Sustainability: Principles and Practices
Spring 2014

PPT Set 1: January 30, 2014

Professor Anthony Serianni

Sources of Resistance to Adopting Sustainable Action and Behaviors

Conflicts of Interest
Scientists
Media
Policymakers
Business

24/7/365 Access to Information/Knowledge

Complexity
Uncertainties

Lack of Knowledge
Public
Policymakers

The Anthropocene (video)

Some basic ideas/principles…….

Some Goals and Outcomes of Sustainability Studies

♦ Greater awareness of externalities

♦ Importance and practical implications of statistical error, uncertainty, theoretical models, projections

♦ Recognition of explicit and implicit assumptions

♦ Creation/promotion of citizen-scientists; translation of theory into action

Sustainability is a ***process or journey*** with no definitive end-point or final destination. Sustainability evolves and changes over time as knowledge and understanding of ***complex systems*** increase.

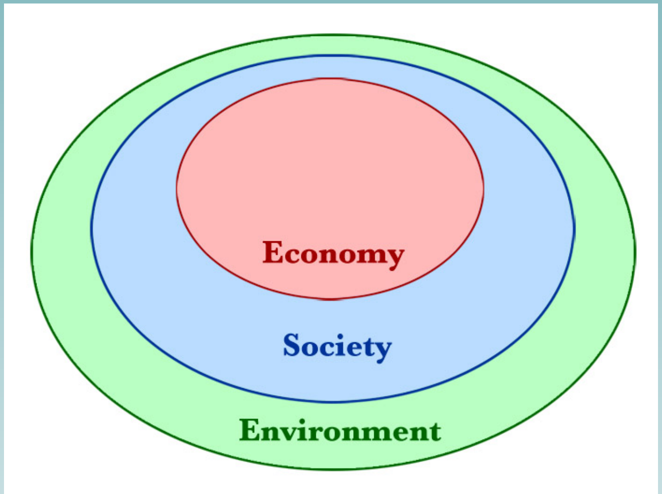
An analogy

cGMP (<u>c</u>urrent <u>G</u>ood <u>M</u>anufacturing <u>P</u>ractices) in the pharmaceutical industry; cGMP is a process; you cannot test your way to cGMP compliance; it is called "<u>c</u>GMP" because <u>current</u> good manufacturing practices are not constant but instead evolve over time.

Sustainability is not only about energy and climate change.

Sustainability involves an interplay between the three E's:

Economy, Energy, Environment



There are questions, problems, challenges.....

and there are answers and solutions.

Some Reasons for Skepticism About Adopting Sustainable Behaviors

(1) Selfishness; lethargy
(2) Conflicting geopolitical missions and/or agendas
(3) Confused or mixed messages
(cargo cult science; pseudoscience)
(4) Incomplete knowledge; uncertainties in predicting/forecasting the future

Aims of the Next Few Lectures

Present some core information and tools; define key terminology

Terms and definitions
Mathematical functions
Climate science
Biological cycles
Thermodynamics
Systems thinking

Identify problems/challenges

Sustainability terms (handout)

Some Mathematical Functions

Change in a given parameter as a function of some variable (*e.g.*, time) can occur in various ways. Mathematical functions (equations) describe <u>quantitatively</u> how a given parameter depends on the variable (for example: how fast a population grows; how fast a non-renewable resource is depleted).

Let's compare *linear growth* in a particular quantity (say, a population) to *exponential growth* in the same quantity.

A **linear function or linear growth** implies a constant (fixed; incremental) change in the quantity (*e.g.*, population) over a fixed time interval.

The equation takes the following form:

$$\mathbf{P_x = P_o + (\mathit{a}P_o)x}$$

where "*a*" is the *fractional increase in* P_o (the initial population) per 1-year time interval; *e.g.*, $a = 0.01$ for a 1% increase or 0.5 for a 50% increase.

In the initial state, x = 0, and $P_x = P_o$. Let's assume an initial population of 100.

If we assume a linear growth of 50% per year, then *a* = 0.5; after Year 1, $P_x = 100 + (50)(1) =$ **150**.

After Year 2, $P_x = 100 + 50(2) =$ **200**.

After Year 3, $P_x = 100 + 50(3) =$ **250**.

The population increases by a *constant or fixed amount* per year, in this case 50. The increase is linear.

Now let's consider **exponential growth** in a quantity (*e.g.*, population). In this case, the incremental increase from one year to the next is *no longer constant or fixed*, but rather increases *non-linearly* over time.

The equation describing this behavior takes the following form:

$$P_x = P_o\ (1+a)^x$$

Note the exponent, x (this is an exponential equation). If we assume an increase of 50% from year to year, then $a = 0.5$. When $x = 0$, the quantity $(1+a)^x = 1$, and $P_x = P_o$. Let's assume $P_o = 100$.

When $x = 1$, $P_x = 150$; when $x = 2$, $P_x = 225$, when $x = 3$, $P_x = 337$; **when $x = 20$, $P_x = 332{,}526$!**

Compare this result to that obtained when $x = 20$ in the linear growth model:

$$\mathbf{P_x = 100 + (100 \times 0.5)20 = 1100.}$$

A far smaller number!

The same amount of time has transpired in both models, but the net growth in population is very different.

Illustration

2% linear *vs* 2% exponential annual growth in a population

x	P_x
0	100
5	110
10	120
50	200
100	300
150	400
200	500
300	700
400	900

x	P_x
0	100
5	110
10	122
50	269
100	724
150	1950
200	5248
300	38023
400	275,466

Summary

Non-linear (exponential) growth is deceptive, especially when the percent annual growth is relatively small. In the banking world, this is the effect of "compounding".

When the annual percent growth is small, linear and exponential growth plots are virtually indistinguishable early in time. But a point in time eventually arrives when the two curves depart dramatically; this is the turning point of the so-called "J-curve" (or hockey stick curve) describing exponential change in a given quantity.

Exponential functions are stealthy and dangerous because they initially behave in a benign (*i.e.*, linear-like) fashion, but eventually produce very large change over a small time interval. Humans are relatively insensitive to exponential change.

A plot of an exponential growth in population:

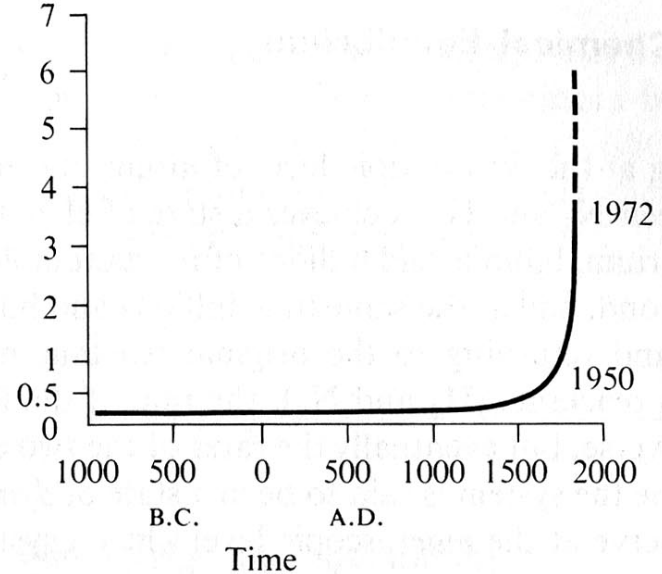


Figure 4-3 The Exponential, or "J," Curve of World Population Growth.

<u>Other terms</u>: In this plot, we vary time to see how the population is affected; thus, time is the *independent variable* and population is the *dependent variable*.

Other types of curves or relationships:

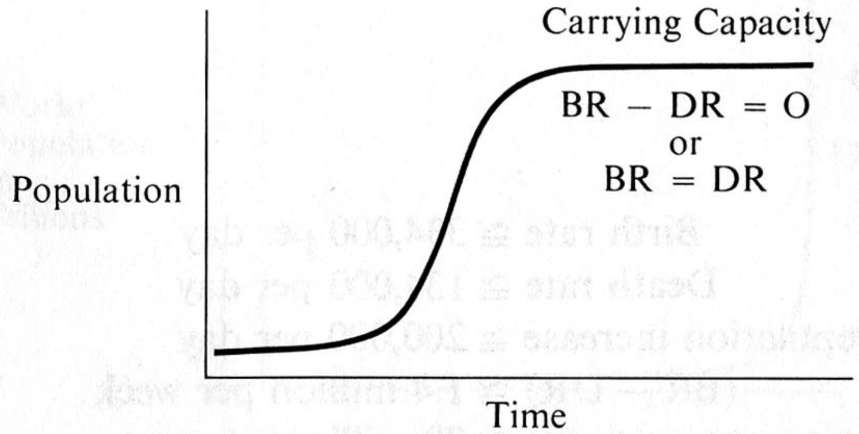


Figure 4-4 The "S" Curve of Dynamic Population Equilibrium, or Zero Population Change, Where Birth Rate (BR) = Death Rate (DR).

Sometimes referred to as a "sigmoidal" relationship

A more realistic S-curve:

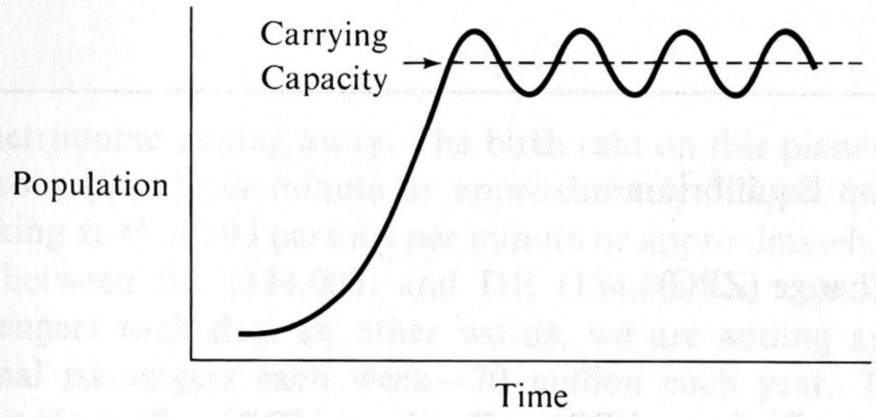


Figure 4-5 Modified "S" Curve to Show Population Fluctuations Around the Carrying Capacity.

Some concepts and terminology in ecobiology……

Time scales of chemical and biological evolution on Earth

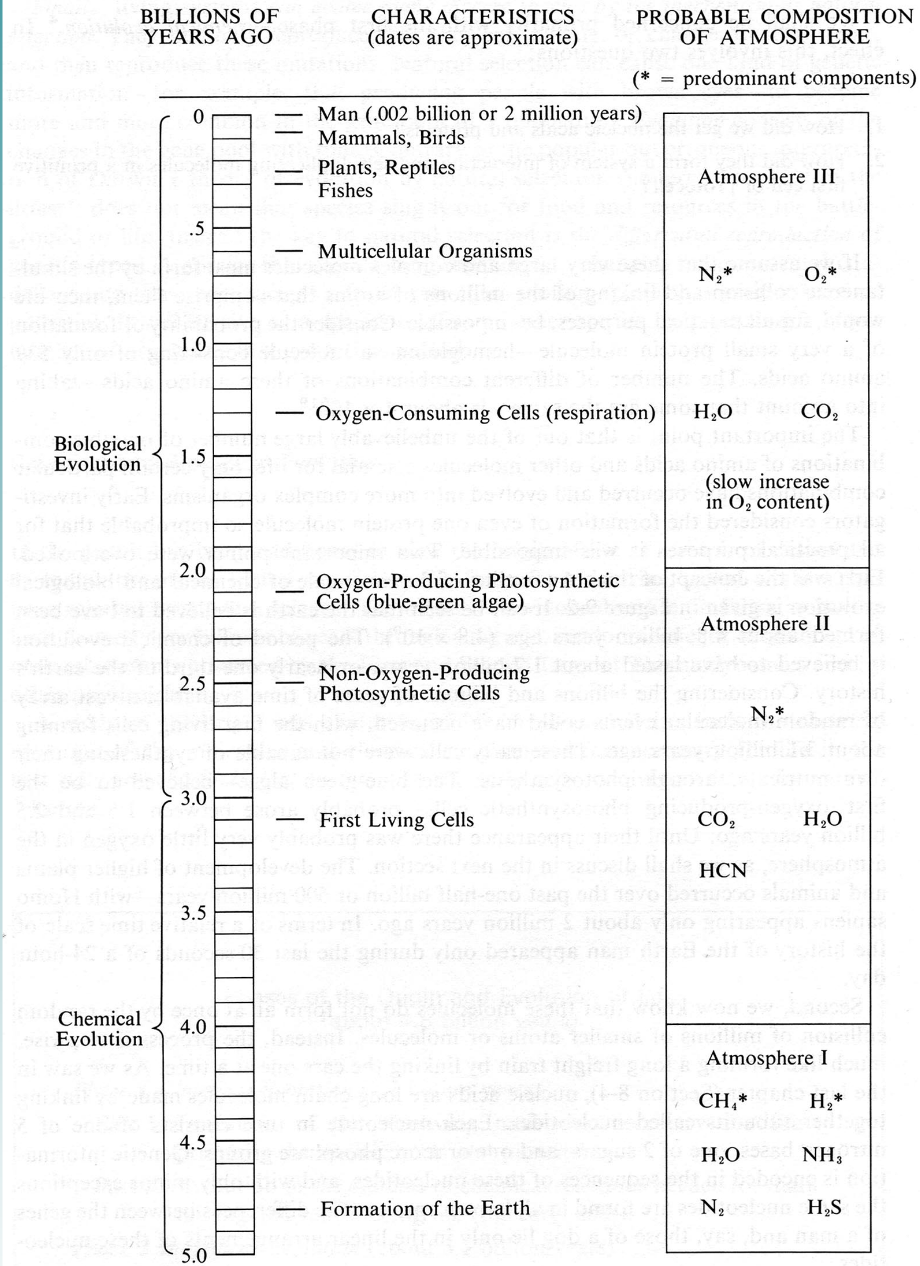


Figure 9-2 Approximate Time Scale of Chemical and Biological Evolution.

The **biosphere** (Edward Suess, 1831-1914; an early practitioner of ecology) is the global sum of all ecosystems; the zone of life on Earth; the thin film of air, water and soil where all life exists on Earth (about 1/1000 of the planet's diameter); it is a closed, self-regulating system.

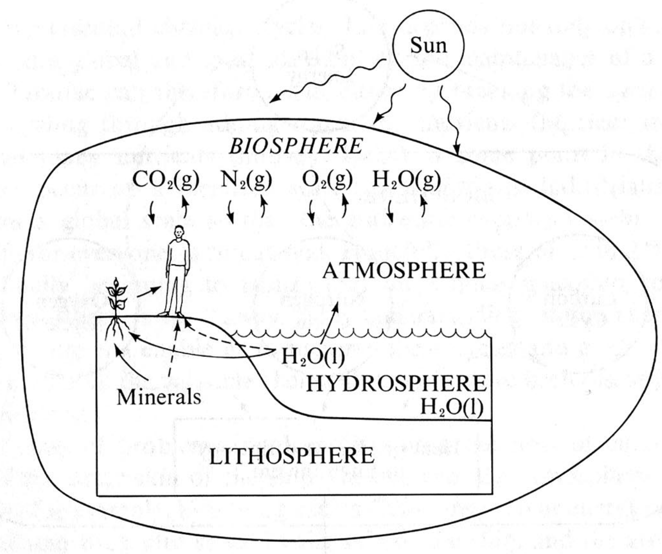


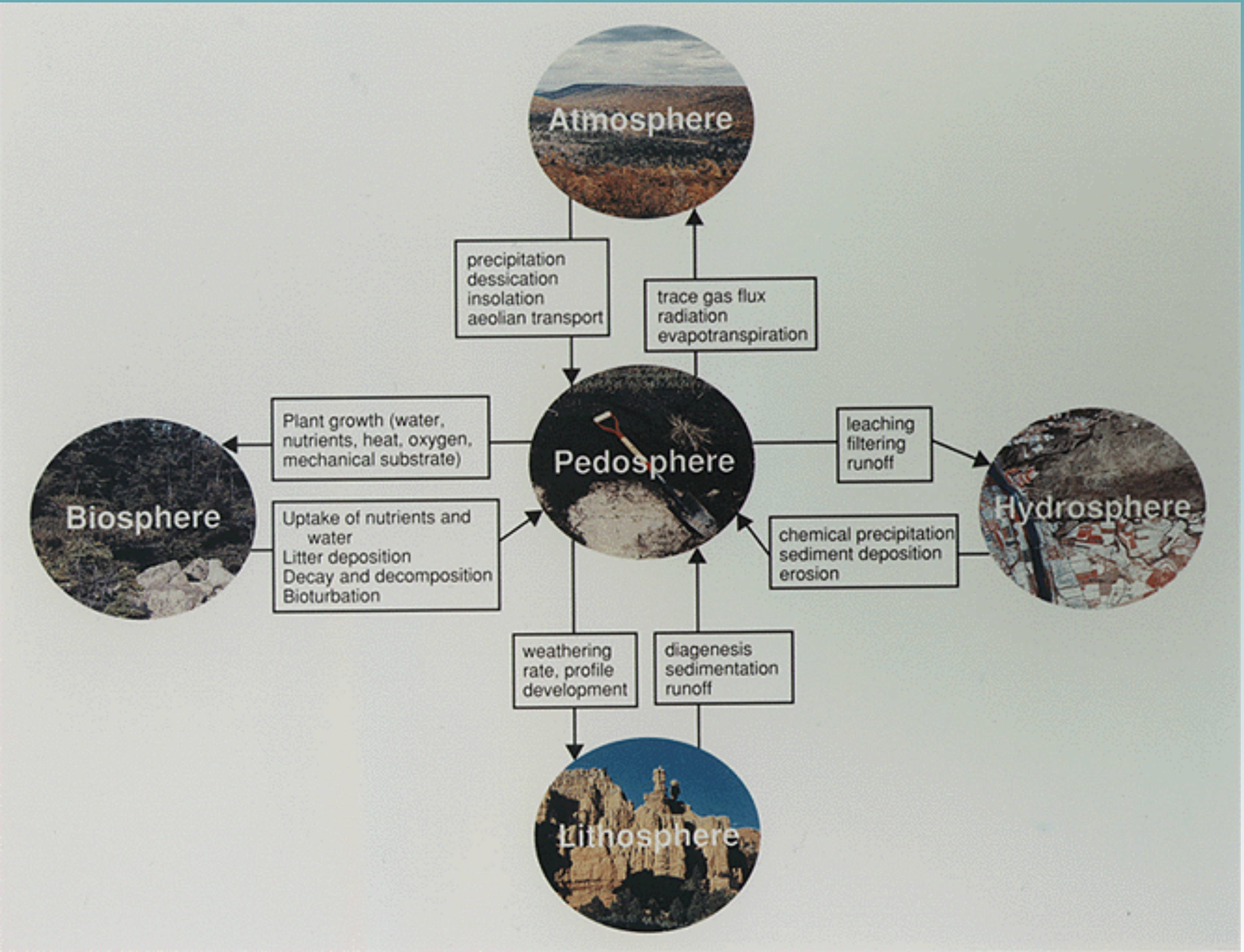
Figure 10-1 Spaceship Earth and the Major Components of Our Life-Support System—the Biosphere.

atmosphere
hydrosphere
lithosphere

"…one thing seems to be foreign on this large celestial body consisting of spheres, namely, organic life. But this life is limited to a determined zone at the surface of the lithosphere. The plant, whose deep roots plunge into the soil to feed, and which at the same time rises into the air to breathe, is a good illustration of organic life in the region of interaction between the upper sphere and the lithosphere, and on the surface of continents it is possible to single out an independent biosphere."

(*The Face of the Earth*,1885-1901 – three volumes)

The Pedosphere: The "Skin" of the Earth



The Biogeochemical Cycles

Three major gas cycles in the biosphere

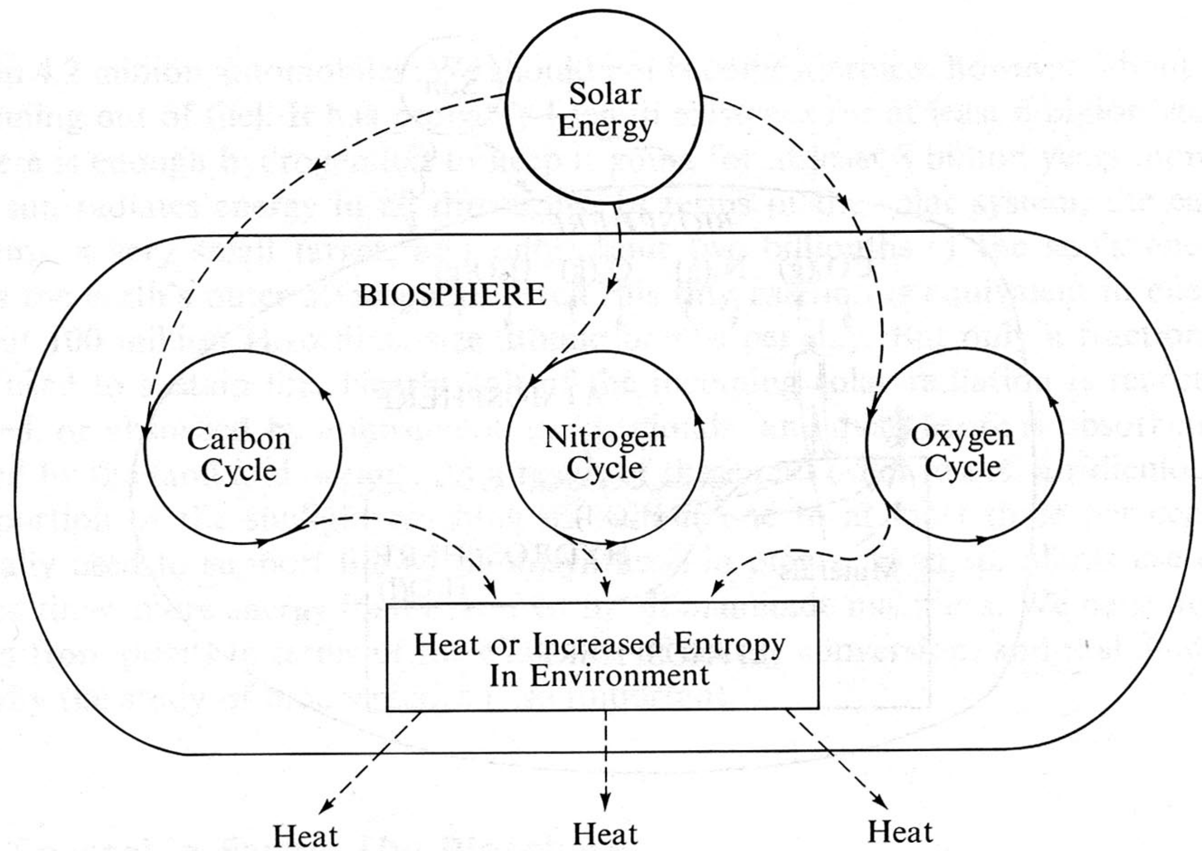


Figure 10-2 Life on Spaceship Earth Depends on the Cycling of Critical Chemicals and the One-Way Flow of Energy through the Biosphere.

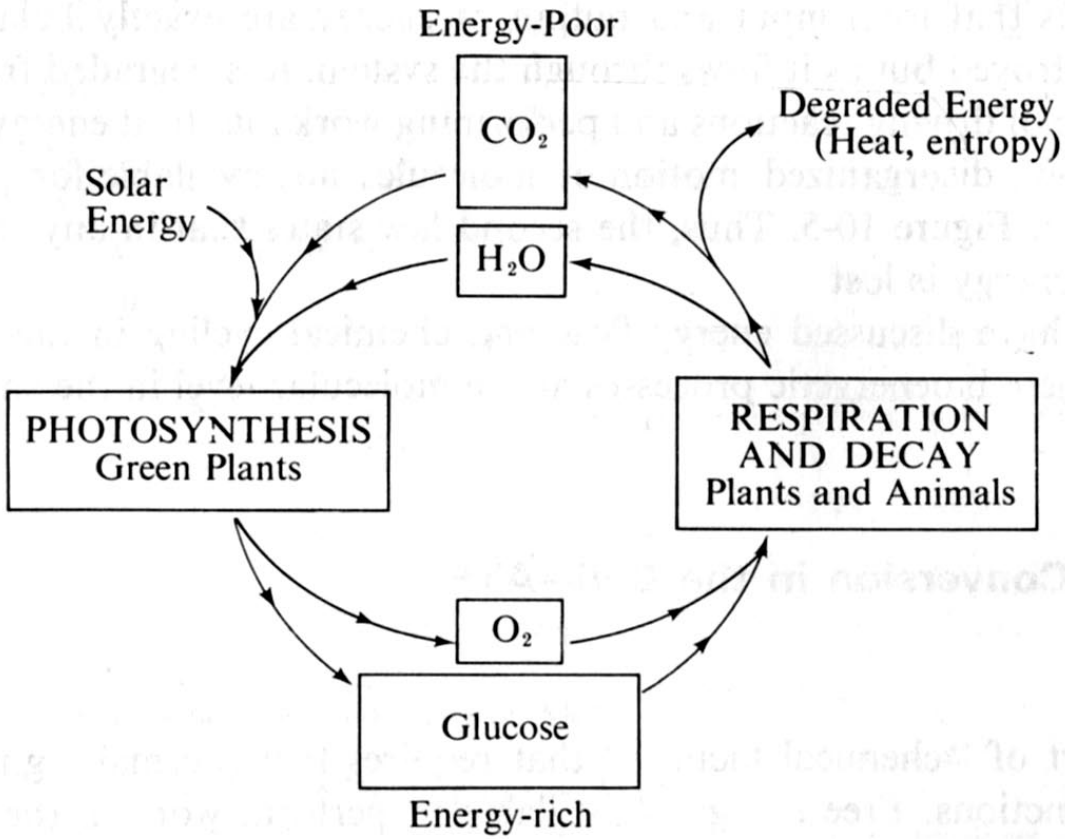
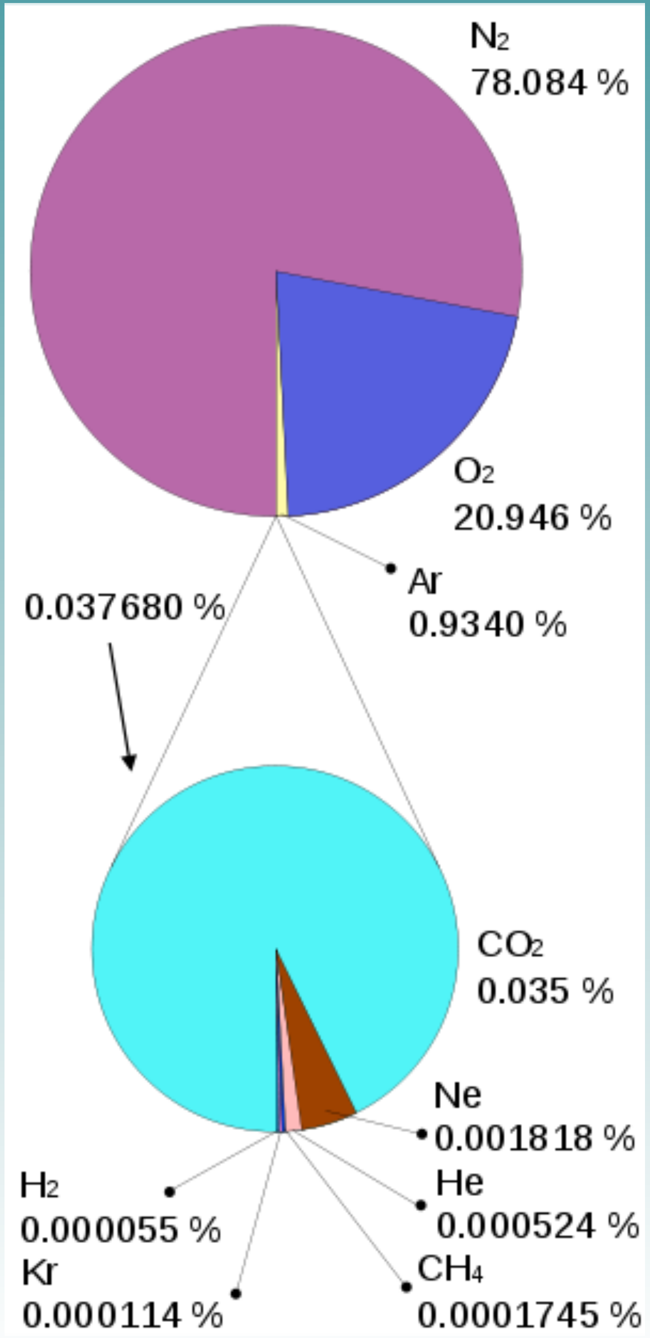


Figure 10-4 Simplified Version of the Carbon and Oxygen Cycles in the Biosphere.

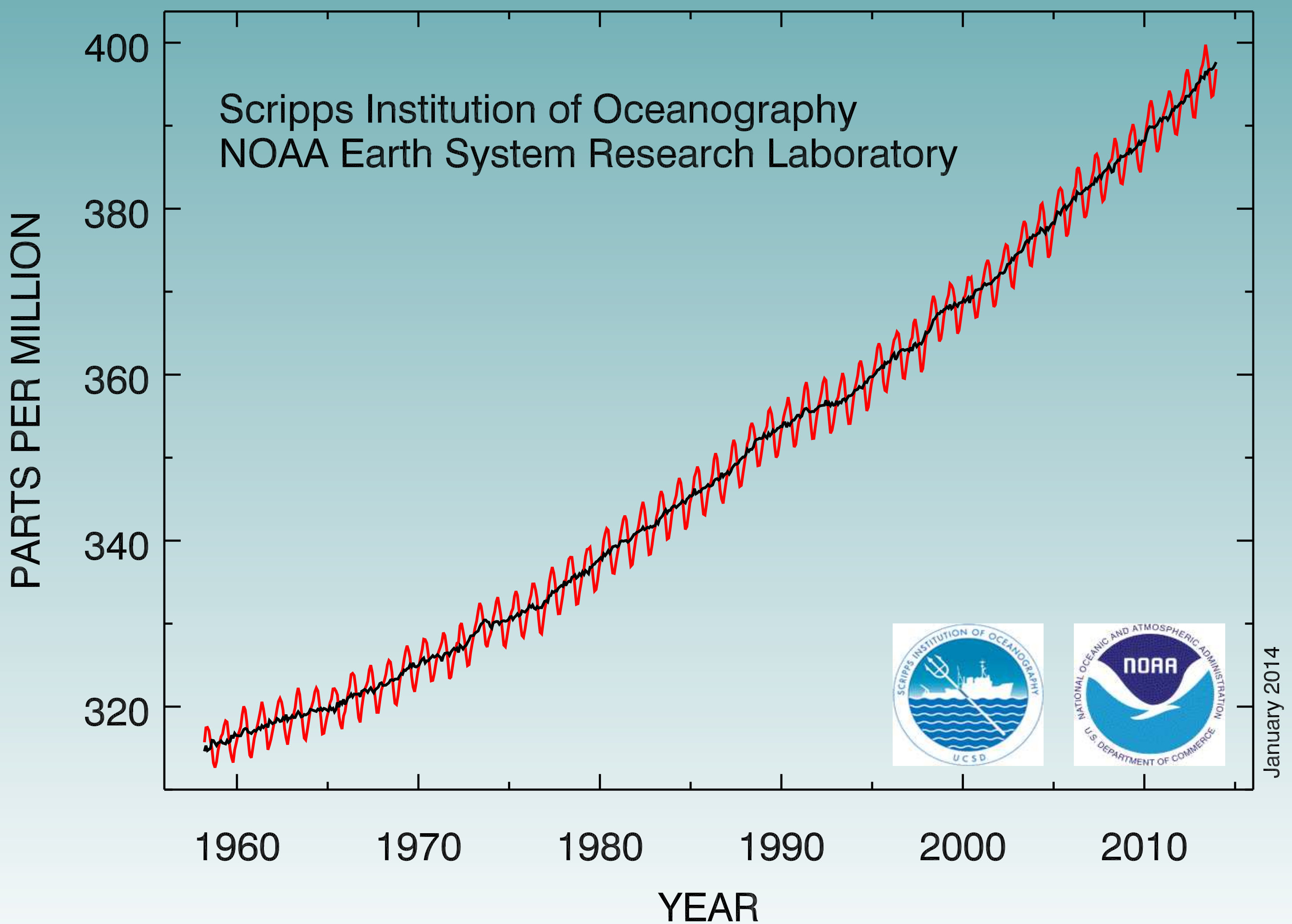
[5] Report of the Study of Critical Environmental Problems, *Man's Impact on the Global Environment*, The MIT Press, 1970 (paperback). An excellent and readable summary of environmental problems by teams of prominent scientists. An additional source is *Global Effects of Environmental Pollution*, S. F. Singer (ed.), Springer-Verlag, New York, Inc., 1970.



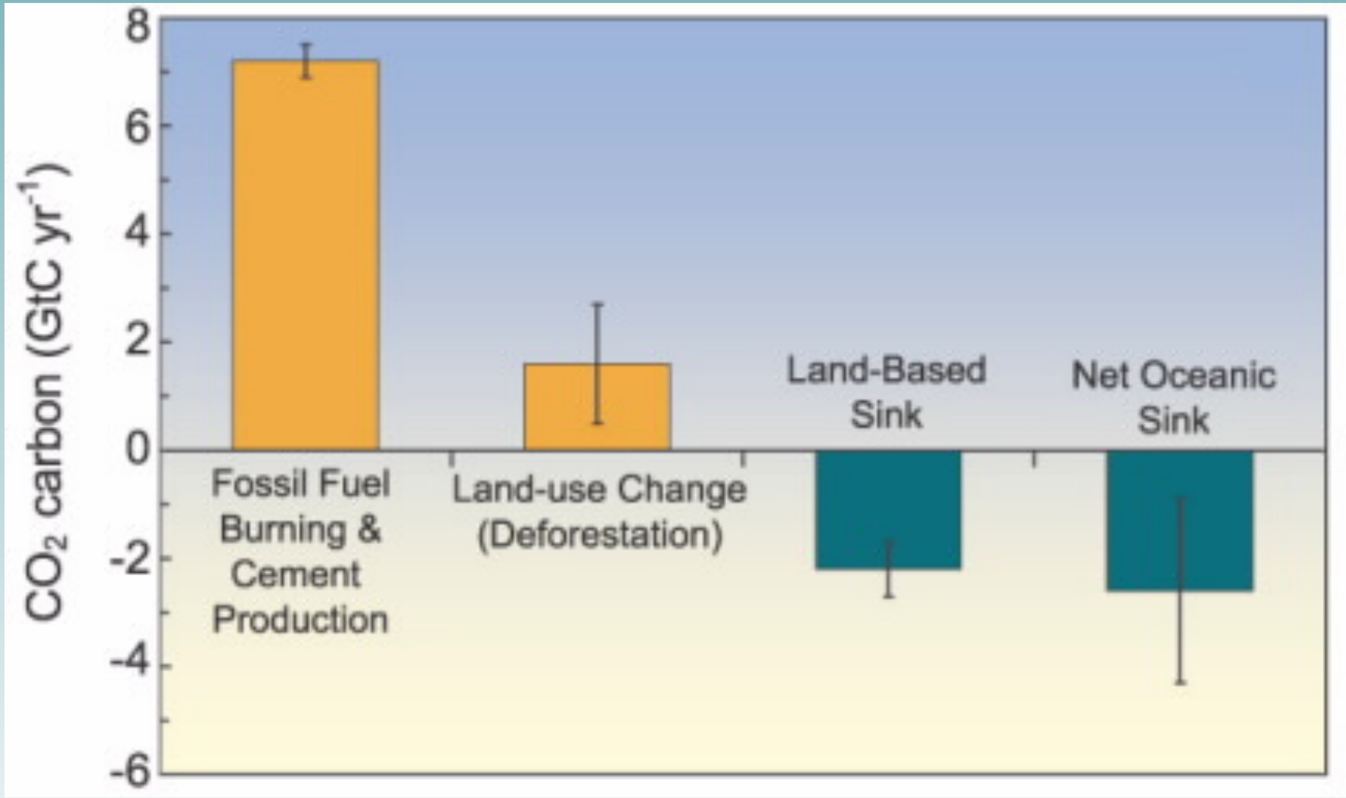
Current composition of Earth's atmosphere

Carbon dioxide and methane data: 2009

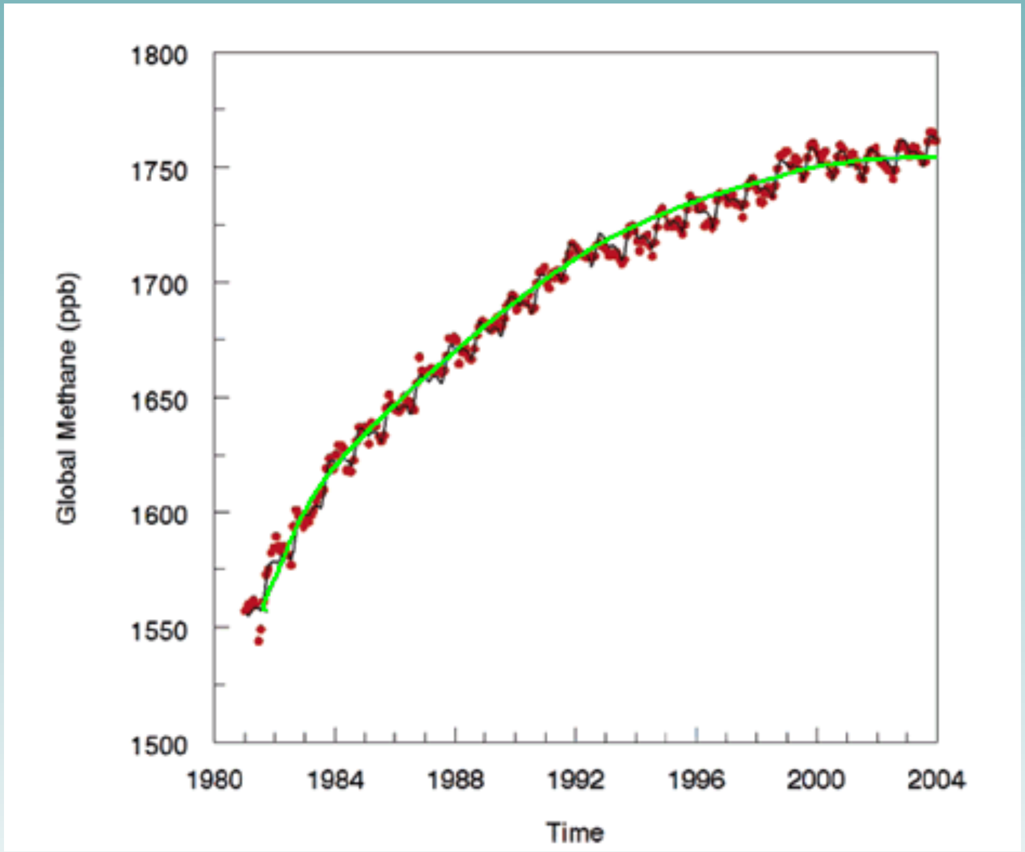
Atmospheric CO_2 at Mauna Loa Observatory



Major atmospheric CO_2 sources and sinks



Global atmospheric CH_4 concentrations (1980-2004)



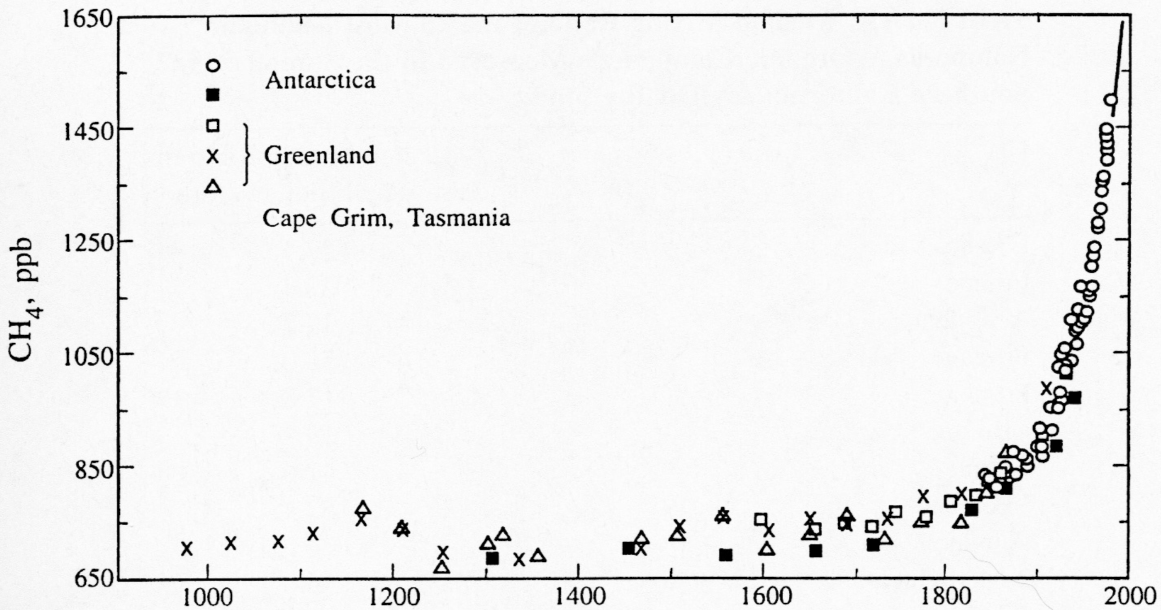
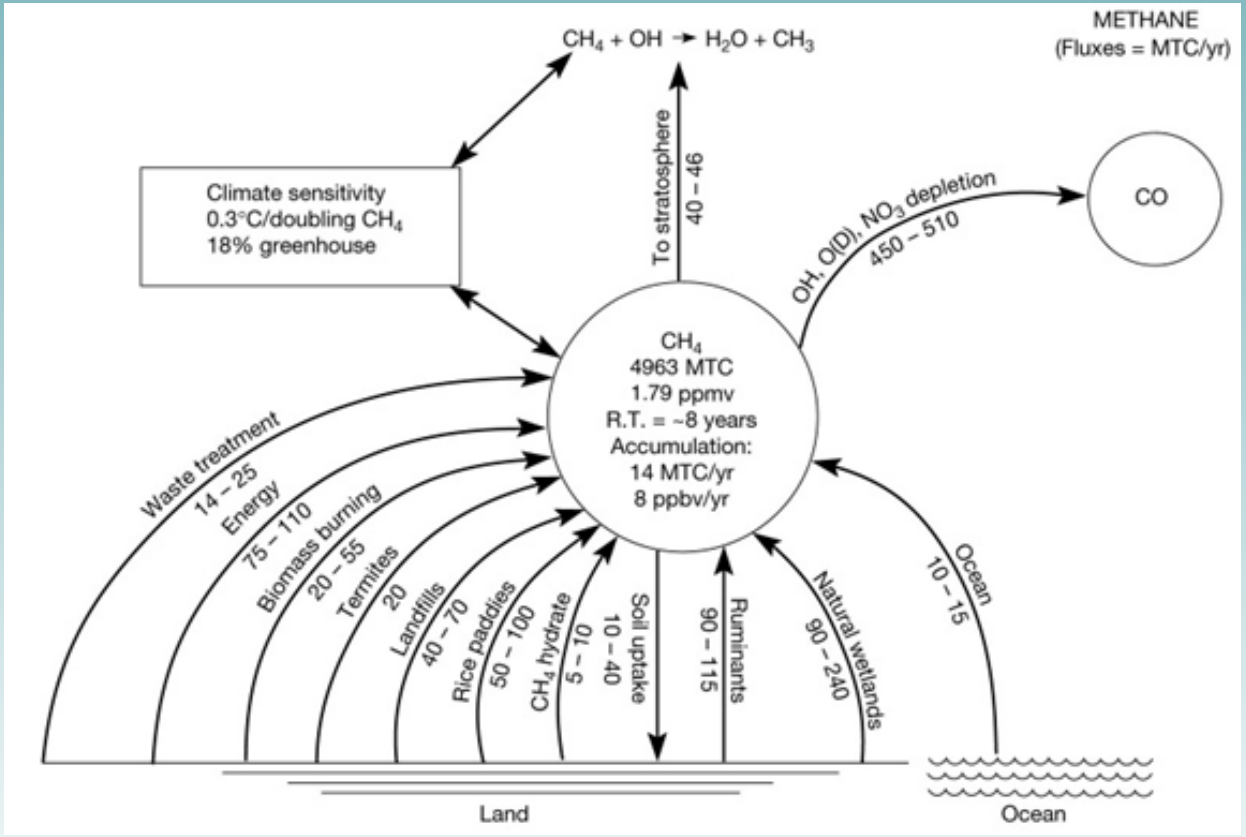
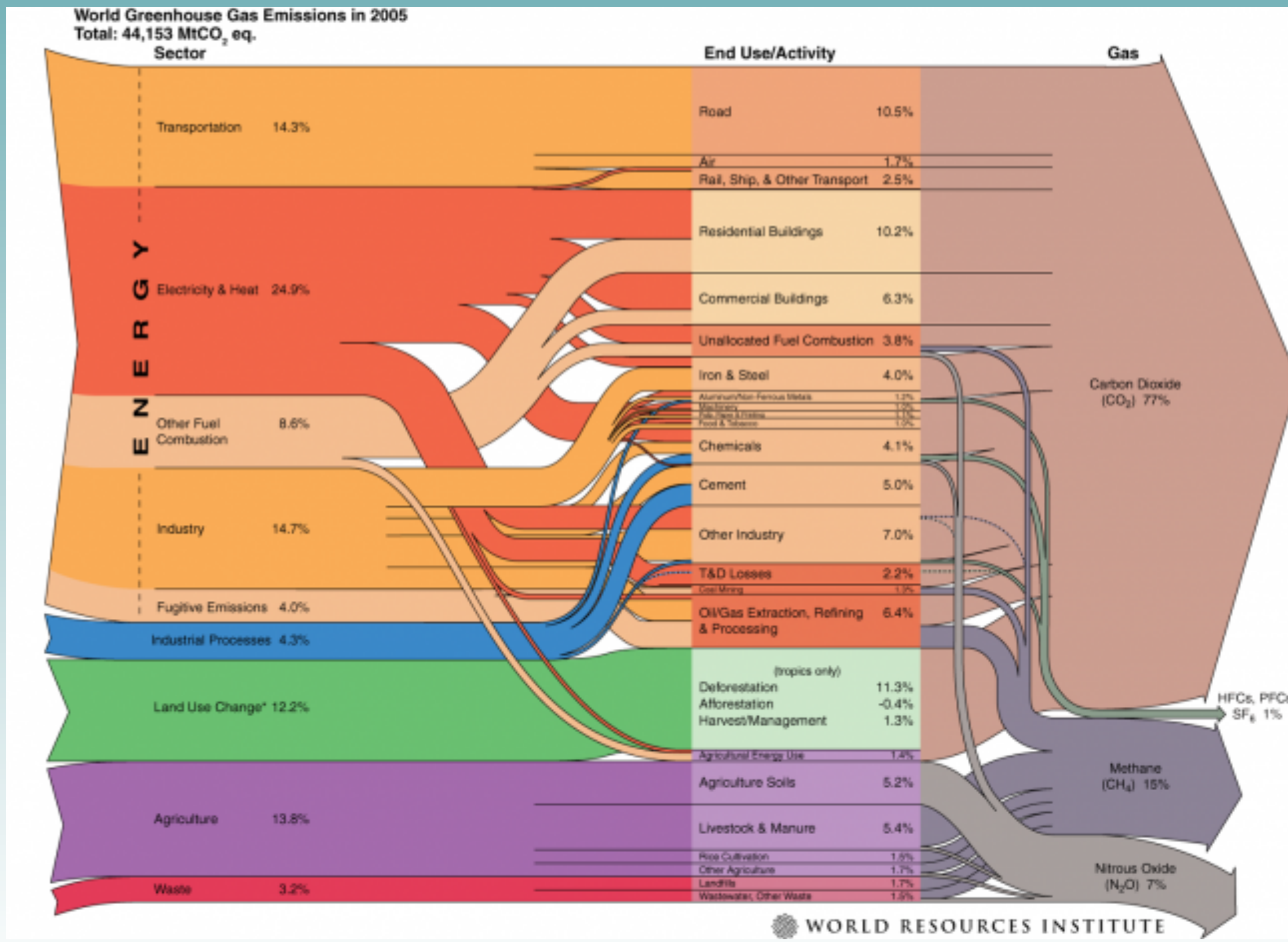


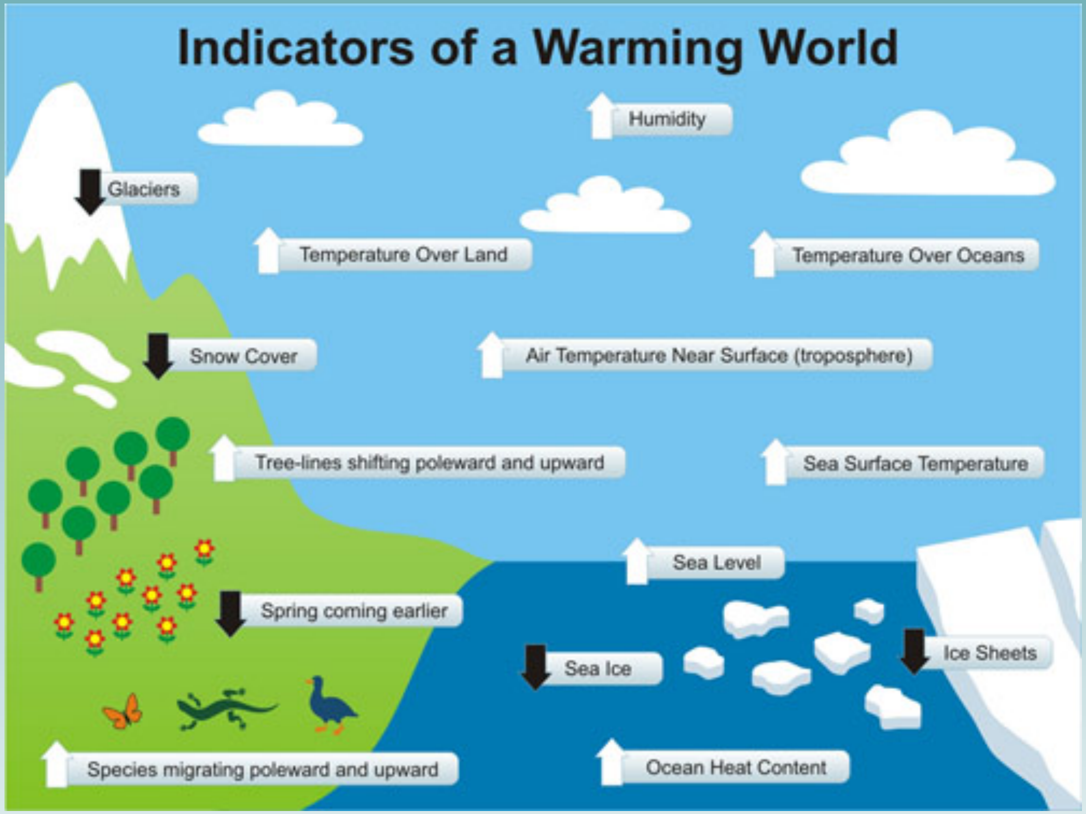
FIGURE 2.4 Methane mixing ratios over the last 1000 years as determined from ice cores from Antarctica and Greenland (IPCC 1995). Different data points indicate different locations. Atmospheric data from Cape Grim, Tasmania, are included to demonstrate the smooth transition from ice core to atmospheric measurements.

Sources of, and Sinks for, Atmospheric CH_4



Human activity and CO_2/CH_4/N_2O emissions




Indicators of a Warming World
Humidity
Glaciers
Temperature Over Land
Temperature Over Oceans
Snow Cover
Air Temperature Near Surface (troposphere)
Tree-lines shifting poleward and upward
Sea Surface Temperature
Sea Level
Spring coming earlier
Sea Ice
Ice Sheets
Species migrating poleward and upward
Ocean Heat Content

The Gaia Principle (Hypothesis/Theory)

James Lovelock and Lynn Margulis, 1970's

The Gaia theory regards the earth as, in essence, a single organism, and everything on the planet as a part of that organism. This does not merely mean all living things, or even all organic matter, but postulates that the planet, with its rocks, plants, animals and atmosphere, is essentially "a single, living, self-regulating system."

The implications of this are that all the various components of the Earth's system play a part in regulating the overall biosphere so as to maintain an optimum situation for the living system. Various feedback mechanisms operate so as to maintain the earth as a place where life can continue – for example, atmospheric temperatures have adapted to overcome increasing incoming radiation from the sun.

Temperature is not the only factor affected. The Gaia theory also looks at other variables such as the salinity of the oceans, the hydrological cycle (which affects rainfall), oxygen in the atmosphere, biodiversity and the stability of ecosystems, and the processing of CO_2.

Gaia (from Greek mythology): The Greek goddess of the earth; the mother of all Greek gods through her union with the Sky (Uranus) and the Sea (Pontus).

Articulating the concept of "Gaia":

"It is at least not impossible to regard the earth's parts—soil, mountains, rivers, atmosphere etc,—as organs or parts of organs of a coordinated whole, each part with its definite function. And if we could see this whole, as a whole, through a great period of time, we might perceive not only organs with coordinated functions, but possibly also that process of consumption as replacement which in biology we call metabolism, or growth. In such case we would have all the visible attributes of a living thing, which we do not realize to be such because it is too big, and its life processes too slow."

— Stephan Harding in "*Animate Earth*", 2006 (Schumacher College, Devon, UK)