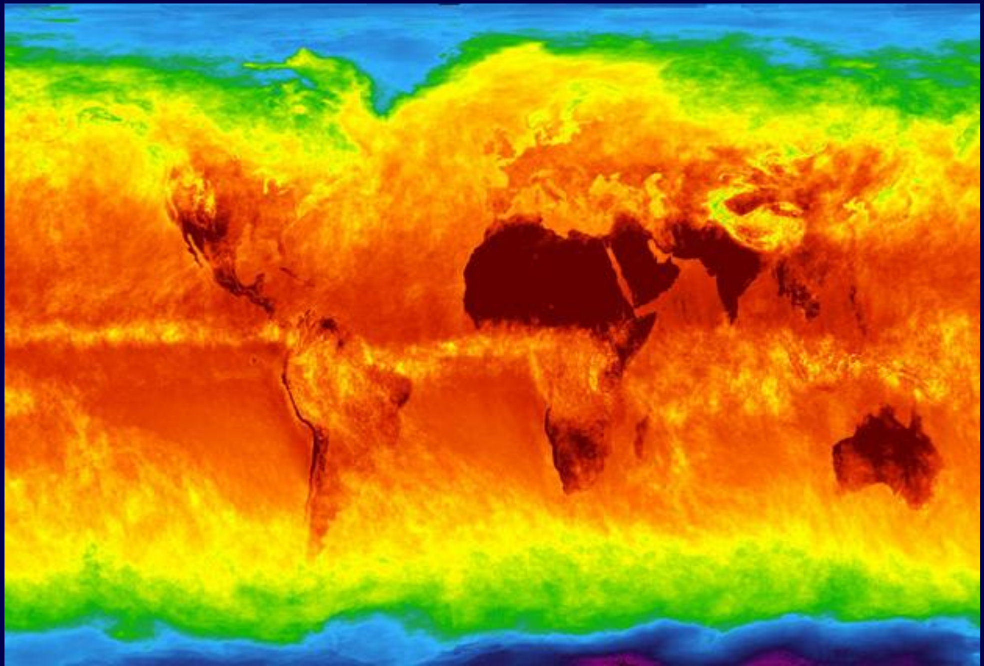
The lower the heat capacity, the quicker the response to a transfer of heat into the substance!

Q6 – As global warming is occurring we will be able to detect it <u>FIRST</u> 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

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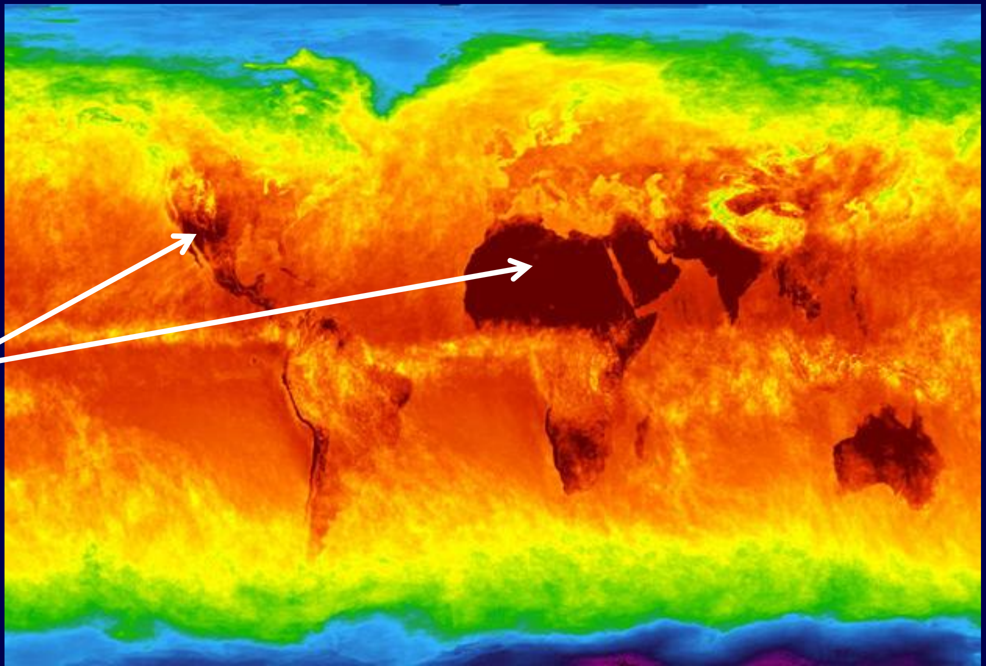
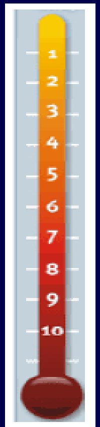
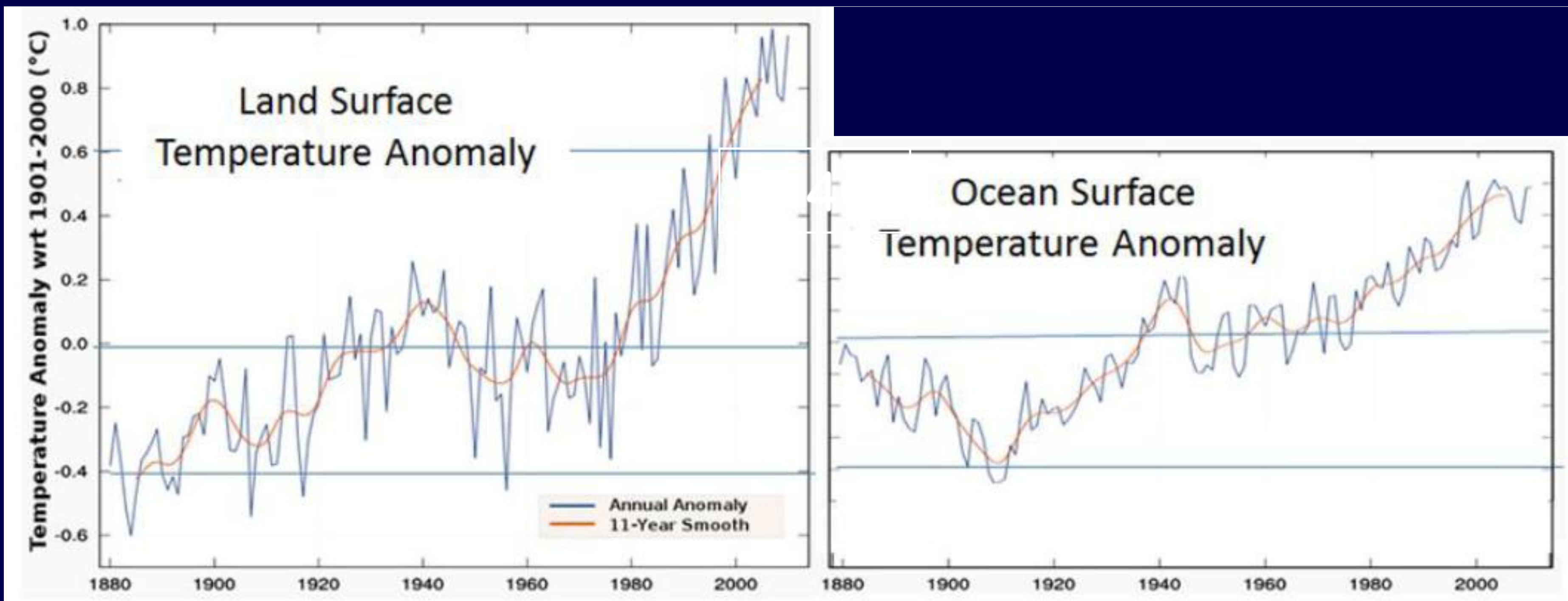


Note where the hottest temperatures occur



INDICATOR INTERLUDE . . .

Q. Why does the ocean surface warm more slowly than the land surface?



http://www.ncdc.noaa.gov/cmb-faq/anomalies.php

Q7 - Why will he burn his tongue, even if the pie crust is cool enough to hold?

1 - Because due to the high specific heat of the water in the apple pie filling, the filling will heat up faster and to a much higher temperature than the crust can achieve

2 – Because, due to the high specific heat and heat capacity of the water in the apple pie filling, the filling will hold the thermal energy longer than the crust will after the pie is taken out of the oven.

3 - BOTH

p 46

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3 - BOTH

Q8 - 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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1. The ATMOSPHERE
2. The CONTINENTS
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INDICATOR INTERLUDE . . .

Q. Why is the heat CONTENT of the ocean so much greater than the land?

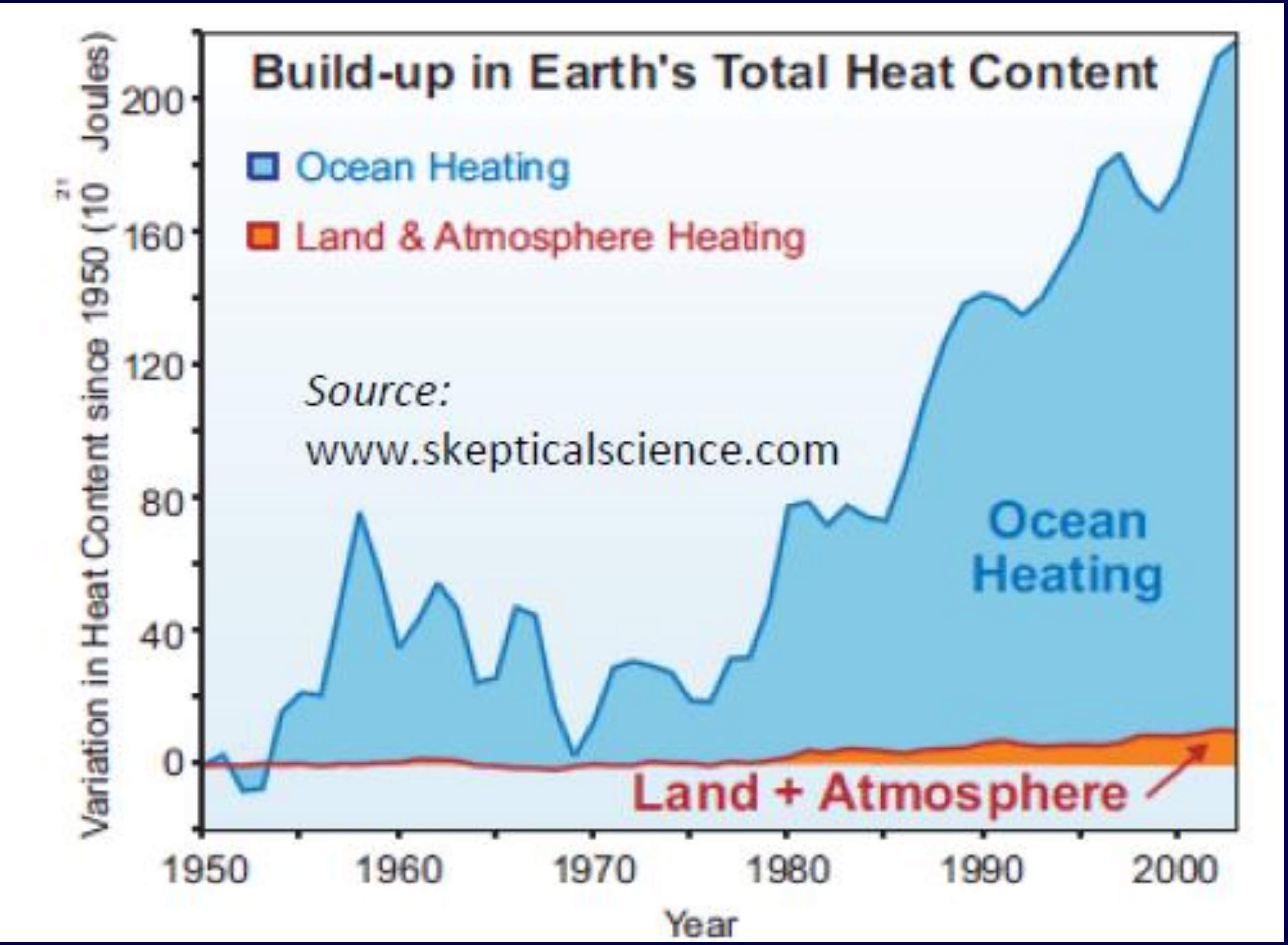

Figure: Total Earth Heat Content from 1950 (Murphy 2009). Ocean data from Domingues et al 2008. http://www.skepticalscience.com/How-do-we-know-global-warming-is-still-happening.html

Can I go now????

YES!!

But don’t forget I-1 is due on THURSDAY before Midnight!