WRAP UP:

TOPIC #7
Atmospheric Structure & Composition

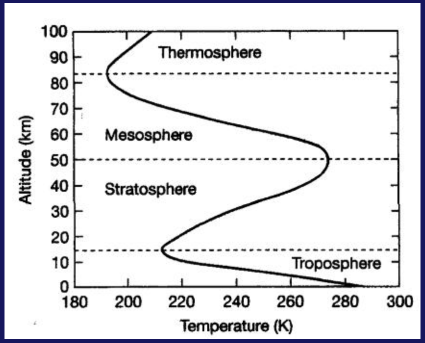
SUMMARY OF KEY CONCEPTS: short version

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 one is a GHG?**

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

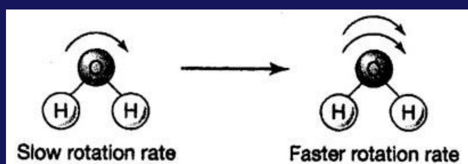
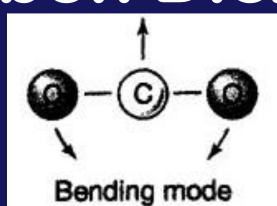
3. Different gases are abundant at certain levels in the atmosphere & where radiation is absorbed by these gases, leads to: vertical temperature profile . . .

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



p 41

Most Abundant Greenhouse Gases:

GAS	Symbol	% by volume	% in ppm
Water Vapor 	H_2O	0.00001 (South Pole) to 4.0 (Tropics)	0.1 - 40,000
Carbon Dioxide 	CO_2	0.0390 (and rising!)	360 (in 1997) **390 ++!**

Greenhouse Gases !

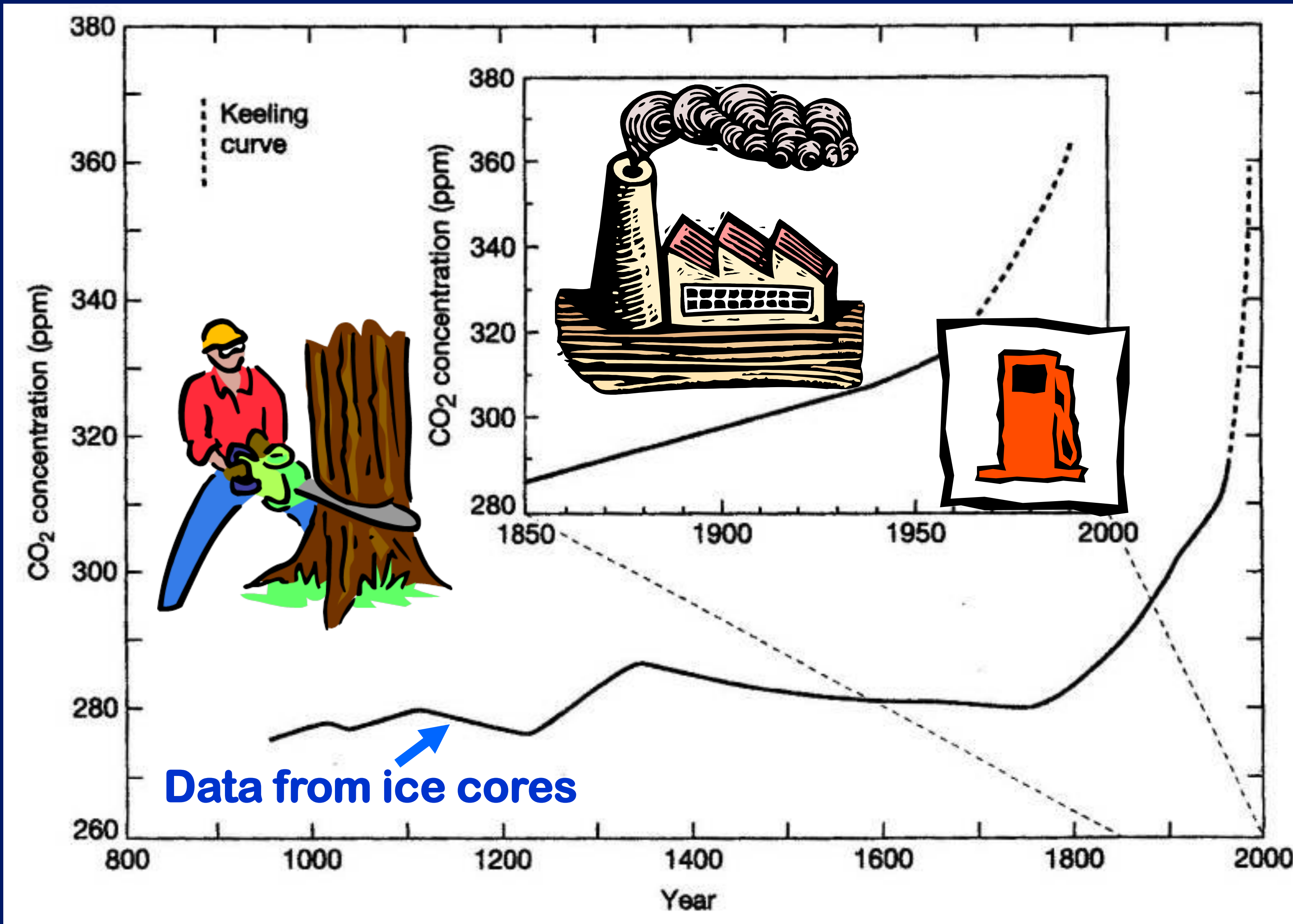
Review p 40

Two other Important Greenhouse Gases:

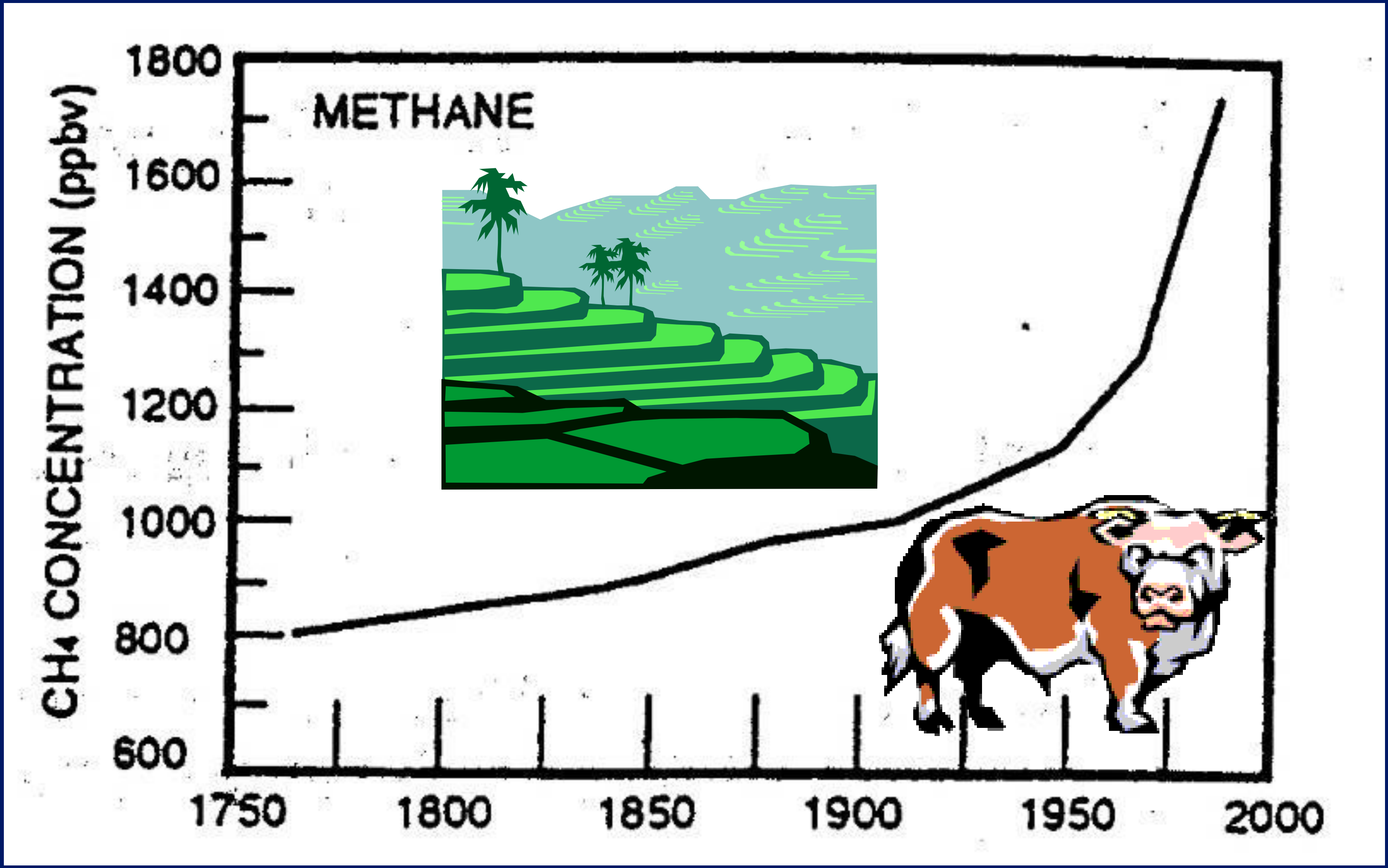
GAS	Symbol	% by volume	% in ppm
Methane	CH_4	0.00017	1.7
Nitrous Oxide	N_2O	0.00003	0.3

Review p 40

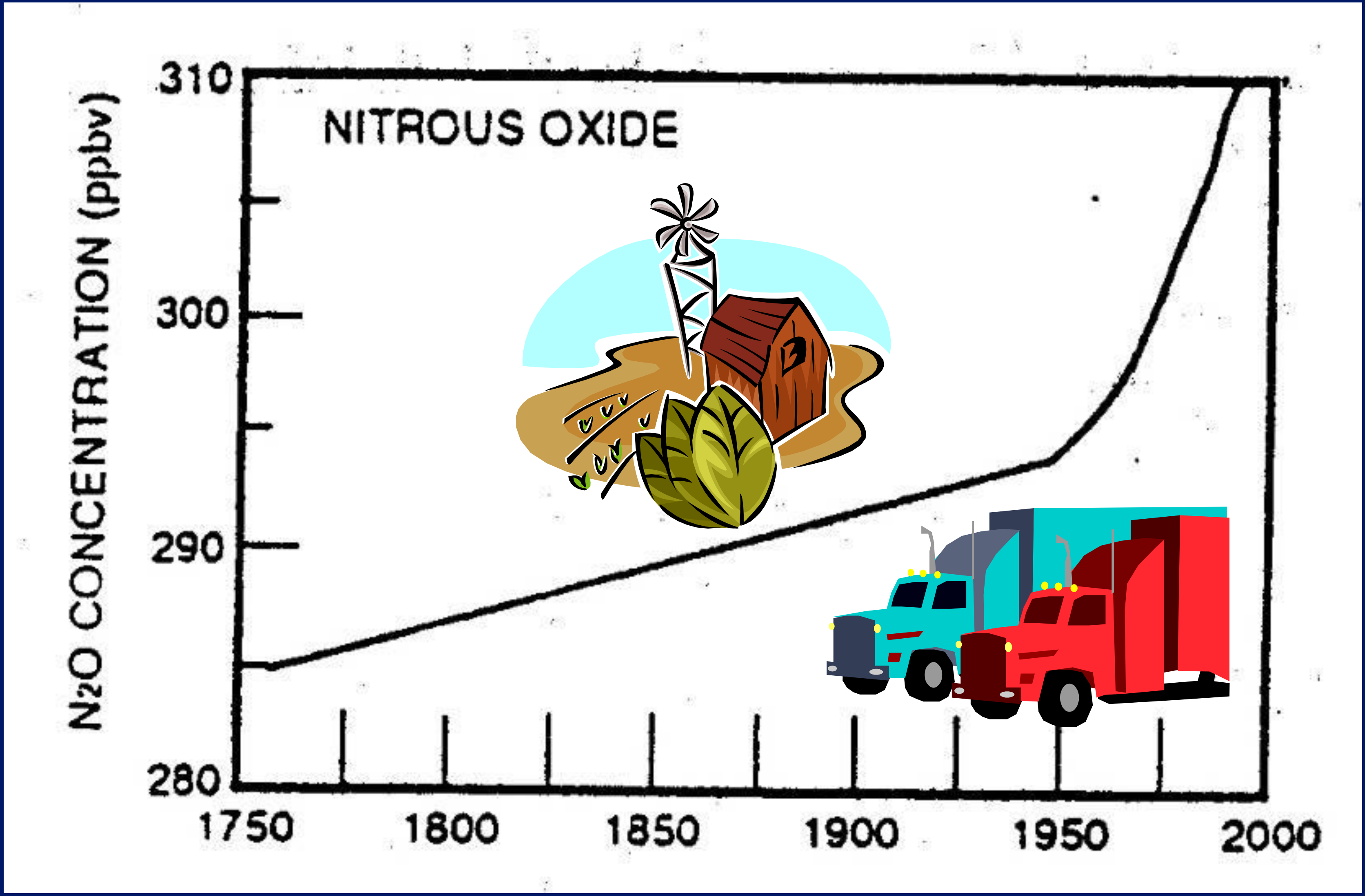
CARBON DIOXIDE: Trends

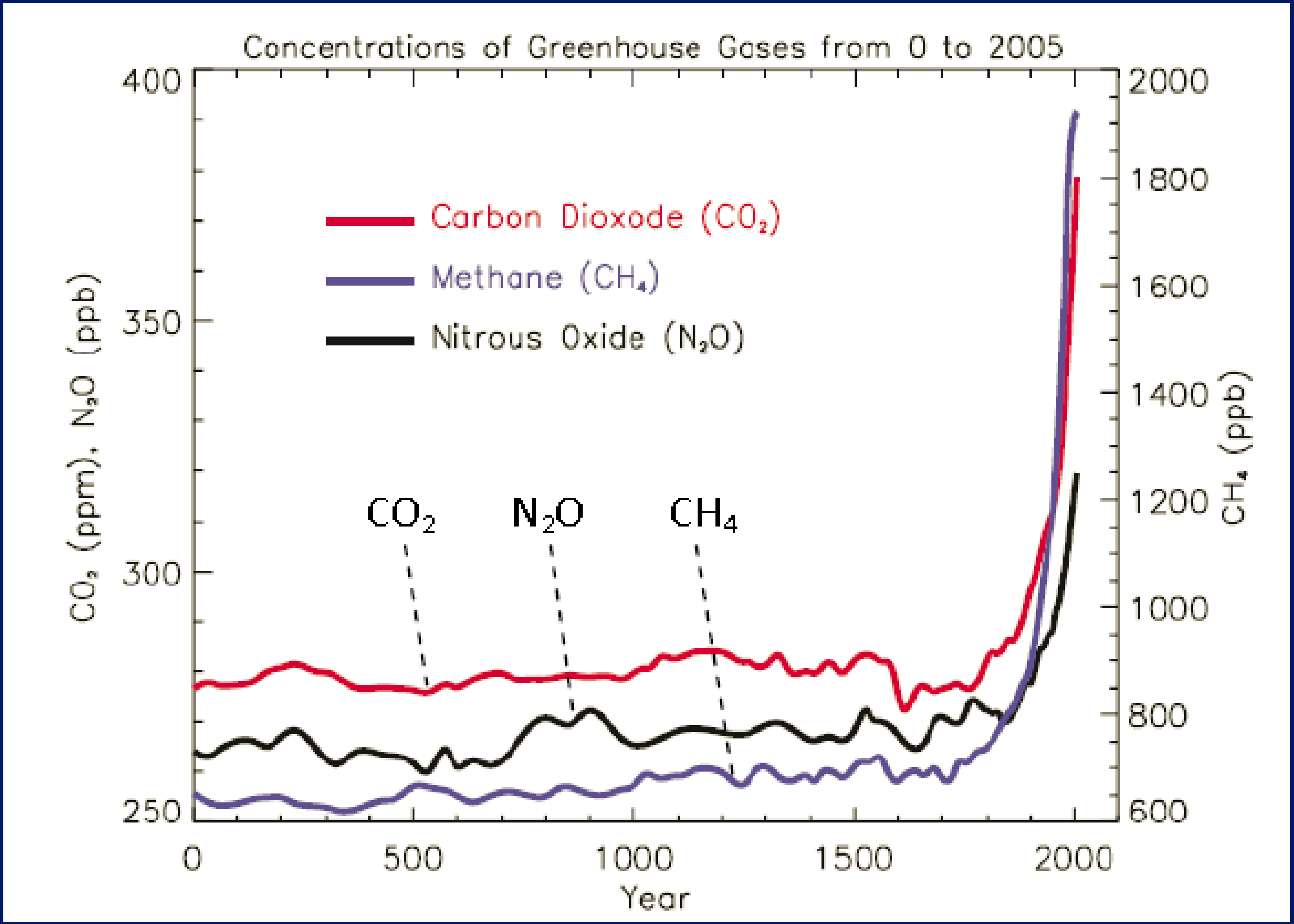


METHANE: Trends



NITROUS OXIDE: Trends

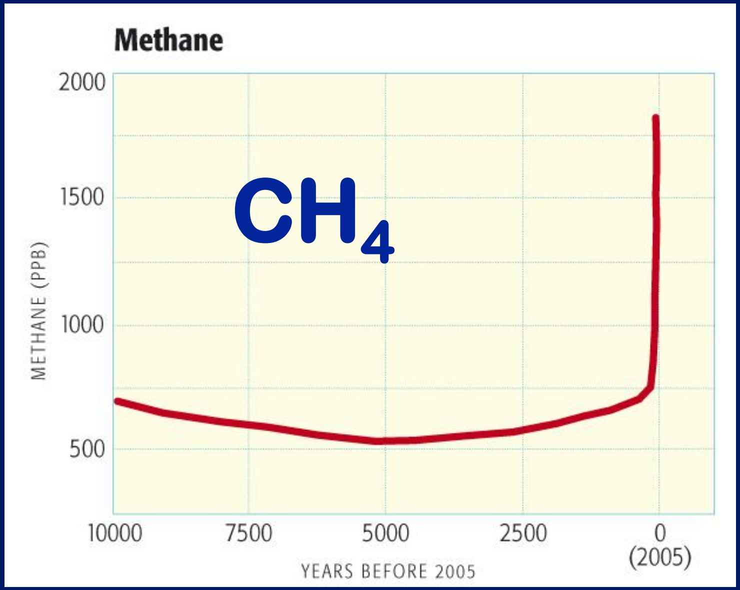


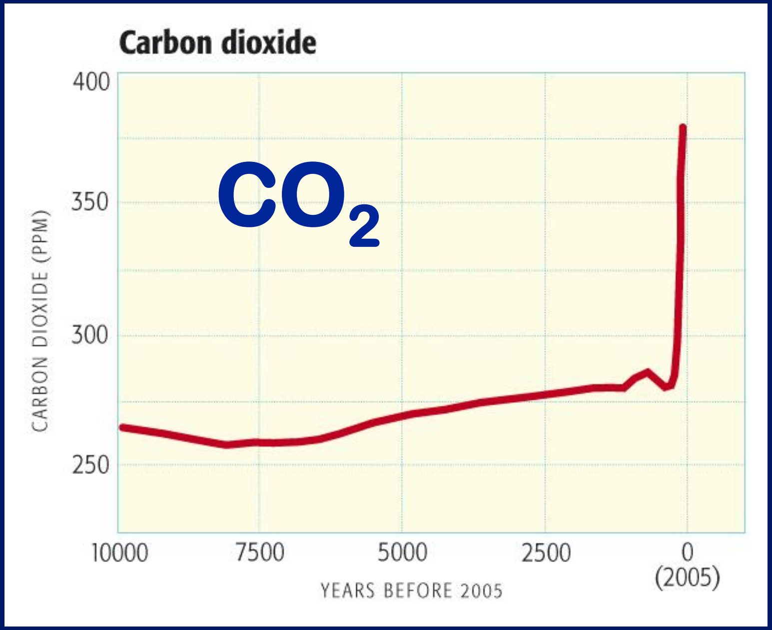


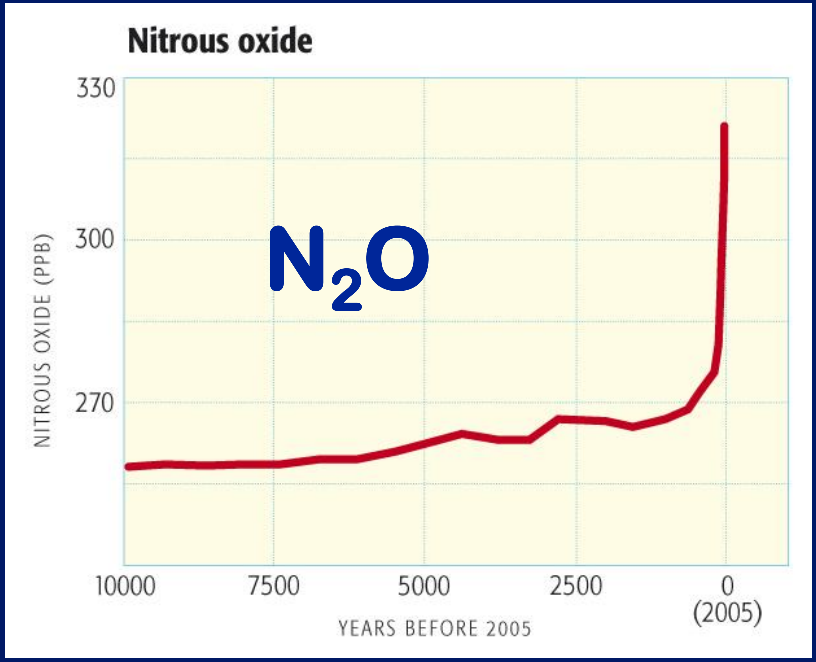
Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO₂)
Methane (CH₄)
Nitrous Oxide (N₂O)
CO2
N2O
CH4
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000
Year
CO₂ (ppm), N₂O (ppb)
CH₄ (ppb)

Since 0 A.D.!

Updated figures from **Dire Predictions** p 33

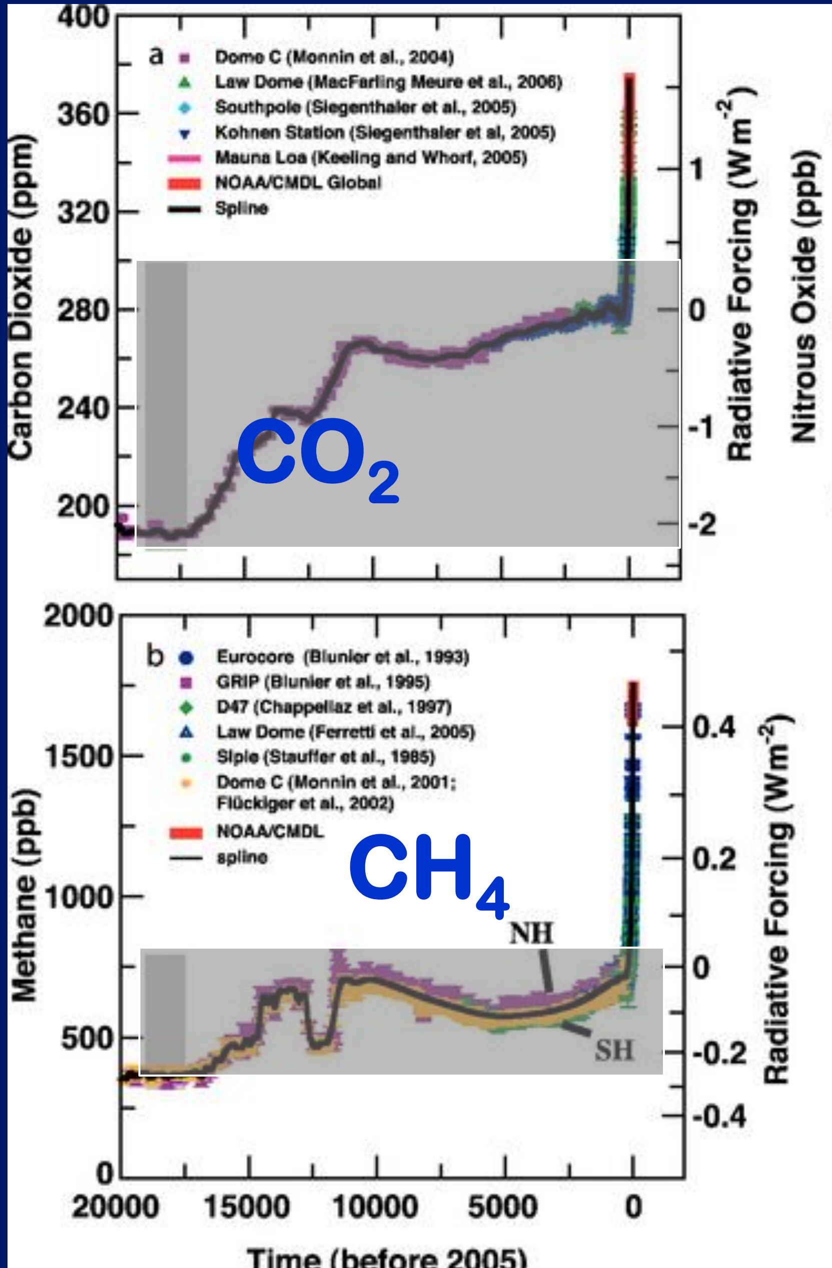


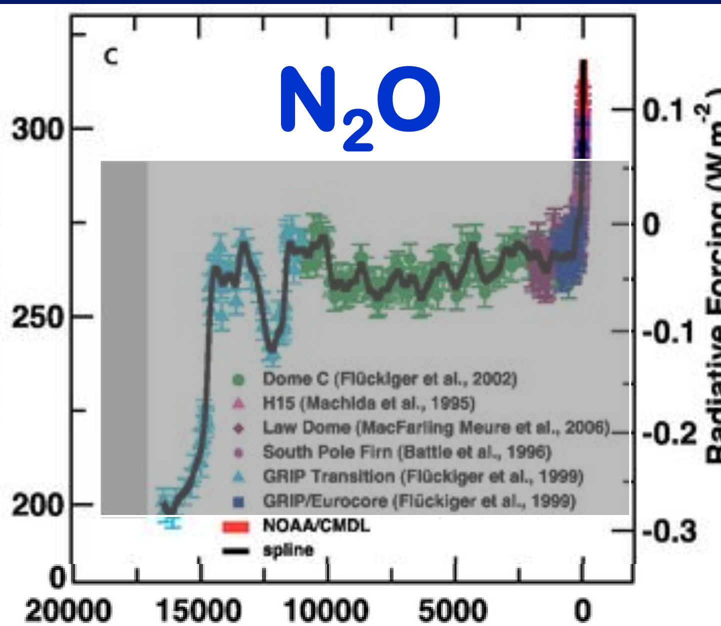


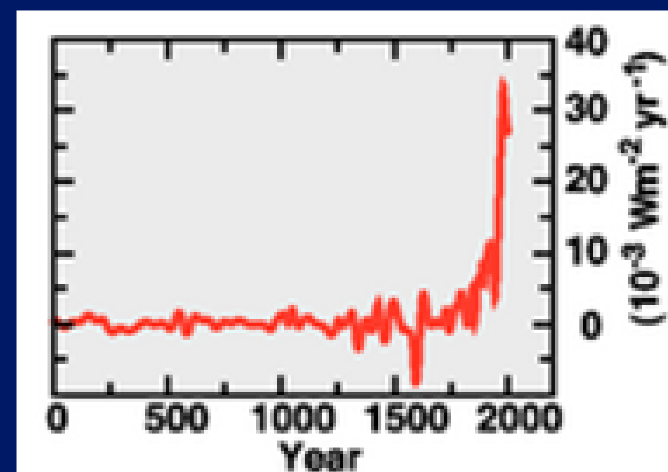


Since 10,000 years ago!

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







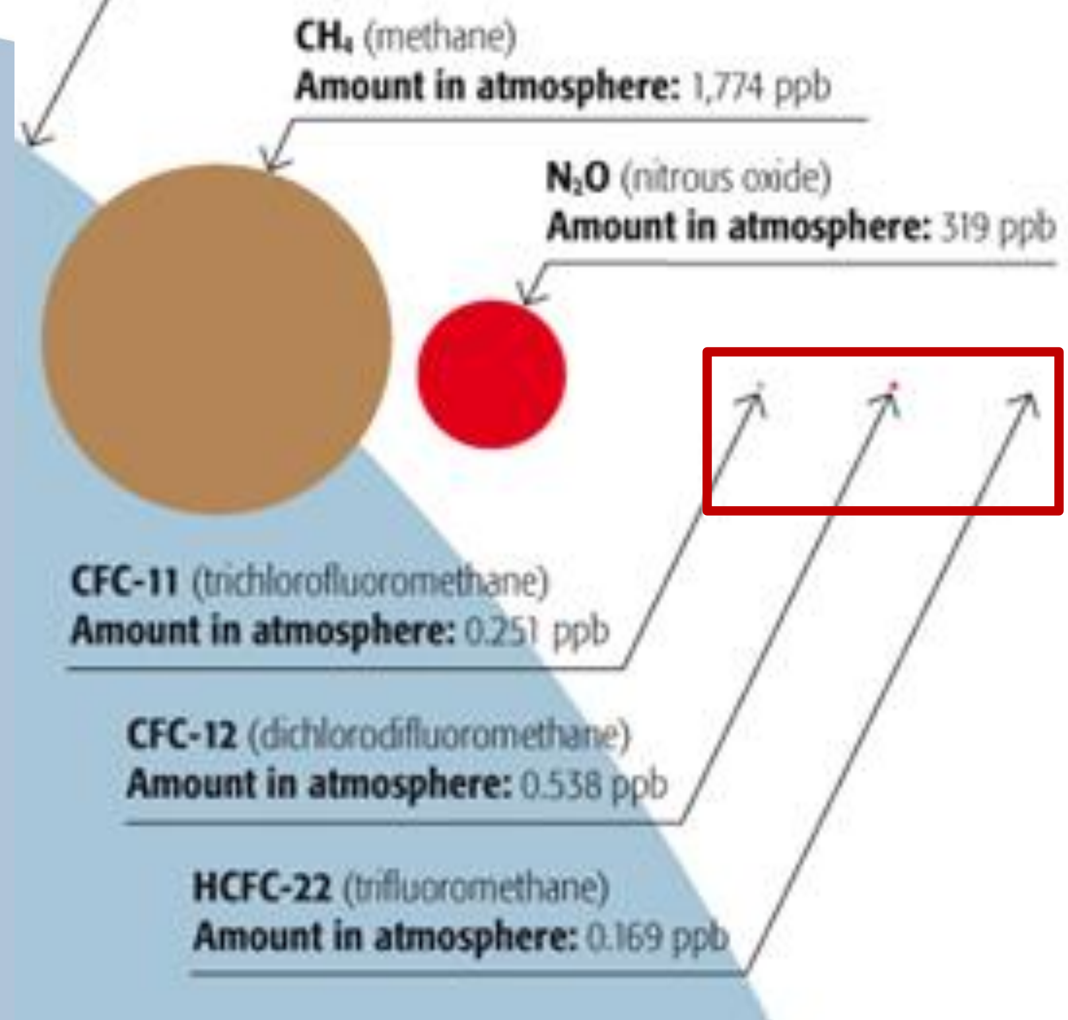
years ago!

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 40



CO_2

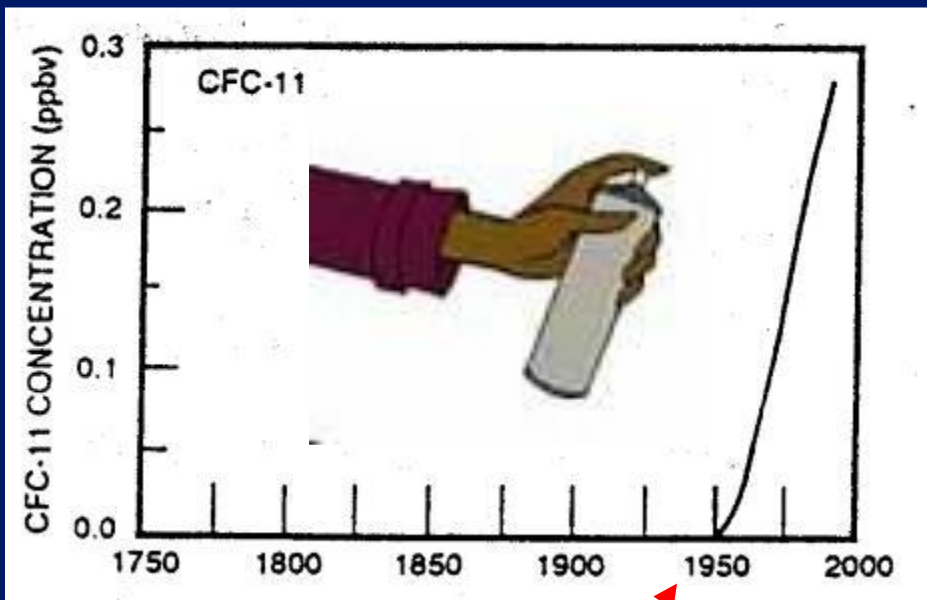
Amount in
Atmosphere = 386,000 ppb

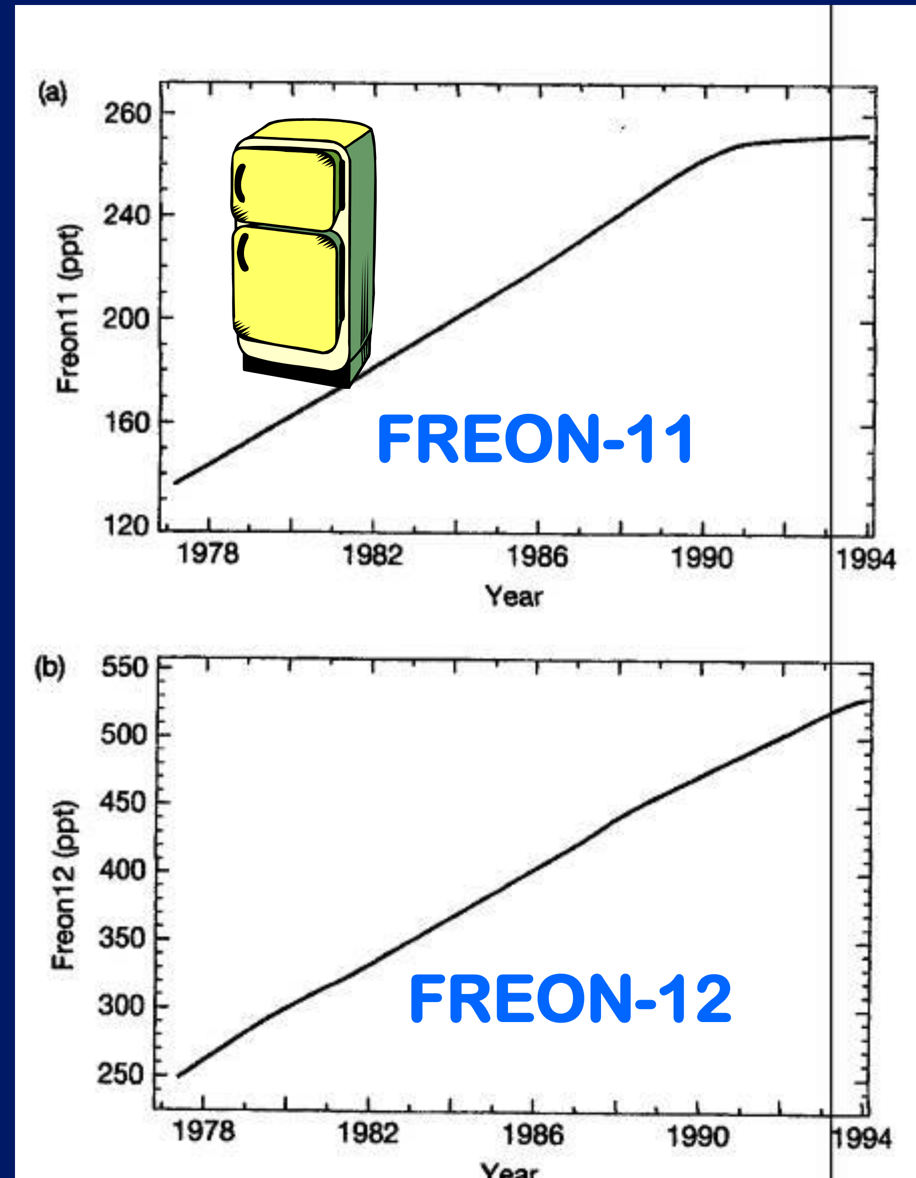
From pp 29-29 in *Dire Predictions*

Name that GAS!!!

MYSTERY
GHG # 4

CFCs: Trends





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

CFCs (Freon-11 & Freon-12)

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

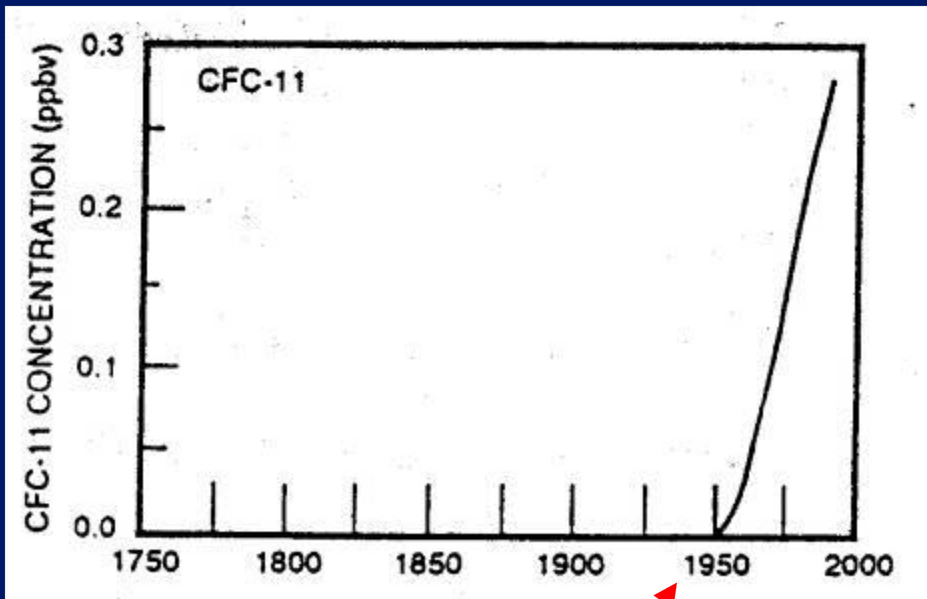
* Have increased at rates faster than any other greenhouse gas; used in refrigerants, fire retardants, some aerosol propellants & foam blowing agents

* 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 (high "Global Warming Potential")

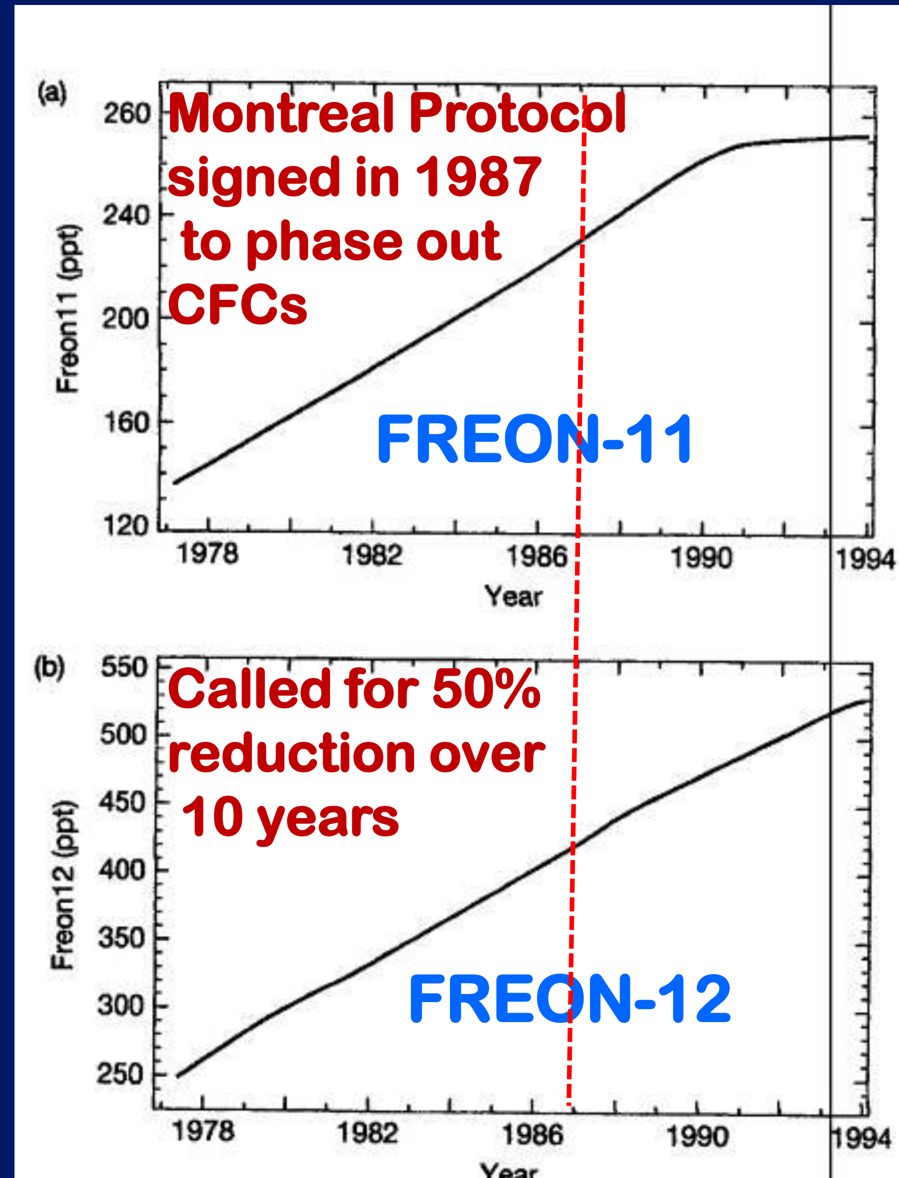
MONTREAL (and subsequent) PROTOCOLS have reduced CFCs!

☺ Table p 40

CFCs: Trends



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



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.

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

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The New York Times

Business Day

Energy & Environment

24 Sep 2011

Robots Extract Coolant From Old Refrigerators

General Electric

A machine in Philadelphia can dismantle a refrigerator in 60 seconds for recycling, removing 99.8 percent of the coolant.

http://www.nytimes.com/2011/09/25/business/energy-environment/recyclers-extract-coolant-from-old-refrigerators.html?_r=1&scp=1&sq=Robots%20extract%20coolant%20from%20old%20refrigeratros&st=cse

☺

Robots Extract Coolant From Old Refrigerators

By ANNE EISENBERG

RECYCLING refrigerators — especially those made more than 15 years ago — is a tricky job. The coolant in old appliances (now banned from newer versions) can cause serious trouble, warming the atmosphere and depleting the ozone layer.

Robots Extract Coolant From Old Refrigerators

General Electric

A machine in Philadelphia can dismantle a refrigerator in 60 seconds for recycling, removing 99.8 percent of the coolant.

General Electric

The refrigerator's foam insulation is turned into pellets that can be used as fuel.

Regulations forbid the release of liquid refrigerants during disposal. But what if the refrigerant was not in the cooling system, but stored up in the old foam used for insulation? The insulation in older machines is full of a gassy refrigerant that can waft away during dismantling and continue to diffuse later when the foam is shredded and sitting in a landfill.

“Companies can use credits from the proper destruction of refrigerants to cover part of their annual emissions,” said Gary Gero, president of Climate Action Reserve in Los Angeles, which certifies projects that reduce greenhouse gas emissions and issues offset credits.

Mr. Dunham of JACO says his company is already taking one of the refrigerants it destroys, CFC 12, to the carbon offset market. “People are buying the credits and banking them, hanging on to them in hopes they will be more valuable when cap and trade comes into effect,” he said.

Many refrigerants that are now banned from production, but are still legally captured and recycled, have about 700 to 10,000 times the heat-trapping potential of carbon dioxide, Mr. Gero said. An average old refrigerator has about half a pound of the now-banned refrigerant in the cooling system and one pound in the foam, he said.

“So the refrigerator has an equivalent of approximately five tons of carbon dioxide,” Mr. Gero said. “For comparison, that is like driving over 10,000 miles in an average car.”

“If you capture these gases and take them to a destruction facility,” he said, “you’ve prevented a problem, and we give you credit.”

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

Some examples:

Hydrofluorocarbons (HFCs)

Perfluorocarbons (PFCs)

Sulfur Hexafluoride (SF_6)

Like CFCs, some of these are especially harmful because they have high **"Global Warming Potential" (GWP)**

A high GWP depends on:

- a large infrared absorption in the right wavelengths
- and a long atmospheric lifetime.

Now on to today's topic . . . .

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

The Next Piece in the Puzzle to Understand Global Changes

Featuring . . . .

CLASS NOTES: pp 45-49

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 *<u>motion</u>* *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!

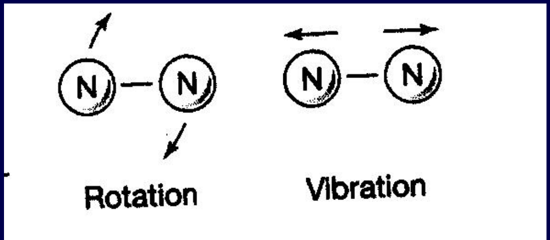
"Internal Energy"

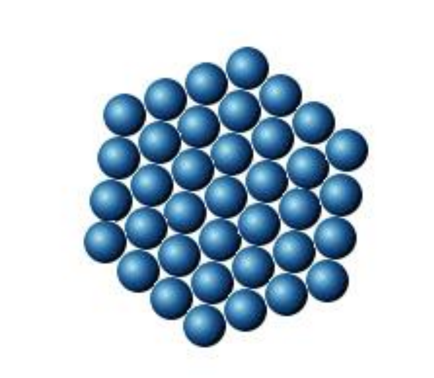
-- specifically: a measure of the quantity of ***atomic kinetic & potential energy*** contained in every object

Thermal Energy

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

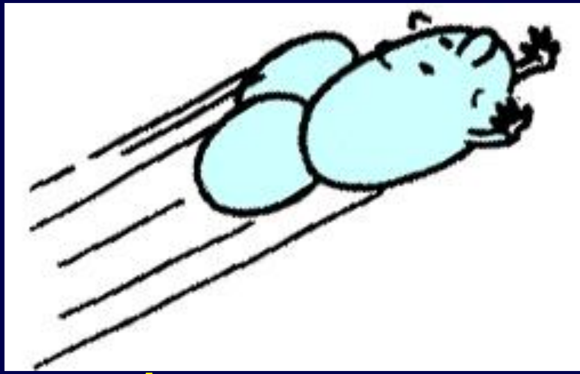
The greater this molecular kinetic energy is in a substance, the <u>hotter</u> the substance is.



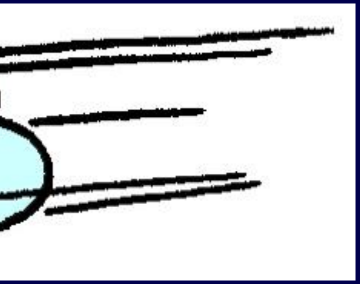


Thermal Energy & Temperature

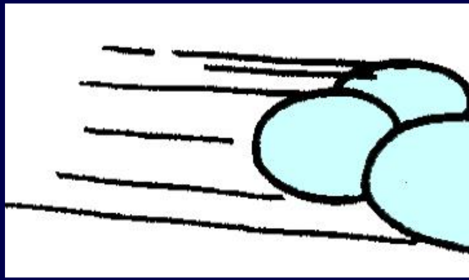
- ***Temperature*** = tells how warm or cold a body is with respect to some standard (e.g., Fahrenheit (°F), Celsius (°C), or Kelvin (K) standard scales).
- **Temperature is a measure of the average kinetic energy of each molecule in a body.**

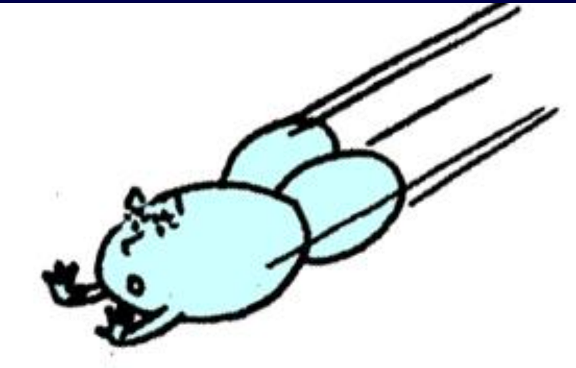


If a body has a high temperature, each of its molecules has, on the average, a large amount of kinetic energy.



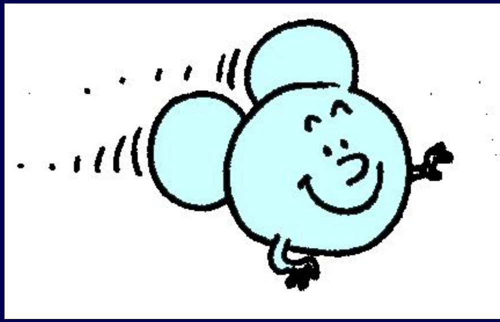
e.g. water vapor -- H_2O molecule at high temperatures





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

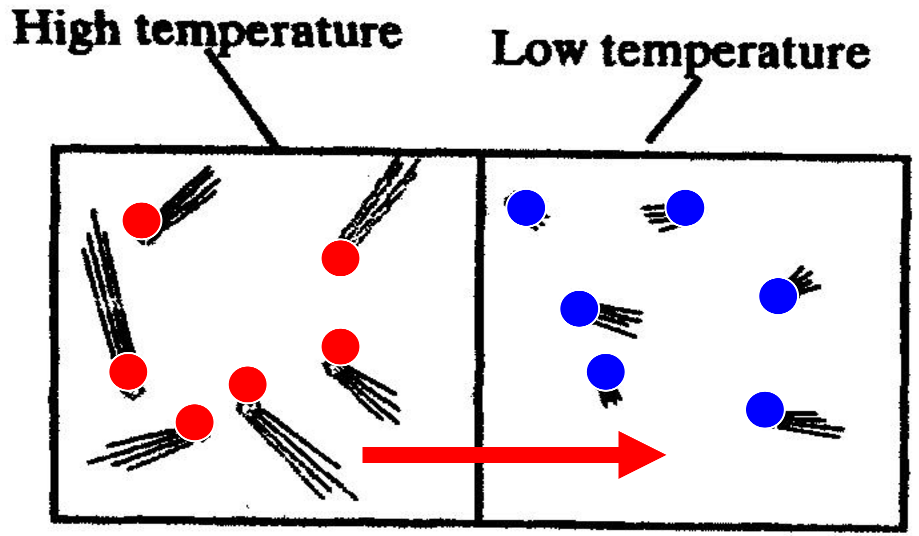
e.g. water vapor molecule – H_2O at lower temperature



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

p 43

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

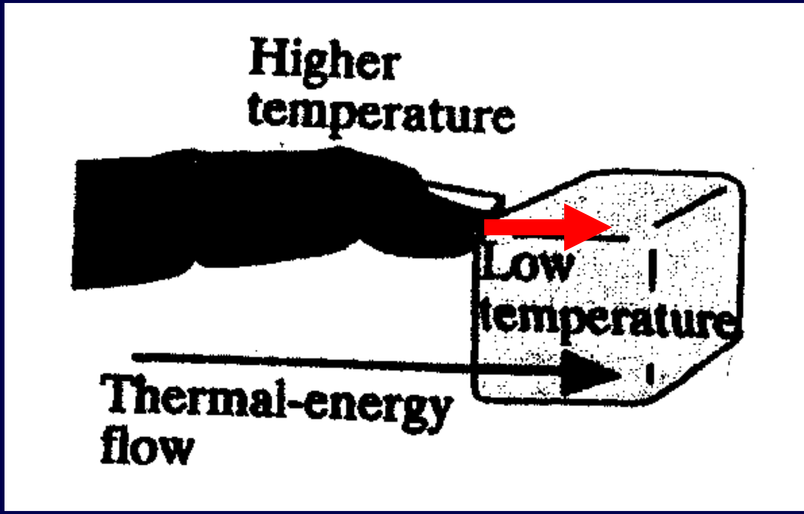
Thermal Energy vs. Heat

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

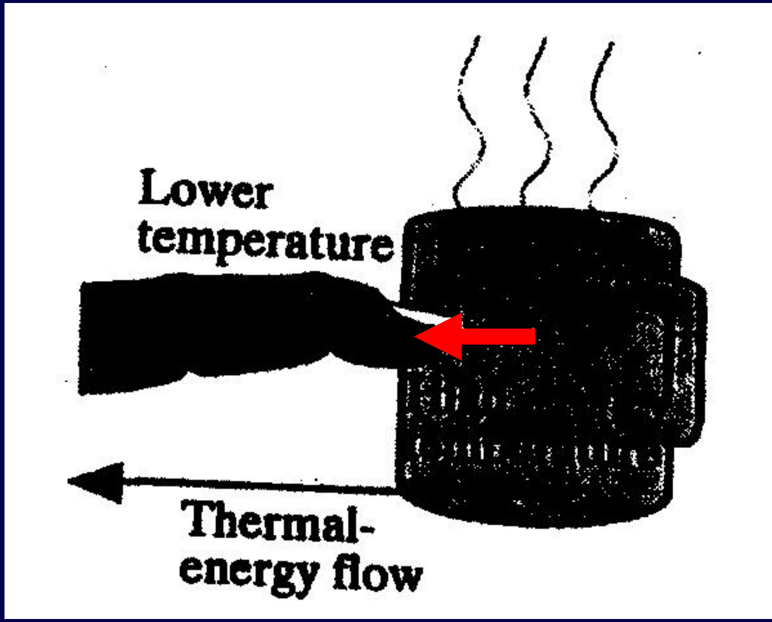
Heat will always pass from a substance of higher temperature to a substance of lower temperature, until both come to a common temperature.

Higher T ➔ Lower T

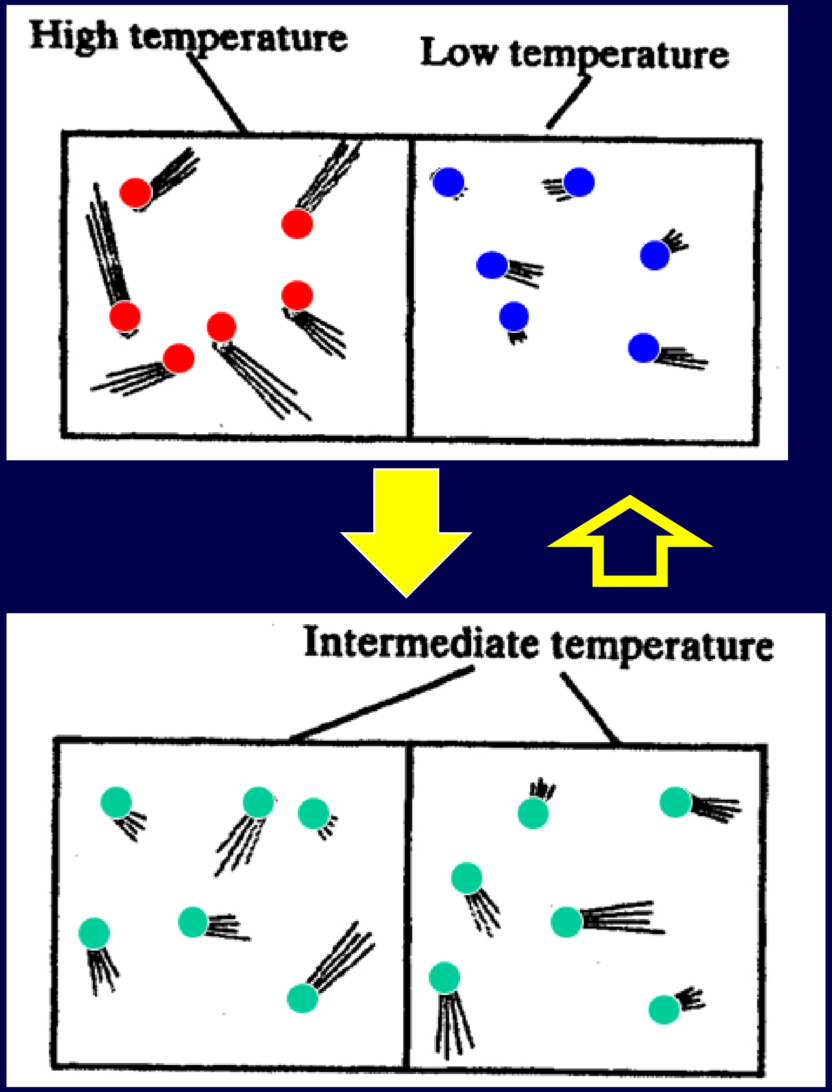
p 43



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

p 43

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

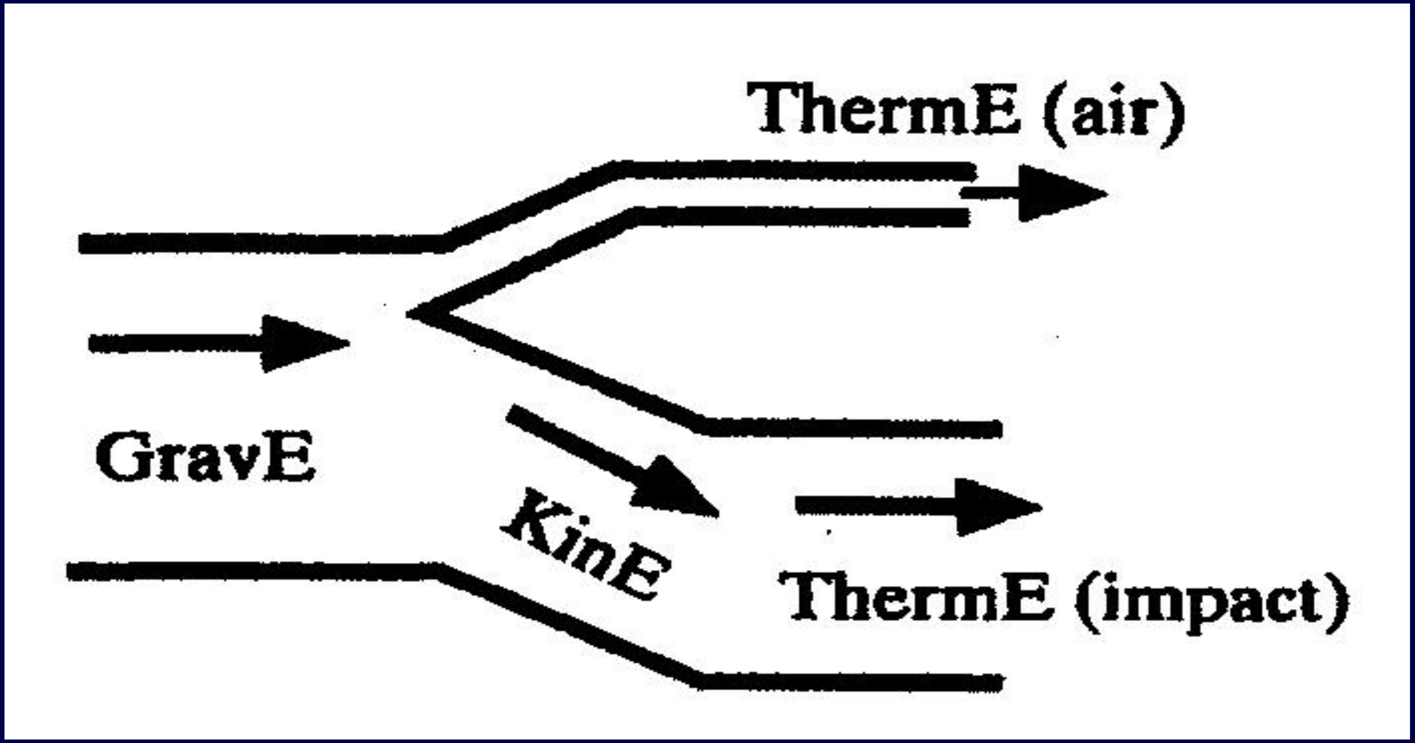
(stated as the "Law of Conservation of Energy")

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.

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 total amount of energy
(including heat energy)

is conserved,

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

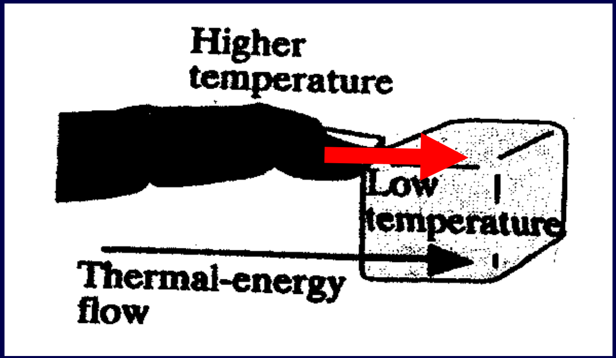
SECOND LAW OF THERMODYNAMICS
(stated as the "Law of Heating")

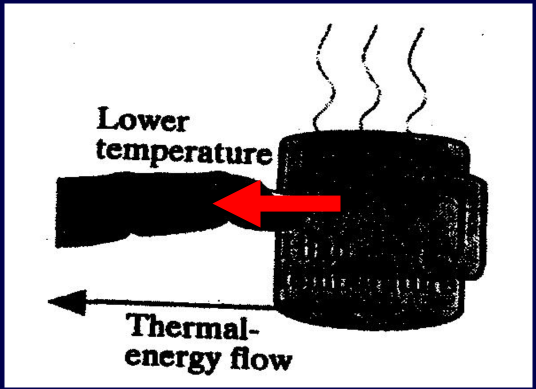
Heat will not flow spontaneously from a cold to a hot body.

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

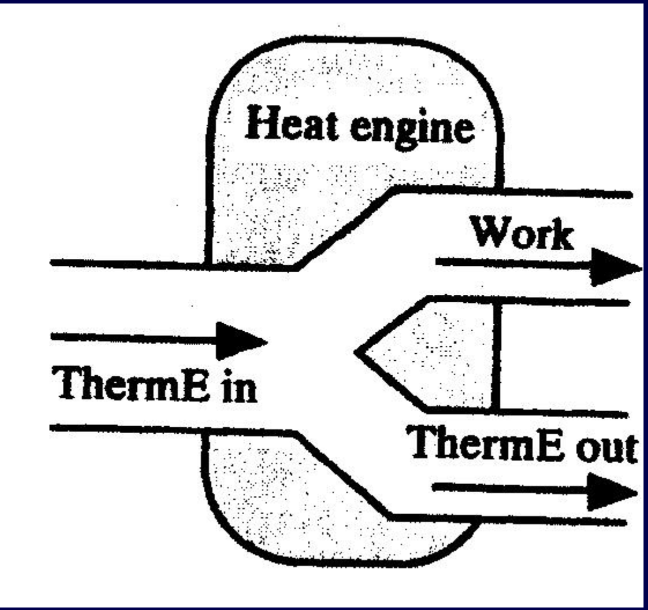
It will not spontaneously flow the other way!

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!

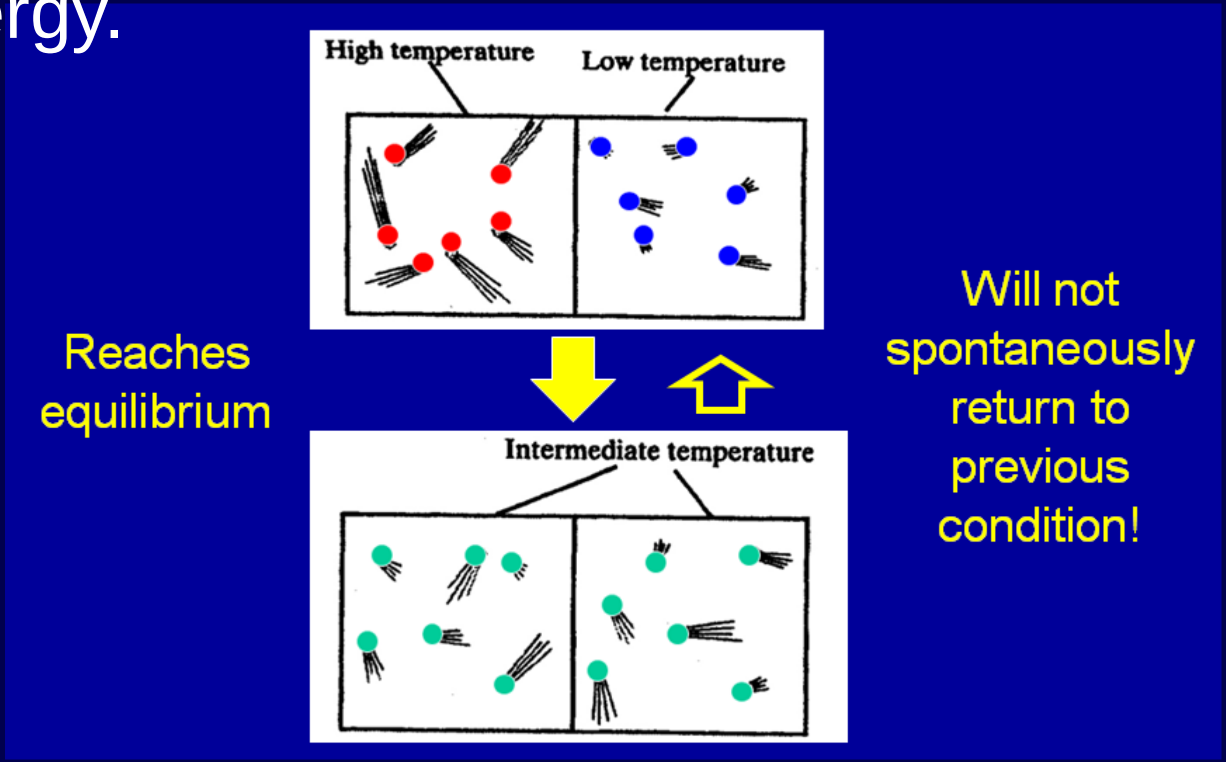
The 2nd Law stated a <u>THIRD</u> way:

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.



Got all that Homer?

boring . . . . !

CLICKER SELF-TEST TIME!!! . . . . ➔

Channel 32

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?

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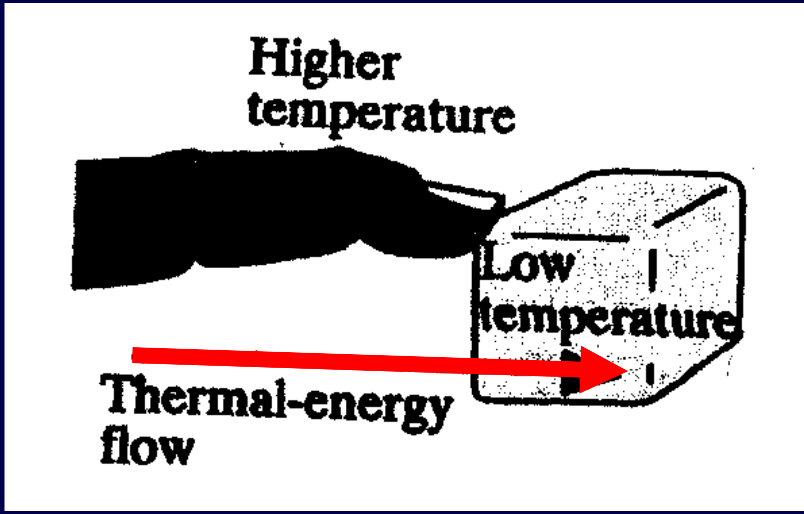
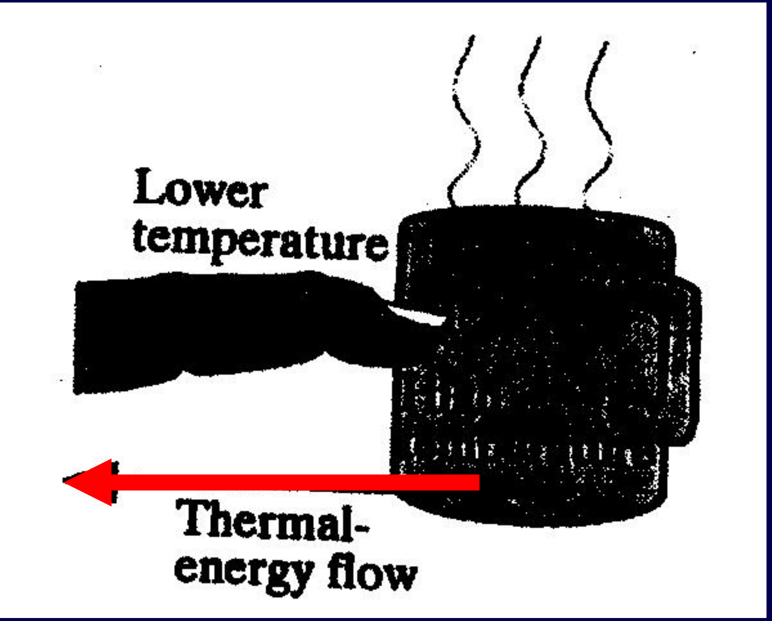


Explanation for answer to Q2:

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.



Can I go now????

NO!

It’s time for a Sustainability Segment!!!

The last segment of:

http://www.pbs.org/wgbh/nova/solar/

Can I go now????

YES!!

But don't forget RQ-4

on Wednesday before class!!