Ecosystem Ecology

- Read Chps 18-19 (know N, P, C cycles)
- **Ecosystem:** A community of organisms plus its nonlinving (=abiotic) environment
- At the individual level, the abiotic environment affects organisms (physiology, behavior, etc.)
- At the whole community level, organisms can also affect the abiotic environment

Ecosystems as machines

- Ecosystems process matter and energy
- Distinctly different approach from individual, population, & community ecology
  - mostly non-evolutionary
  - more non-biological processes (chemistry, physics)
  - Laws of physics determine a lot of what goes on in ecosystems

Simple laws of physics

- **Conservation of matter** -- matter is neither created nor destroyed, only changed in form
- **Conservation of energy** -- energy is neither created nor destroyed, only changed in form
- **Entropy** -- Any transfer or change of energy cannot be 100% efficient. Some energy is degraded to lower quality, less useful energy (=heat)

Energy

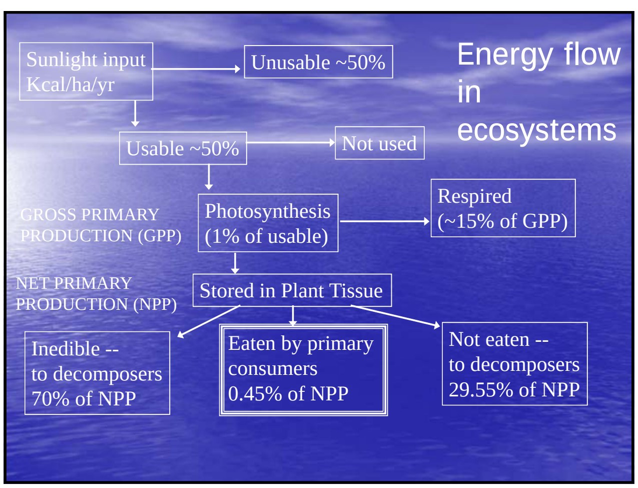
- Ability to do work
  - Kinetic -- energy now doing work
  - Potential -- energy stored (e.g., in chemical bonds within living organisms)
- Consequence of entropy
  - material moves spontaneously down a concentration gradient
  - the reverse requires expenditure of energy
  - Organisms move matter up concentration gradients by expending energy

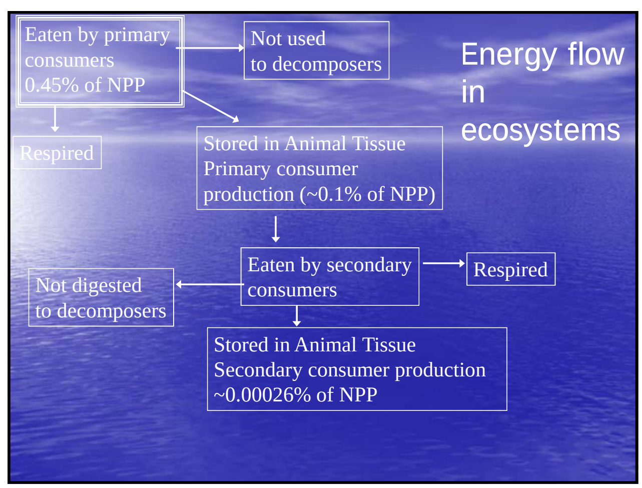
Energy flows within ecosystems

- Energy moves one way within ecosystems
- No cycles
- Every transfer results in reduction in usable energy (production of some heat)
- Input is energy from nonliving sources, primarily the sun via photosynthesis

Trophic levels: steps in energy transfer

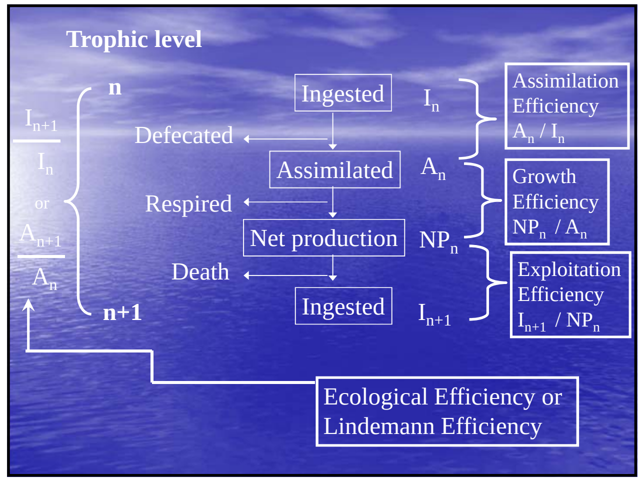
- 1st trophic level -- Primary producers
  - photosynthetic autotrophs, some chemosynthetic autotrophs
- 2nd tropic level -- Primary consumers
  - heterotrophs consume primary producers (herbivores)
- 3rd trophic level -- Secondary consumers
  - heterotrophs consume primary consumers (carnivores)
- 4th trophic level -- Tertiary consumers
  - heterotrophs consume secondary consumers (carnivores)
- Decomposers -- mostly bacteria & fungi
  - heterotrophs that consume dead organisms (detritivores)





Energy flow

- Most energy is either:
  - Respired (work, entropy)
  - Unused (to decomposers)
- Patterns vary a lot globally
- **Efficiency:** Proportion of available energy at one point in a food chain that is transferred to another point



Efficiencies

- Ecological (Lindemann) Efficiency -- transfer between adjacent trophic levels
- Broadly averages <u>10%</u> (varies a lot)
- Assimilation efficiencies:
  - detritivore (rotten wood) 15%
  - herbivore (foliage) 30%
  - carnivore 96%
- Growth efficiencies:
  - Ectotherms 33%
  - Endotherms 5%

Matter cycles

- Consequence of the **conservation of matter**
- Every element of any biological significance is cycled within ecosystems
- C, N, P, S, others
- Cycled from organisms to nonliving environment and back to organisms
- Example: Carbon cycle

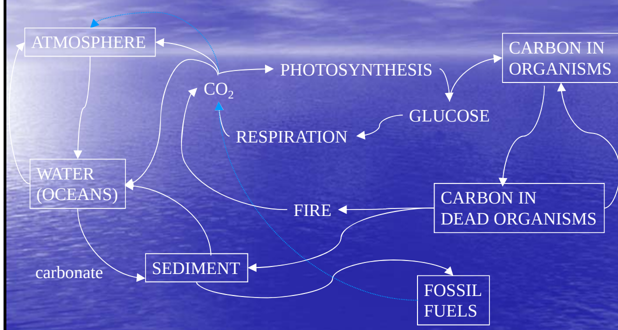
Carbon cycle

- Carbon -- primary molecule in organisms
- Photosynthesis:

LIGHT

  – $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$
- Respiration:
  – $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

CARBON CYCLE

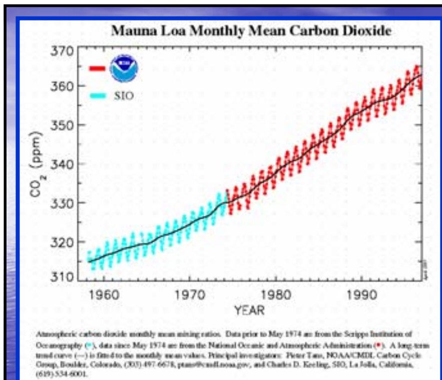


Carbon cycle

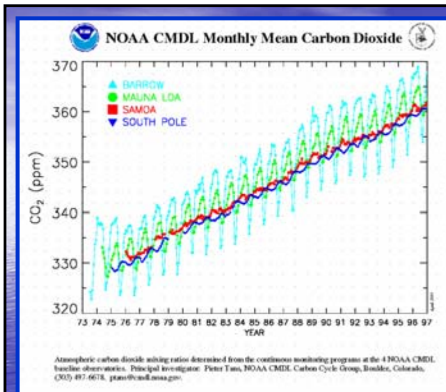
– current CO_2 ~391.03 ppm and rising

Fossil fuels & Carbon Cycle

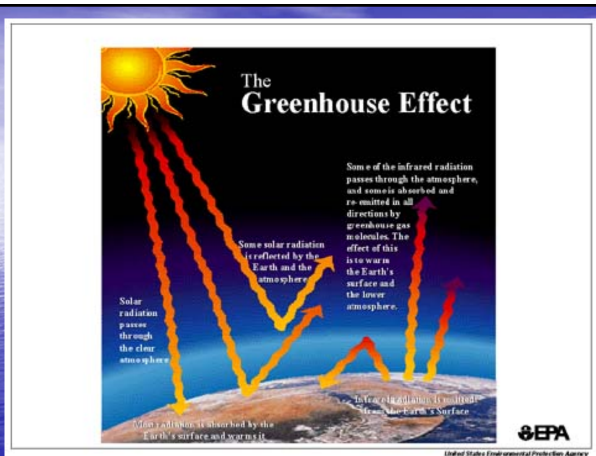
- Read Ch. 19
- Burn fossil fuels at a high rate
- Carbon stored over millions of years released to atmosphere in a few decades
- Atmospheric CO_2 increases



CO_2 increase



CO_2 increase



Consequences of CO_2 increase

- CO_2 absorbs infrared radiation - heats atmosphere
- Visible light hits earth - reradiated as infrared
- Greenhouse effect -- heats atmosphere
- Expectation: with addition of more CO_2, climate of earth changes
- Global climate change
  - "Global warming"

Other greenhouse gases

- H_2O, CH_4, N_2O, & flourocarbons also absorb infrared radiation
- Also increased by human activities
- CH_4 absorbs 25X more infrared than CO_2
- N_2O absorbs 320X more infrared than CO_2

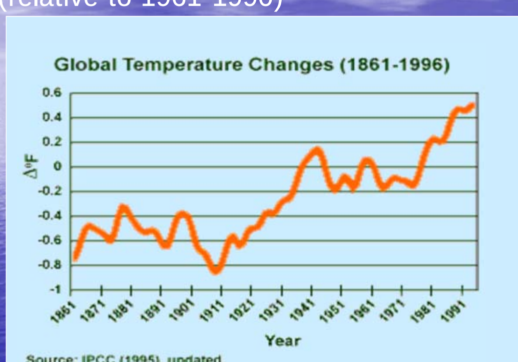
Sources of greenhouse gases

Table 1-1, (IPCC 1995)

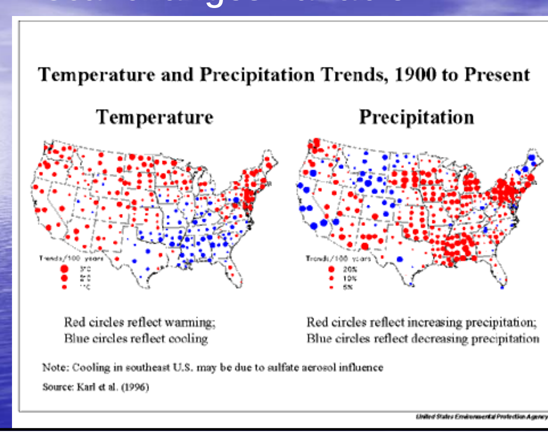
Sources	CO_2	N_2O	CH_4
Natural		• Microbial activity in soil	• Wetlands • Termites • Oceans & freshwater
Anthro-pogenic	• Fossil fuel combustion • Net emissions from changes in tropical land use	• Land clearing • Biomass burning • Fossil fuel combustion • Nitrogenous fertilizer	• Fossil fuel mining & processing • Rice paddies • Enteric fermentation • Animal waste • Domestic sewage treatment • Landfills • Biomass burning

Climate warming

(relative to 1961-1990)



Local changes variable



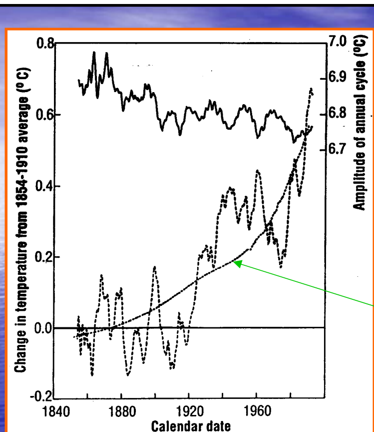
Are these changes predicted by greenhouse models?

- Last century -- average temperature ⇑ by ~ 0.3 to 0.6ºC
- Last 40 years -- average temperature ⇑ by ~ 0.2 to 0.3ºC
- Climate models based only on greenhouse gases predict ⇑ of 1.0ºC
- Improved models incorporate aerosols (small particles) that reflect solar radiation
- Yield much more accurate predictions (global & local)

Alternative hypothesis

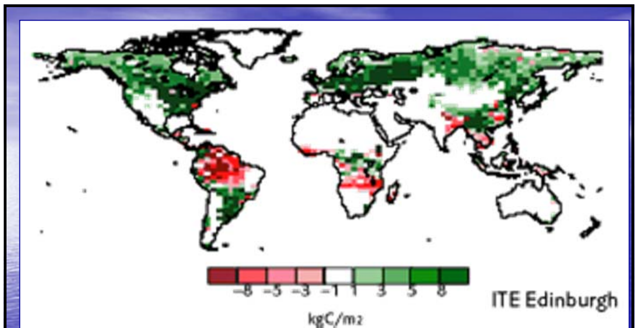
- Change in solar input
- Sun heats in summer & winter but more in summer
- Change in solar input ⇒ raise temperature more in summer than in winter
- **Predict:** Amplitude of seasonal temperature cycle should increase

Data on amplitude of seasonal cycle



The future

- Atmospheric CO_2 increase & other changes
  - average temperature ⇑ 1.0 - 3.5ºC (now to 2100)
  - average precipitation ⇑, mostly in winter
  - summers may be drier
  - lots of local variation
  - predicted loss of vegetation biomass in tropical rainforests
  - much more to this than “global warming”



Change in vegetation biomass between the 1990s and the 2080s in response to climate change due to unmitigated emissions.

The consequences

- Natural ecosystems
  - distributions change
  - productivity, energy flow, cycles change
- Predictions have high uncertainty

The consequences

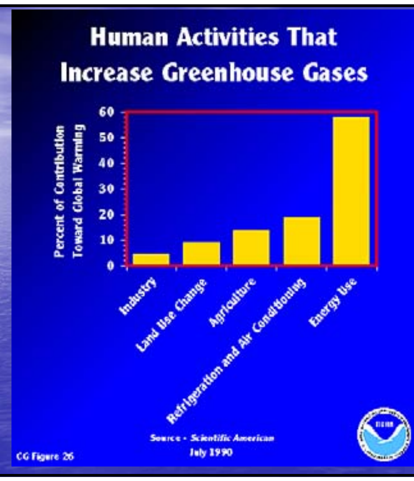
- Health effects (direct & indirect)
  - heat
  - tropical diseases
    - Dengue
    - Yellow fever
    - Malaria
    - Shistosomiasis
  - Dependent also on land use changes
- Uncertainty high

The consequences

- Agriculture
  - Importance of location
  - Northern areas: agricultural production increases
    - Greater duration of growing season
    - Greater CO_2
  - South: Europe, S. America: production declines
    - Reduced precipitation
    - Summer drought
- Uncertainty high

The consequences

- Sea level
  - +10 - 25 cm in past 100 years
  - Predict +45 cm by 2100
    - New York, Baltimore, Miami
    - Netherlands, Bangladesh
  - Causes
    - Expansion
    - Melt
    - Antarctic ice surge



Dilemma

- Human population and economic activity increase CO_2
- Predicted to produce climate change
- Effects uncertain
- **Uncertain costs vs. known economic benefits**
- Action?

Policy

- Adapt to new climate
- Reduce greenhouse gas emissions
- Given:
  - Economic benefits of fossil fuel use
  - Growing population
  - Economic development
- Adaptation to climate change seems likely.
- However, reducing emissions is possible
- **Expect elected officials to address the issue**

Individual action

- Energy conservation
- Population
- Consumption

Country	Year	Total	Population (millions)	Per capita emissions (t CO_2-e)
Australia	1998	**518.5**	18.75	27.6
Canada	1998	**662.0**	30.25	21.9
Denmark	1998	**74.6**	5.30	14.1
France	1998	**481.6**	58.40	8.2
Germany	1998	**975.4**	82.05	11.9
Ireland	1998	**57.3**	3.71	15.4
Italy	1998	**515.8**	57.59	9.0
Japan	1997	**1280.4**	126.09	10.2
Netherlands	1998	**224.2**	15.70	14.3
New Zealand	1998	**53.5**	3.79	14.1
Norway	1998	**36.5**	4.43	8.2
Russian Fed.	1996	**1086.3**	147.74	7.4
Spain	1998	**331.2**	39.37	8.4
Sweden	1998	**42.6**	8.85	4.8
UK	1998	**672.7**	59.26	11.4
USA	1998	**5806.2**	274.89	21.1

Source: UNFCCC 2001a; UNFCCC 2001b; World Bank 2001