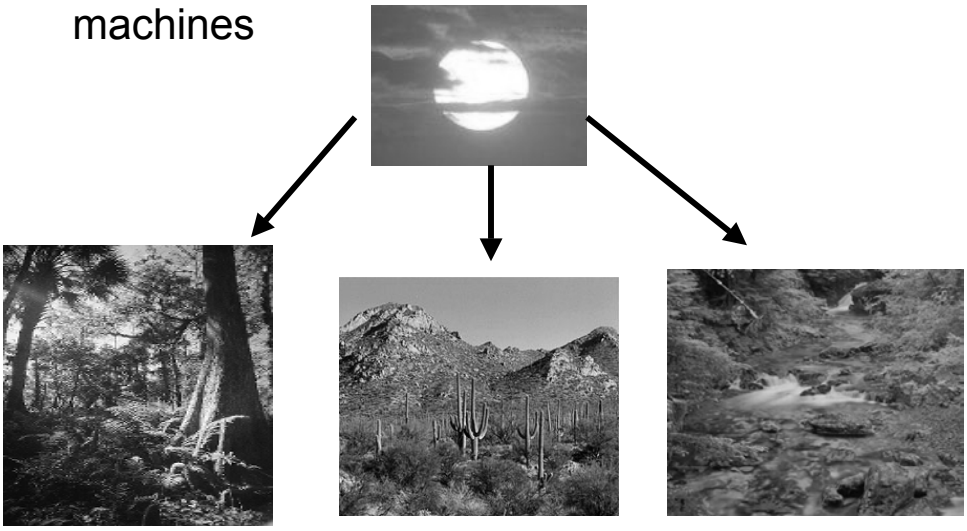
Energy flow in the ecosystem

Educational Goals

- History and fundamental concepts pertaining to energy flux in ecosystems
- Ecosystem Concept and thermodynamic underpinnings
- Primary production and its measurement, limiting factors, and global patterns
- Secondary Production
- Intratrophic transfers of energy
- Ecological efficiency

Ecosystem Ecology

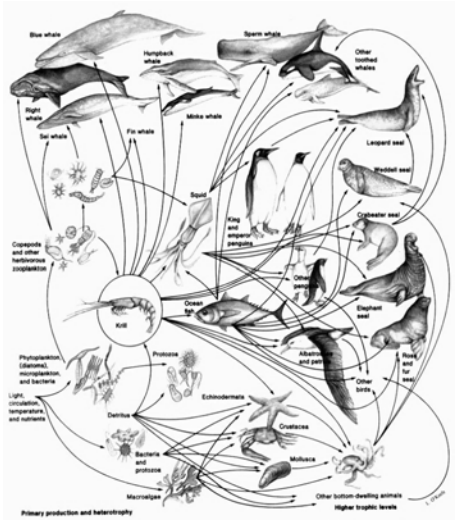
- Ecosystems as giant **energy-transforming** machines

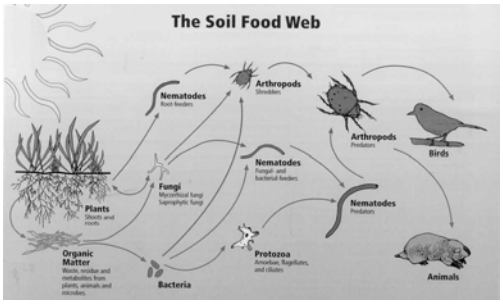


Background: Organizing Concepts

- Charles Elton – 1920's revolutionary concept:
  - Organisms living in the same place have similar tolerances of physical factors AND
  - Feeding relationships link organisms

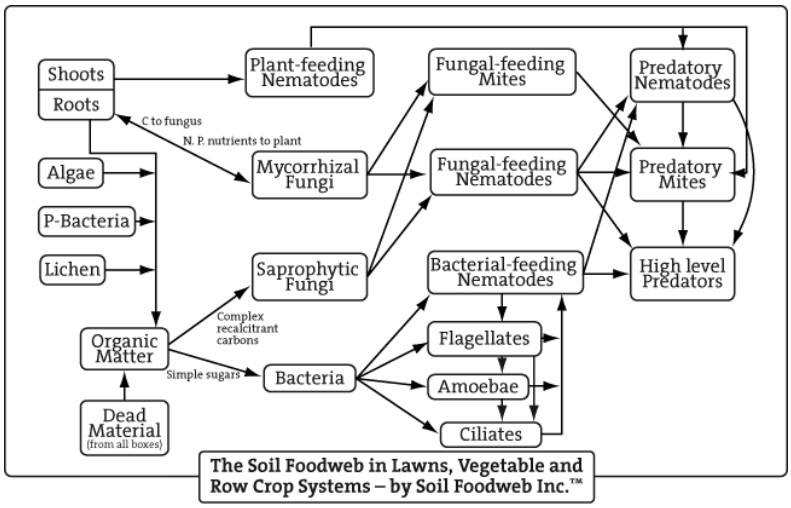
Food Webs



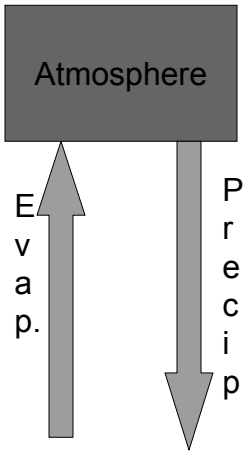


Conceptual Organization

Focus on **compartments** and **fluxes** of energy and materials

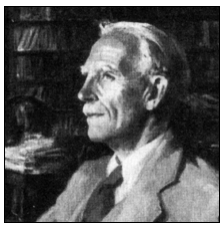


A Simple Compartment Example



- Pool size
- Flux rate (input = output)
- Residence Time
- Turnover Rate

Ecosystem Concept



A.G. Tansley (1935) – built on Elton's

- Coined the word "ecosystem"

A.J. Lotka and Thermodynamics

The ecosystem as an energy-transforming machine:

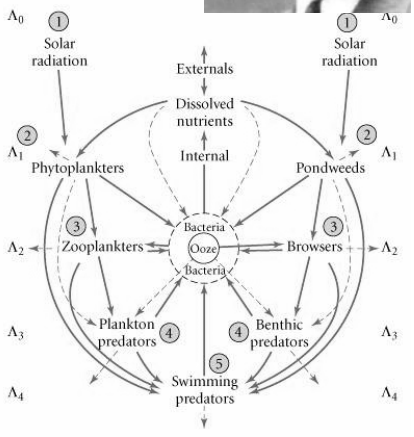
- Set of equations representing exchanged of matter and energy

First law of thermodynamics

Second Law of Thermodynamics

Synthesis – Lindeman (1942)

- Elton – food web structure
- Tansley – fundamental unit
- Lotka - thermodynamics



Lindeman's Foundations of Ecosystem Ecology

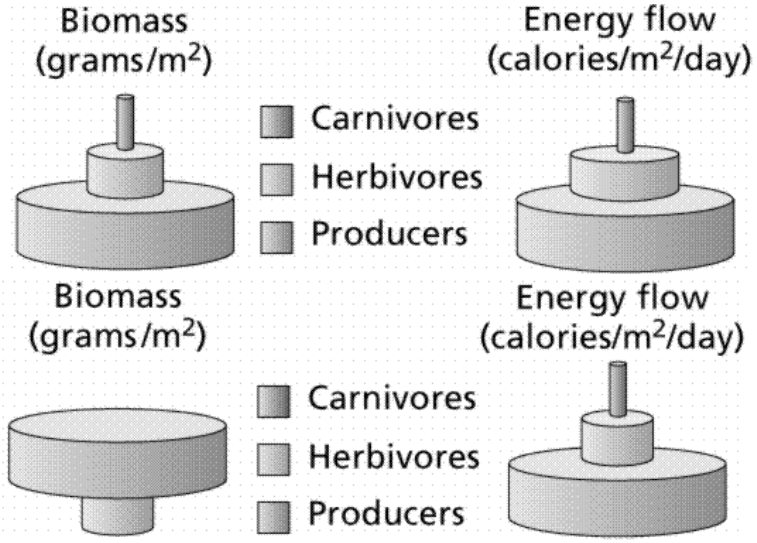
- The **ecosystem** is the fundamental unit of ecology.
- **Food chain**
- **Trophic level**
- **Pyramid of energy**

Trophic Structure

Functional Classification:

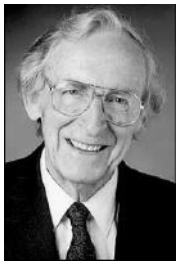
- **Producers** (autotrophs)
- **Reducers** (heterotrophs)

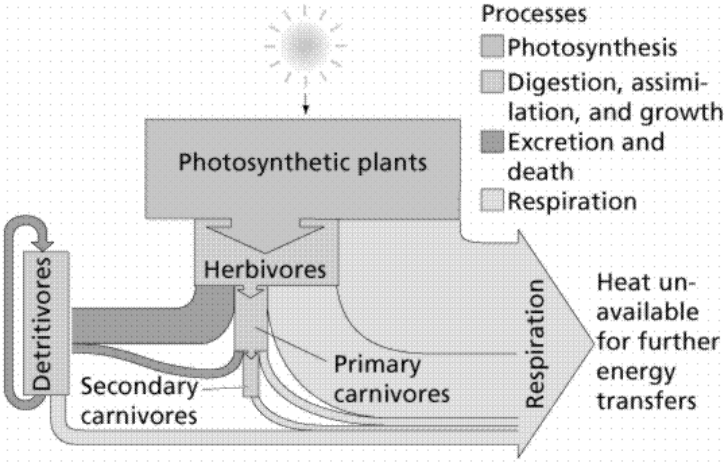
Trophic Pyramids



Odum's Energy Flux Model

- Used **energy** as currency in **compartment analysis**





Primary Production

- Primary producers capture light and transform it to energy
  - $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
  - for each g of C assimilated, 39 kJ energy stored

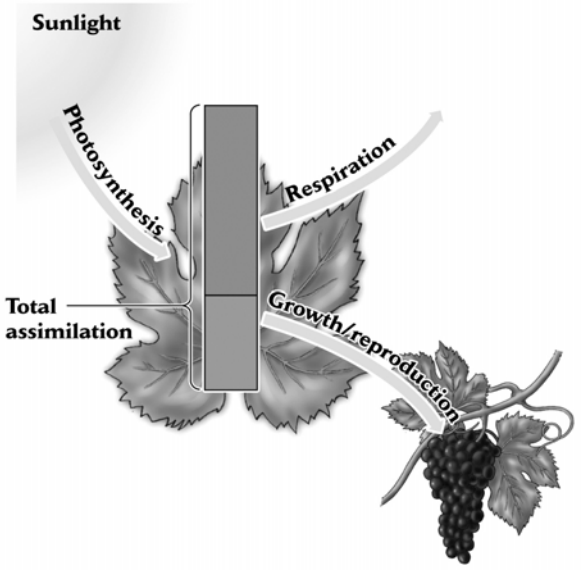
Components of Primary Production

- **gross primary production**

- **net primary production**

- gross - net = **respiration**

Components of Primary Production



Measurement of Primary Production

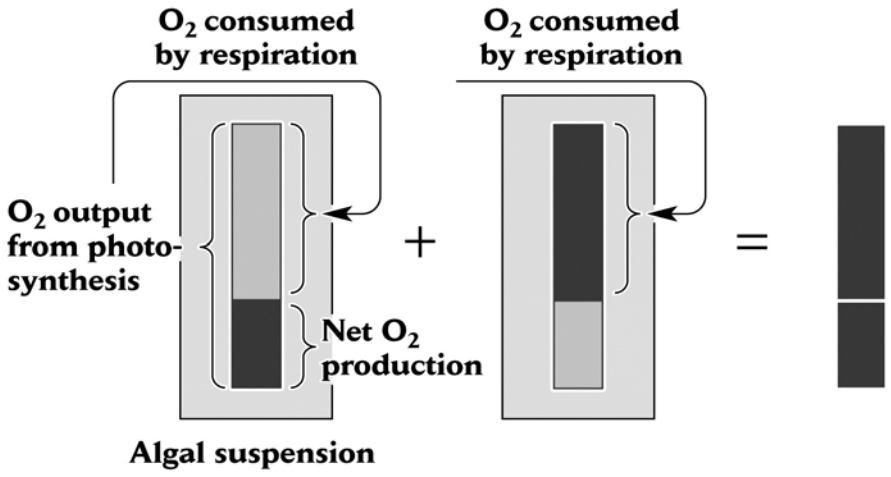
- **harvest techniques**

- **gas exchange techniques**

- Radioactive carbon (^{14}C) may also determine net uptake of carbon by plants

Application of Odum's Approach

Gas Exchange in Aquatic Systems

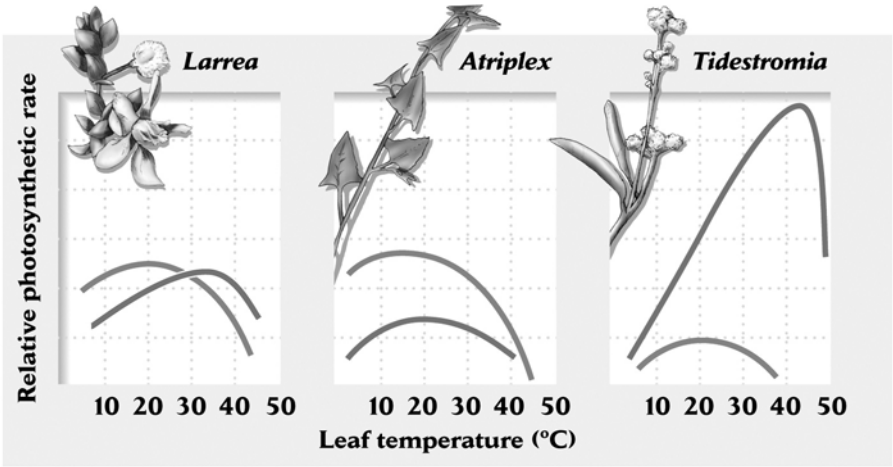


Limits to primary productivity?

- Photosynthetic efficiency – 1-2%

- Limits:
  - Light
  - Temperature
  - Water
  - Nutrients

Photosynthesis and Temperature

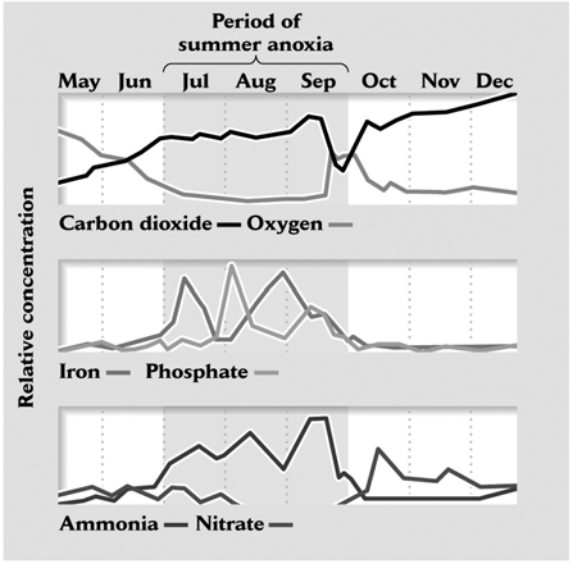


Water limits primary productivity

Nutrients stimulate primary production

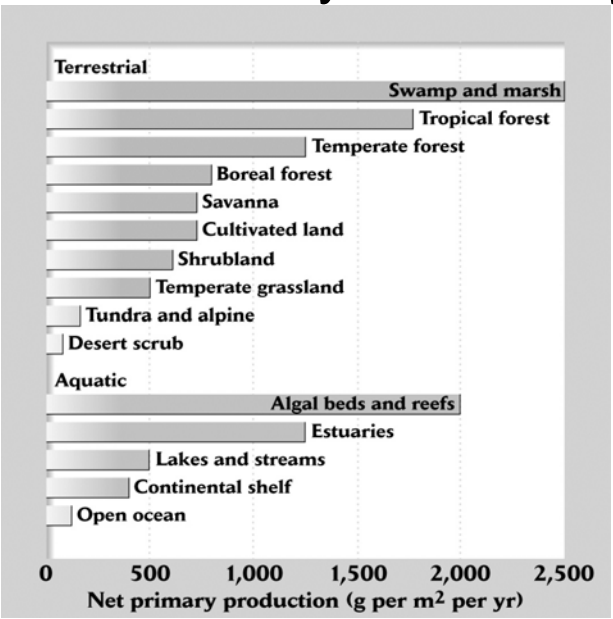
- Terrestrial systems may be nutrient limited

- Aquatic systems often strongly nutrient limited

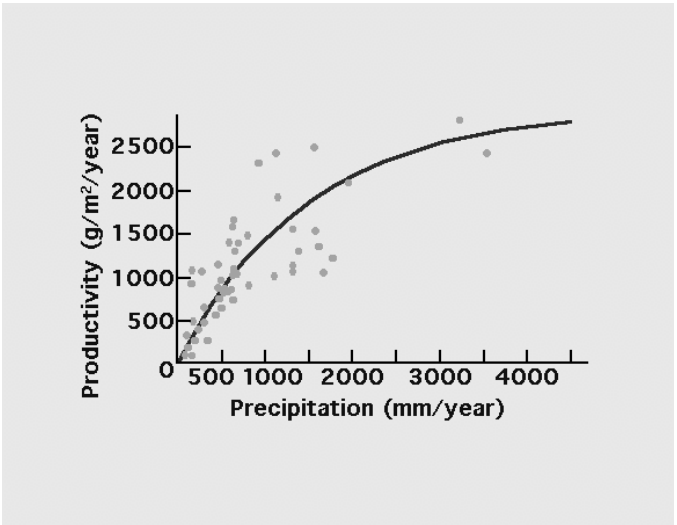


Primary Production varies among ecosystems

Global Primary Productivity



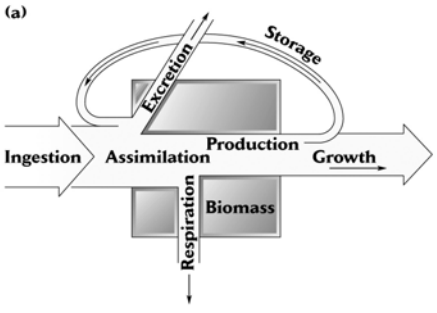
Global Productivity



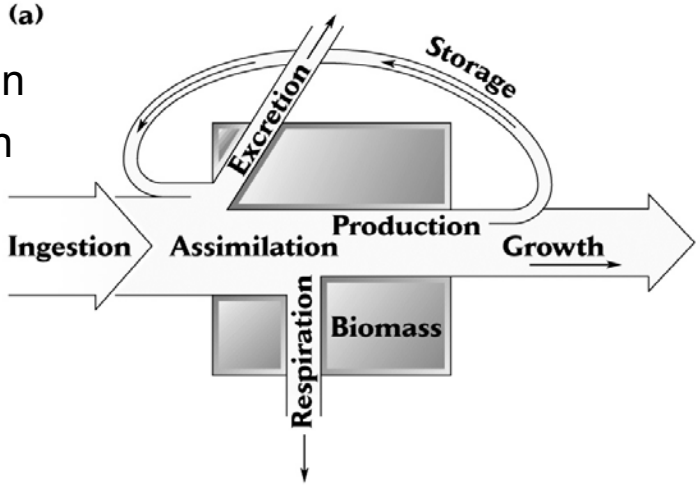
More terminology…..

- Herbivore, carnivore, omnivore
- Trophic link
- Decomposers

Ecological Efficiency



- Ingestion
- Egestion
- Assimilation
- Excretion
- Respiration
- Production



Fundamental Energy Relationships

Limits to Secondary Production?

- Correlated with Primary Production

- Biotic interactions - Predation, etc.

Net Ecosystem Production

Is there anything left over?

Ecosystems support two parallel food chains

herbivore-based (relatively large animals feed on leaves, fruits, seeds)

detritus-based (microorganisms and small animals consume dead remains of plants and indigestible excreta of herbivores)

- herbivores consume:
  - 1.5-2.5% of net primary production in temperate forests
  - 12% in old-field habitats
  - 60-99% in plankton communities

Energy moves through ecosystems at different rates.

Indices of energy cycling speeds

- **residence time**

Energy moves through ecosystems at different rates.

Indices of energy cycling speeds

- **biomass accumulation ratio**

Ecosystem Energetics

Compare systems with different inputs:

- Autochthonous – produced within the system
- Allochthonous – produced outside the system

Biomass Accumulation Ratios

- Become larger as amount of stored energy increases:
  - humid tropical forests have net production of 1.8 kg/m^2/yr and biomass of 43 kg/m^2 = 23yr
  - forested terrestrial communities >20 yr
  - planktonic aquatic ecosystems <20 days

Residence Time for Litter

- Decomposition of litter is dependent on

- **Residence time**

humid tropics	–3 mos
dry and montane tropics	–1-2 yr
southeastern US	–4-16 yr
boreal ecosystems	–>100 yr

Stream study…..

- Assimilation of energy by herbivores indicates subsidy

  – **autochthonous**

  – **allochthonous**