Ecology, Ecosystems, & Food Webs

tutorial by Paul Rich

Outline

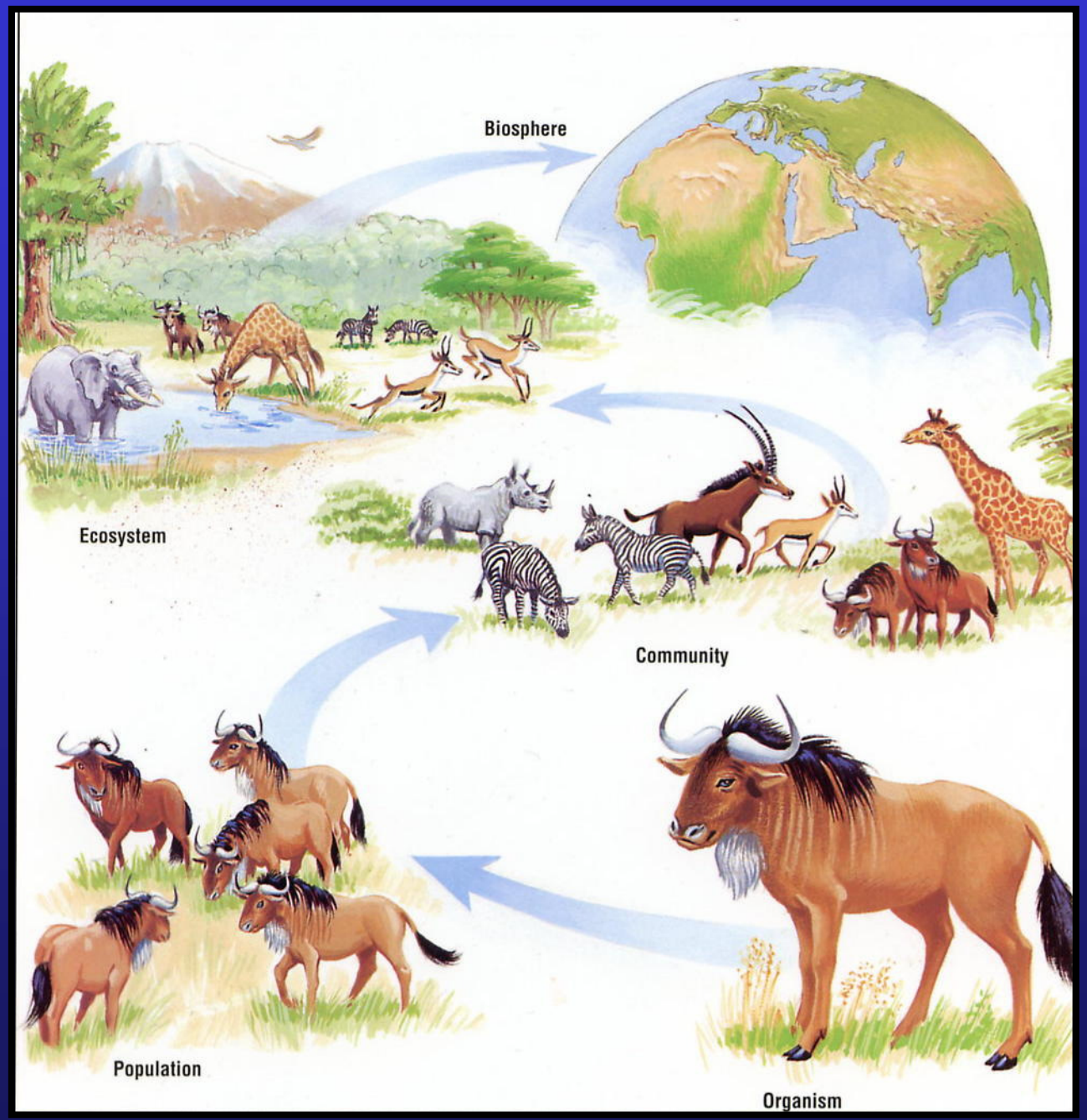
1. Characteristics of Life
   What is ecology? What is life?
2. Earth's Life–Support Systems
   What sustains life?
3. Ecosystem Concepts
   living components, limiting factors, tolerance
4. Food Webs & Energy Flow
   productivity, efficiency
5. Ecosystem Services & Sustainability
6. How do Ecologists Learn?

1. Characteristics of Life

- Organisms are **composed of cells** that have highly organized internal structure;
- Cells of organisms **contain deoxyribonucleic acid (DNA)**, which form the basis of heredity;
- Organisms **capture & transform matter & energy** from their environment to supply needs **for growth, survival, & reproduction**;
- Organisms maintain favorable internal conditions, despite changes in their environment, through **homeostasis**;
- Organisms perpetuate themselves through **reproduction**;
- Organisms adapt to changes in environmental conditions through **evolution**.

Ecology – study of the relationships between organisms and their environment

Levels of organization:



Organisms

organism: any form of life.

- organisms are classified into species.
- **species**: groups of organisms that resemble each other, &, in cases of sexually reproducing organisms, can potentially interbreed.
- estimates of 5 to 100 million species, most are insects & microorganisms; so far only about 1.8 million named; each species result of long evolutionary history.
- **wild species**: population that exists in its natural habitat (= native species).
- **domesticated or introduced species**: population introduced by humans (= non–native species).

Populations

population: a group of interacting individuals of the same species.

- examples: sunfish in a pond, white oak trees in a forest, people in a city;
- **habitat**: the place where a population usually lives.
- **genetic diversity**: in natural populations individuals vary in their genetic makeup.

Communities

community: populations of all species living together in a given area.

- a biological community is a complex interacting network of plants, animals, & microorganisms.
- example: redwood forest community, consisting of populations of redwoods & other trees, shrubs & herbaceous species, animals, & microorganisms.

Ecosystems

ecosystem: a community of different species interacting with one another (*biotic) & with their non–living (**abiotic) environment of matter & energy.

examples:
a patch of woods, a lake or pond, a farm field, an entire watershed in a tropical rain forest.

***biotic**: living components or biota (exs: plants, animals, & microorganisms)

****abiotic:** non–living components (exs: water, air, nutrients, & solar energy)

Biomes & Life Zones

biome: large regions characterized by a distinct climate & specific life–forms, especially vegetation, adapted to the region.

major biomes: temperate grassland, temperate deciduous forest, desert, tropical rain forest, tropical deciduous forest, tropical savannah, coniferous forest, tundra

aquatic life zone: major marine or freshwater areas containing numerous ecosystems.

major aquatic life zones: lakes, streams, estuaries, coastlines, coral reefs, & the deep ocean

Ecosphere

ecosphere (=biosphere): all of Earth's ecosystems together.

2. Earth's Life–Support System

Earth's major components

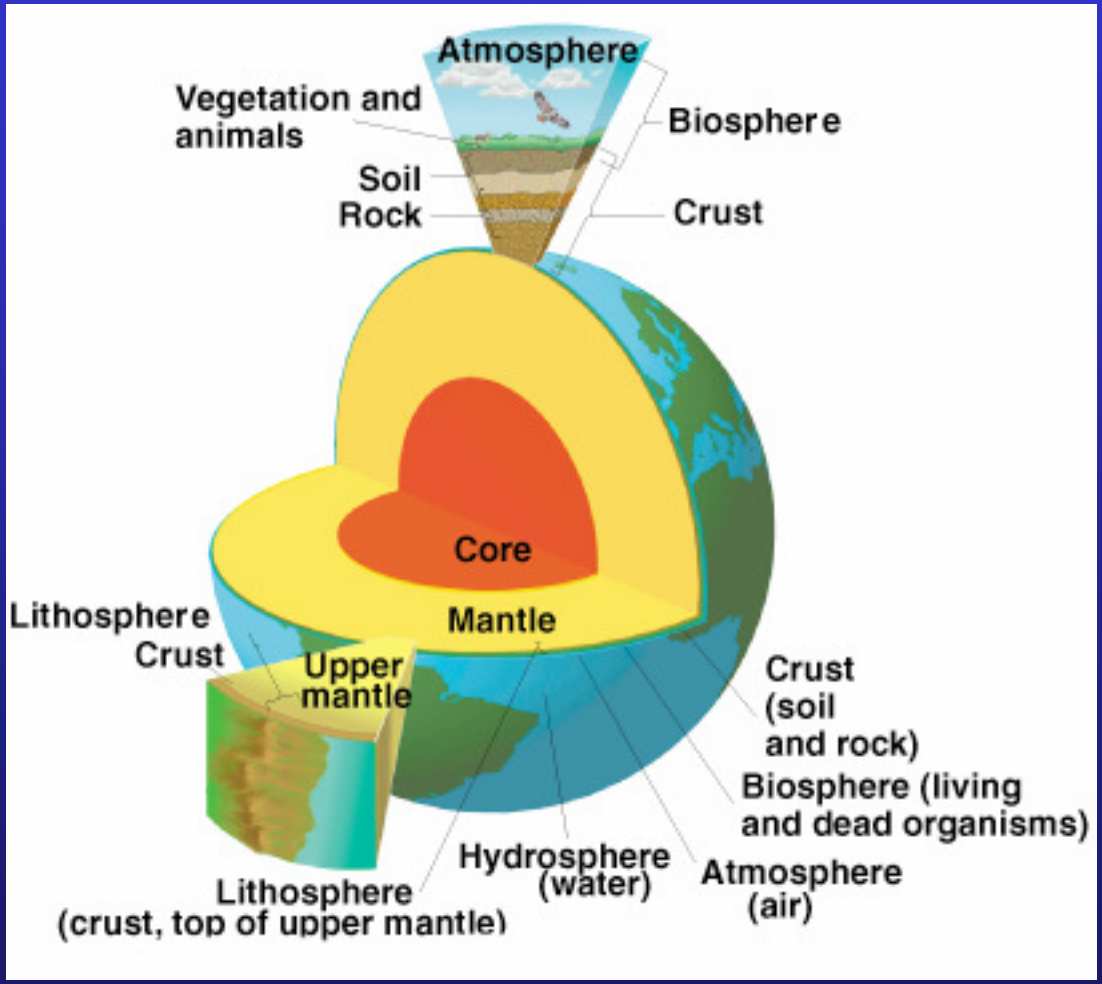


Fig. 4–5

What Sustains Life?

Energy From Sun

- one–way flow of usable energy from sun, through feeding interactions, to low–quality forms (heat);

Cycling of Matter

- the continual flow of matter between the nonliving environment & living organisms;

Gravity

- enables Earth to hold its atmosphere; causes downward movement of matter in nutrient cycles.

Energy Flow

The ultimate source of energy in most ecosystems is the sun.

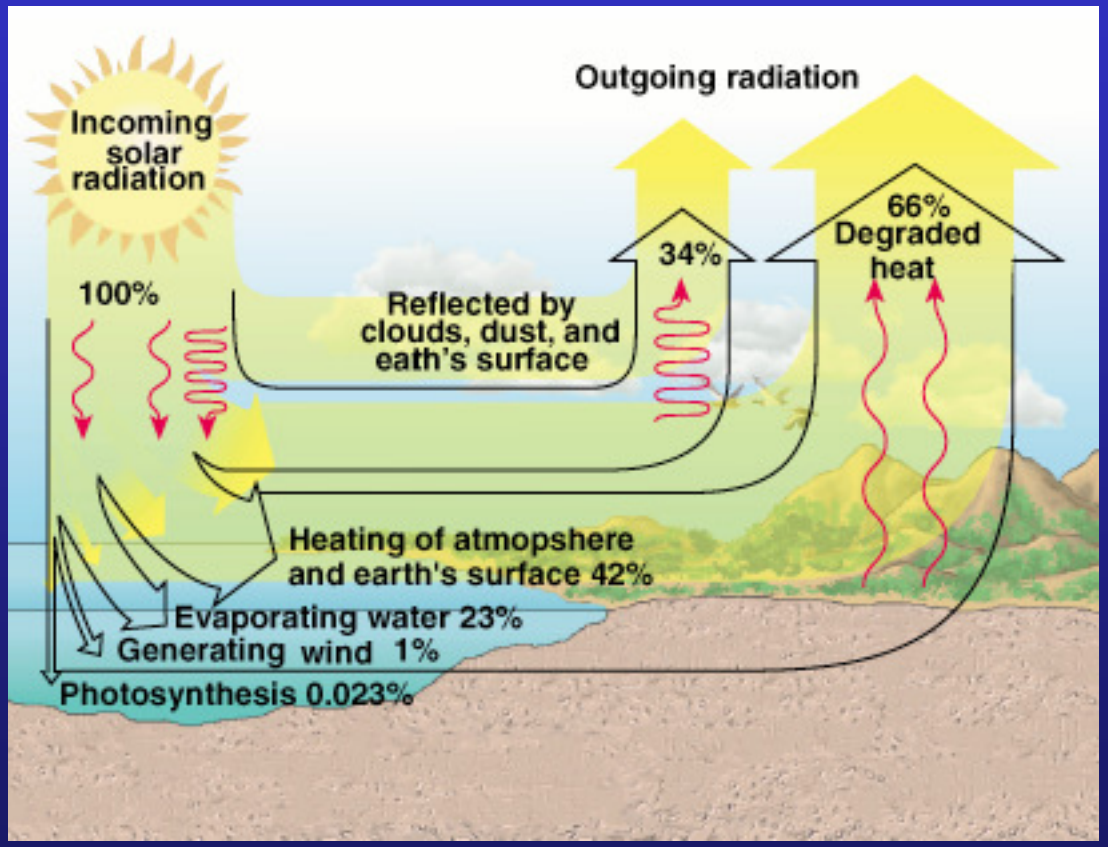


Fig. 4–7

Energy Flow & Nutrient Cycling

Life on Earth depends upon one–way flow of high–quality energy from sun & cycling of crucial elements.

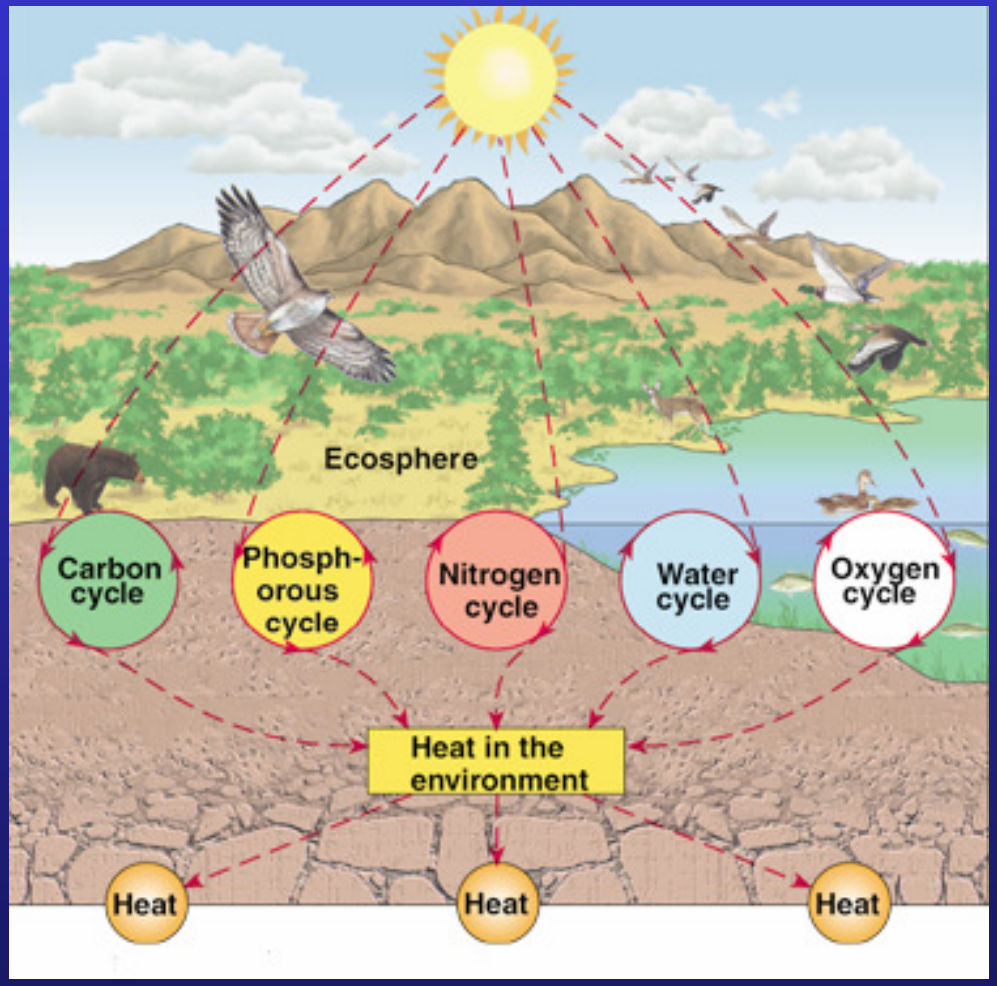


Fig. 4–6

Nutrient Cycles

nutrient: any atom, ion, or molecule an organism needs to live, grow, or reproduce.

- **macronutrients** needed in relatively large amounts e.g., C, O, H, N, P, S, K, Ca, Mg, Fe
- **micronutrients** needed in relatively small amounts e.g., Na, Zn, Cu, Cl, I
- **nutrient cycles** (= biogeochemical cycles) involve continual flow of nutrients from nonliving (air, water, soil, rock) to living organisms (biota) & back again.
- nutrient cycles driven directly or indirectly by solar radiation & gravity.
- Major cycles: hydrologic (water), carbon, oxygen, nitrogen, phosphorus, & sulfur.

Open vs. Closed Systems

Closed System: a system in which energy, but not matter, is exchanged between the system & its environment.

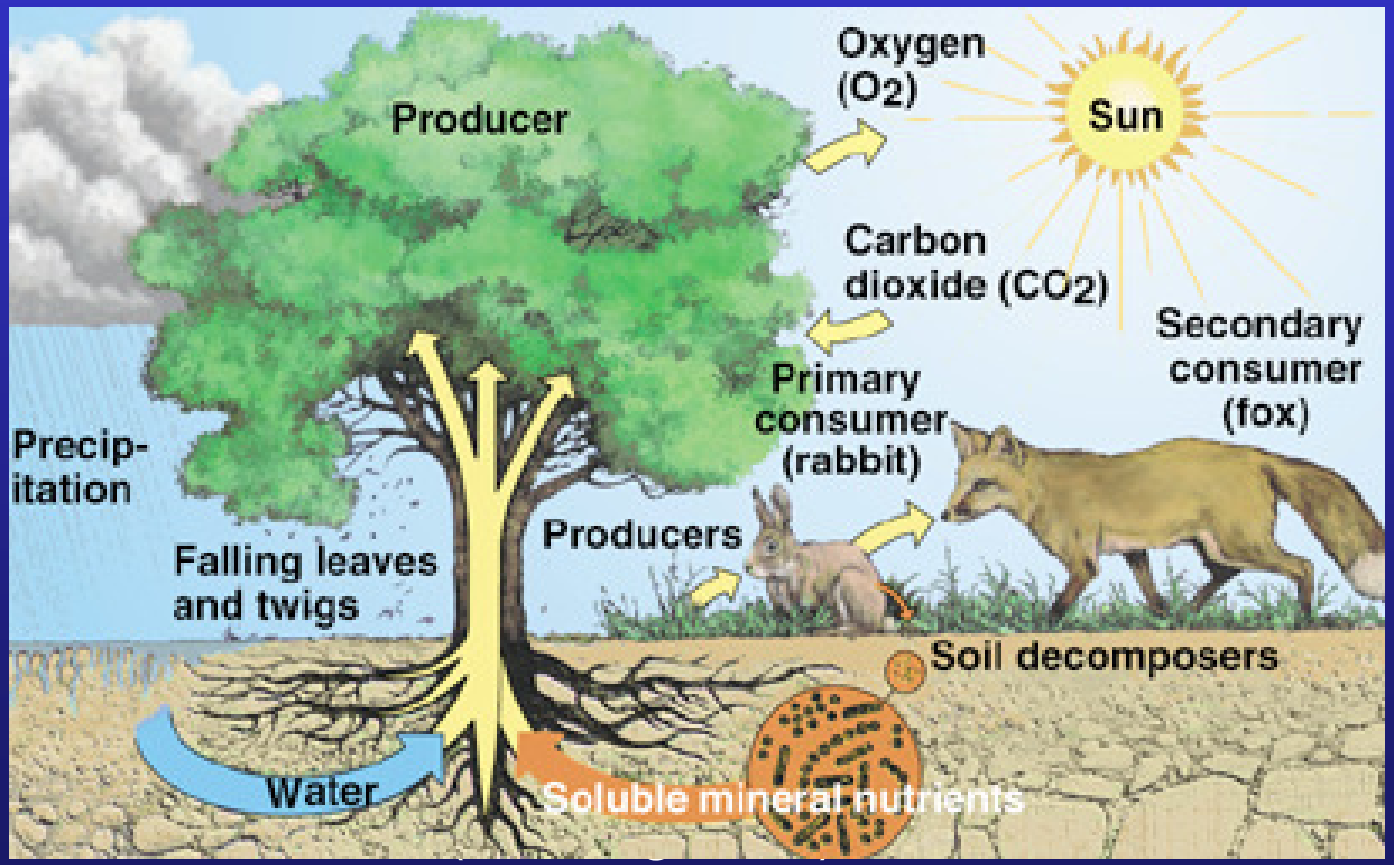
- earth is a closed system, in that matter is neither lost nor gained (except negligible cosmic dust & meteorites) while energy flows through;

Open System: a system in which both energy & matter are exchanged between the system & its environment.

- organisms are open systems because both matter & energy are exchanged with the environment.

3. Ecosystem Concepts

Major components of terrestrial ecosystems.



Major components of aquatic ecosystems.

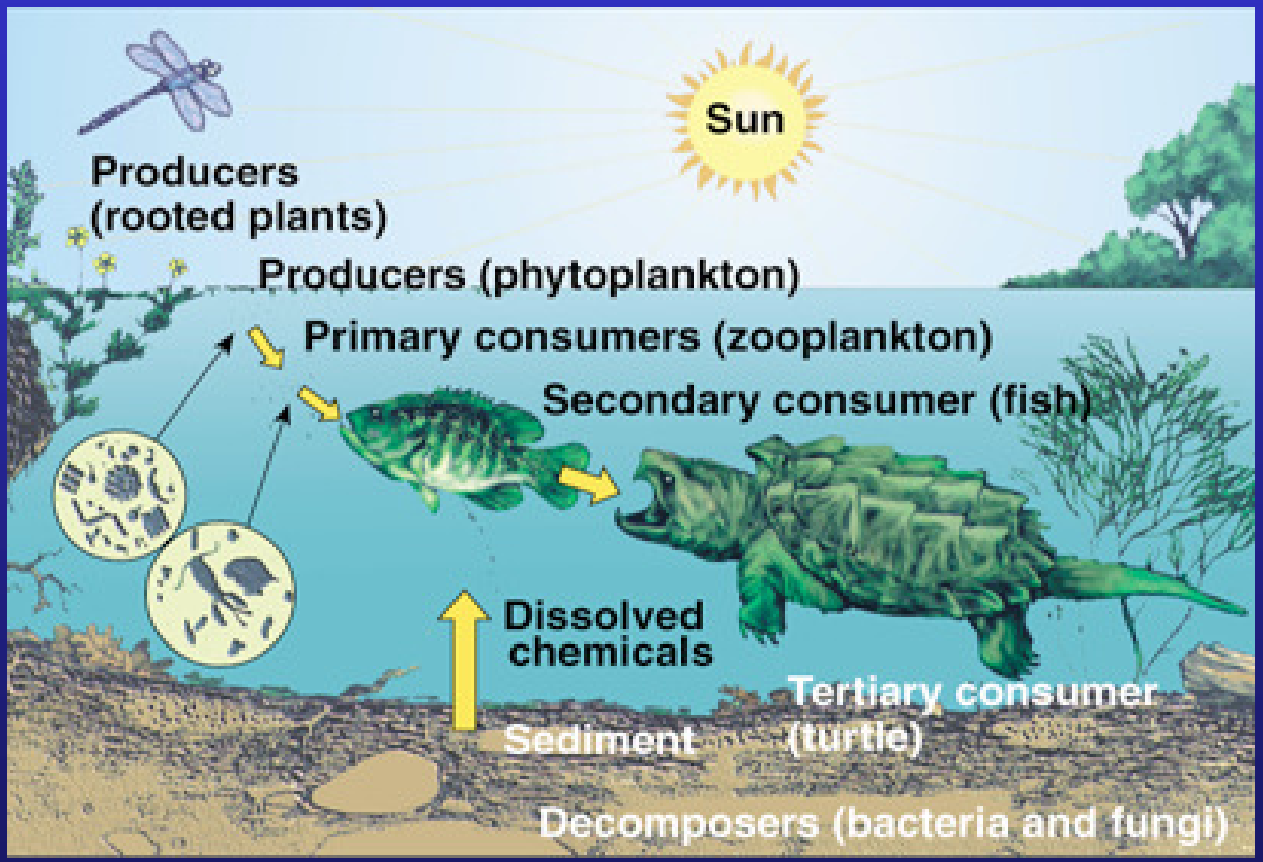


Fig. 4–10

Major Living Components

Two main categories:

1) producers (also called **autotrophs** = "self–feeders") make their own food from compounds obtained in the environment.

- most capture sunlight to make sugars & other organic compounds in a process called **photosynthesis**, e.g., green plants.
- a few, mostly bacteria, convert simple compounds into complex nutrient compounds without sunlight, e.g., bacteria of thermal vents that use hydrogen sulfide (H_2S) & carbon dioxide.

2) consumers (also called **heterotrophs** "other–feeders") get their energy & nutrients by feeding on other organisms or their remains.

- Includes herbivores, carnivores, decomposers, etc.

Photosynthesis & Respiration

photosynthesis: complex chemical reaction in plants, in which solar radiation is captured by **chlorophyll** (& other pigments) & used to combine carbon dioxide & water to produce carbohydrates (e.g., glucose), other organic compounds, & oxygen.

carbon dioxide + water + ***solar energy*** → glucose + oxygen

$6\ CO_2 + 6\ H_2O +$ ***solar energy*** $\rightarrow C_6H_{12}O_6 + O_2$

aerobic respiration: complex process that occurs in the cells of organisms, in which organic molecules (e.g., glucose) are combined with oxygen to produce carbon dioxide, water, & energy.

glucose + oxygen → carbon dioxide + water + ***energy***

$C_6H_{12}O_6 + O_2 \rightarrow 6\ CO_2 + 6\ H_2O +$ ***energy***

Consumers

major kinds of consumers (= heterotrophs)

- **primary consumers**: (=herbivores) feed directly on producers;
- **secondary consumers**: (=carnivores) feed on primary consumers;
- **tertiary consumers**: feed only on carnivores;
- **omnivores**: consumers that feed on both plants & animals;
- **scavengers**: feed on dead organisms;
- **decomposers**: consumers that complete the breakdown & recycling of organic materials from the remains & wastes of other organisms;
- **detritivores**: feed on *detritus* (partially decomposed organic matter, such as leaf litter & animal dung).

Detritus Feeders vs. Decomposers

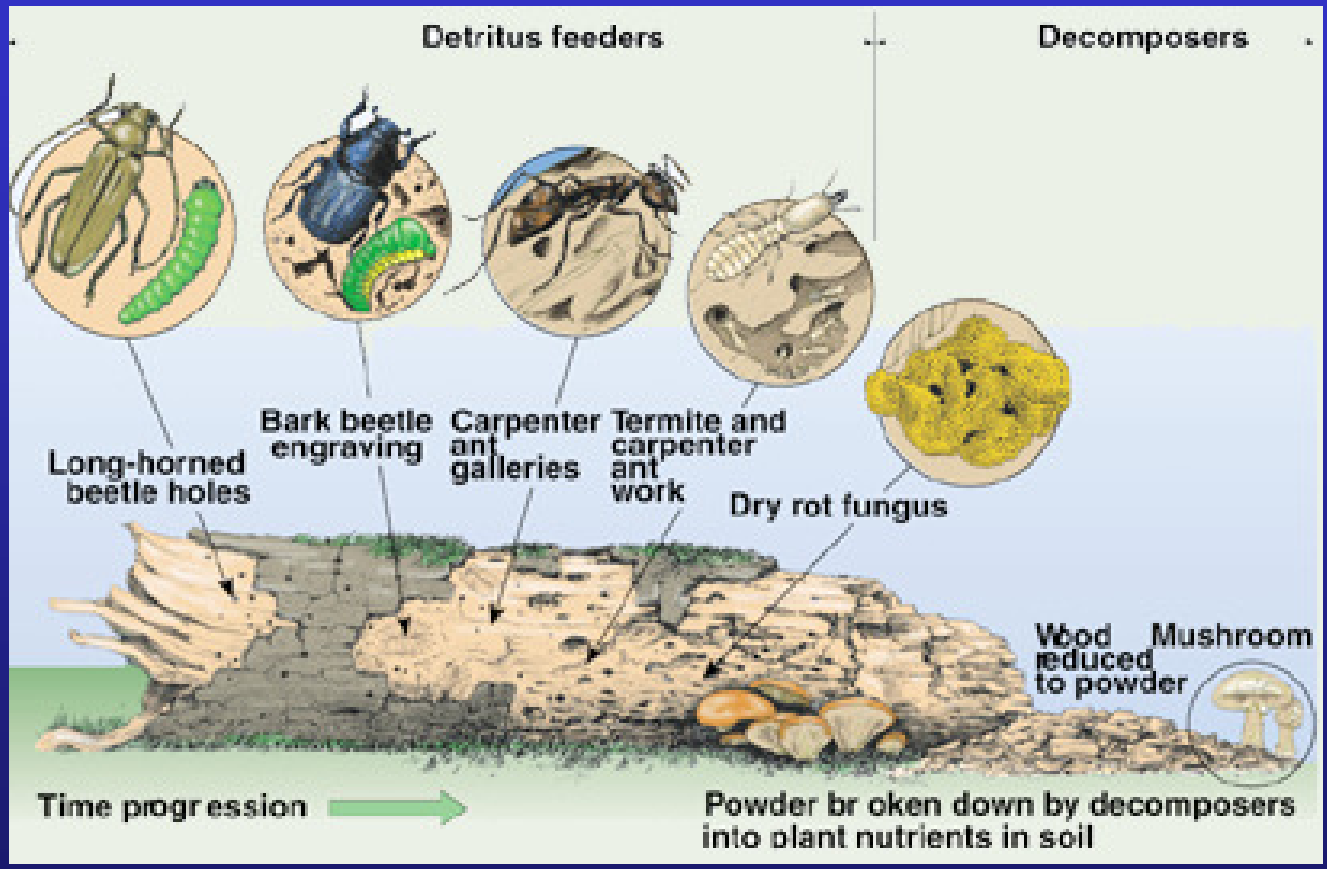


Fig. 4–13

Summary of Ecosystem Structure

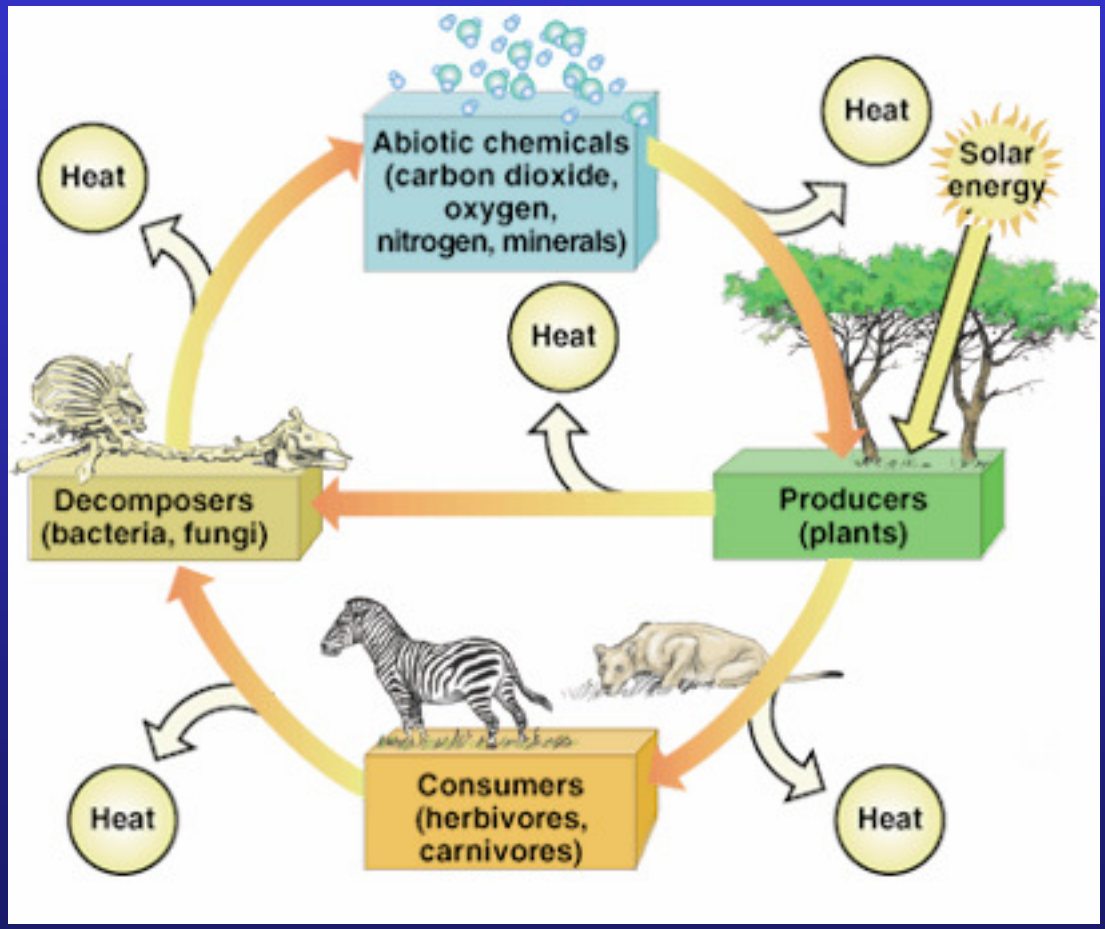


Fig. 4–15

Limiting Factors

limiting factor: an environmental factor that is more important than other factors in regulating survival, growth, or reproduction.

law of tolerance: the existence, abundance, & distribution of a species in an ecosystem is determined by whether the levels of one or more physical or chemical factors fall within the range tolerated by that species.

limiting factor principle: too much or too little of any abiotic factor can limit or prevent growth of a population, even if all other factors are at or near the optimum range of tolerance.

Range of Tolerance

The survival, growth, & reproduction of organisms is determined, in part, by maximum & minimum tolerance limits for physical conditions such as temperature.

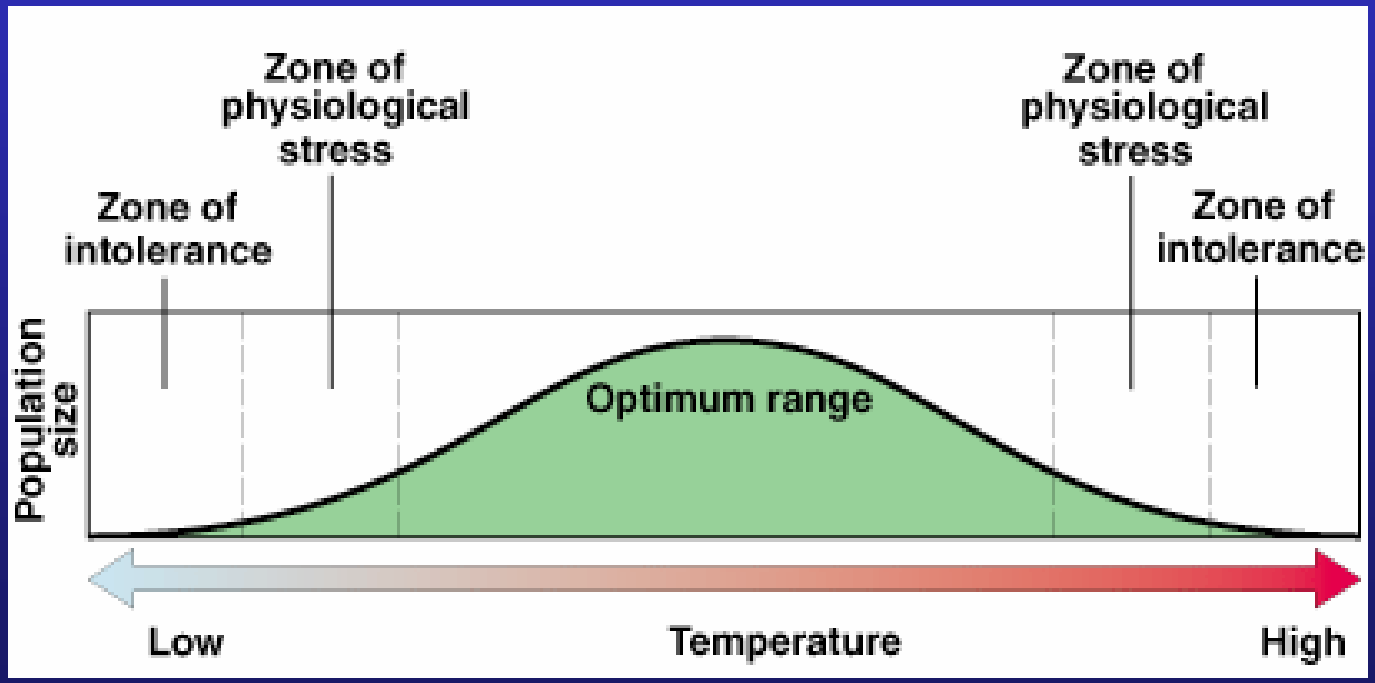


Fig. 4–12

4. Food Webs & Energy Flow

Food chains involve a sequence of organisms, each of which is the food for the next.

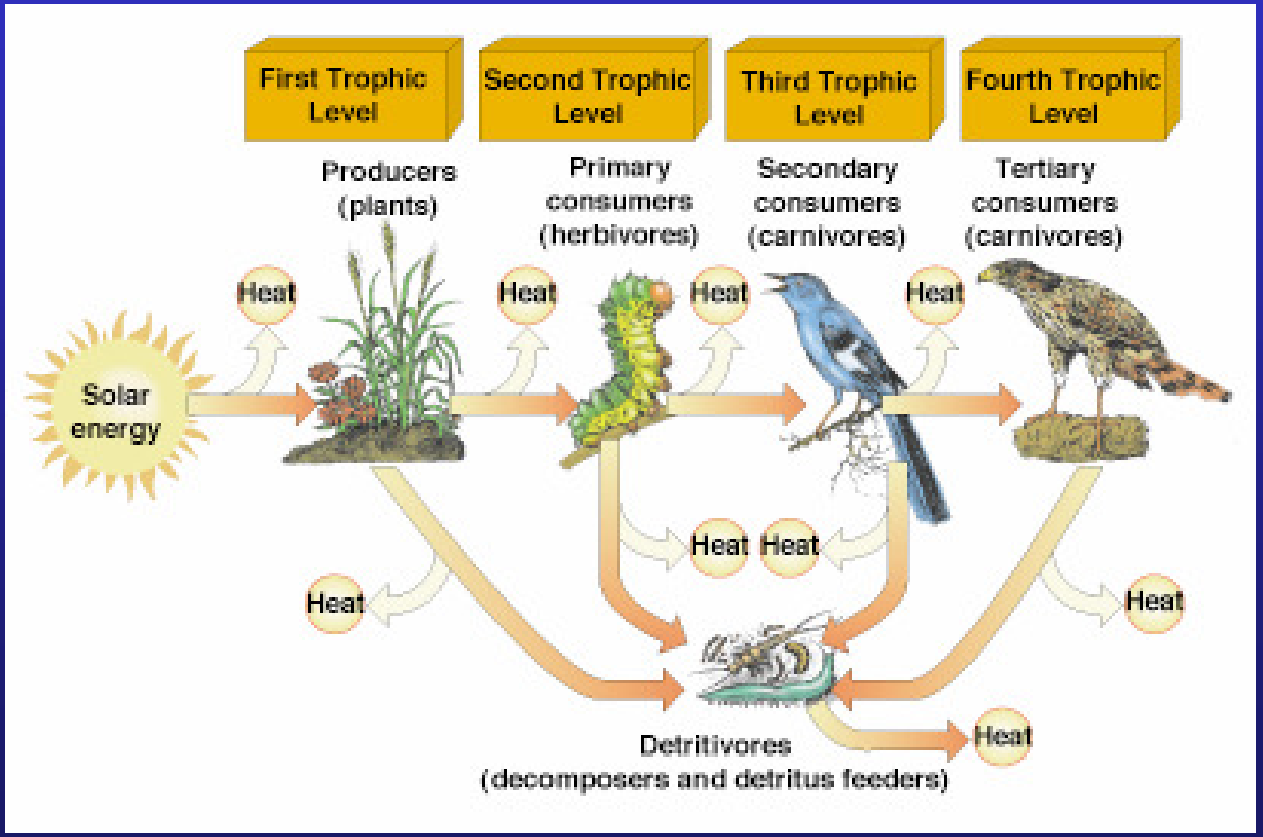


Fig. 4–16

Food Webs & Energy Flow

Example of some of the complexity of a food web in Antarctica.

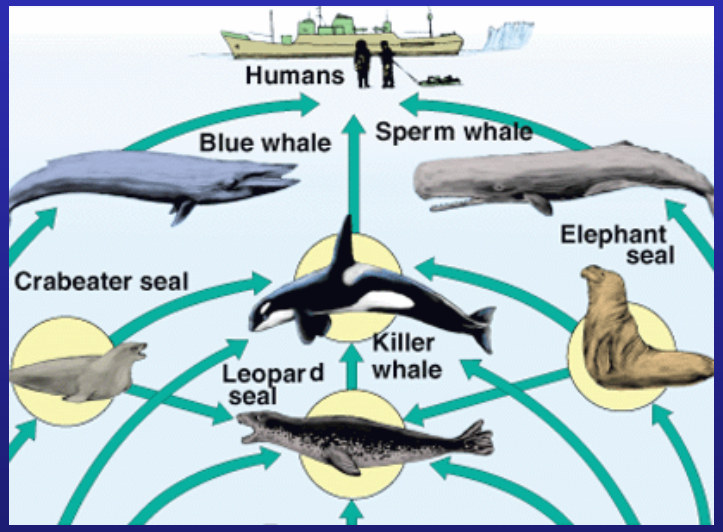
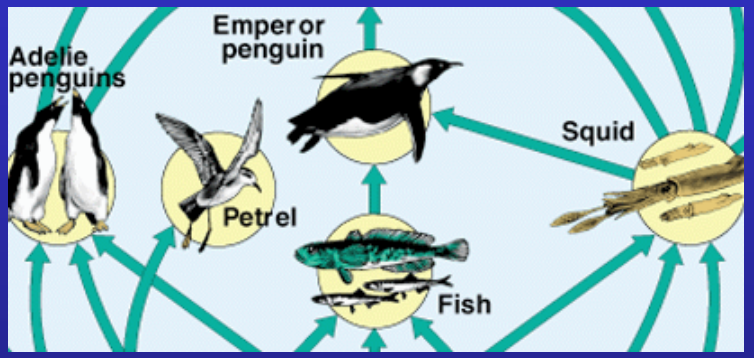
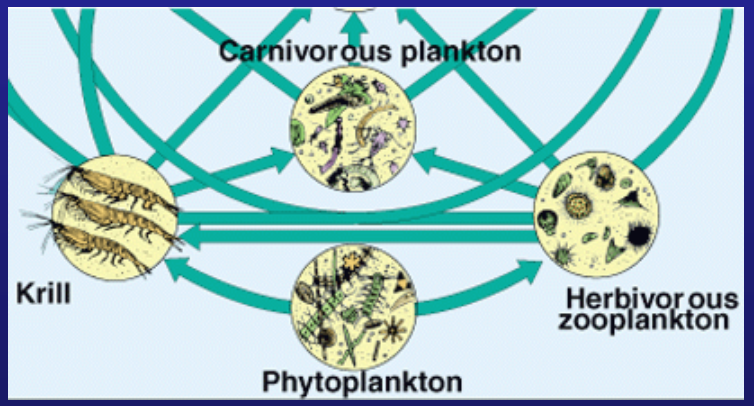


Fig. 4–17





Generalized Energy Pyramid

In nature, ecological efficiency varies from 5% to 20% energy available between successive trophic levels (95% to 80% loss). About 10% efficiency is a general rule.

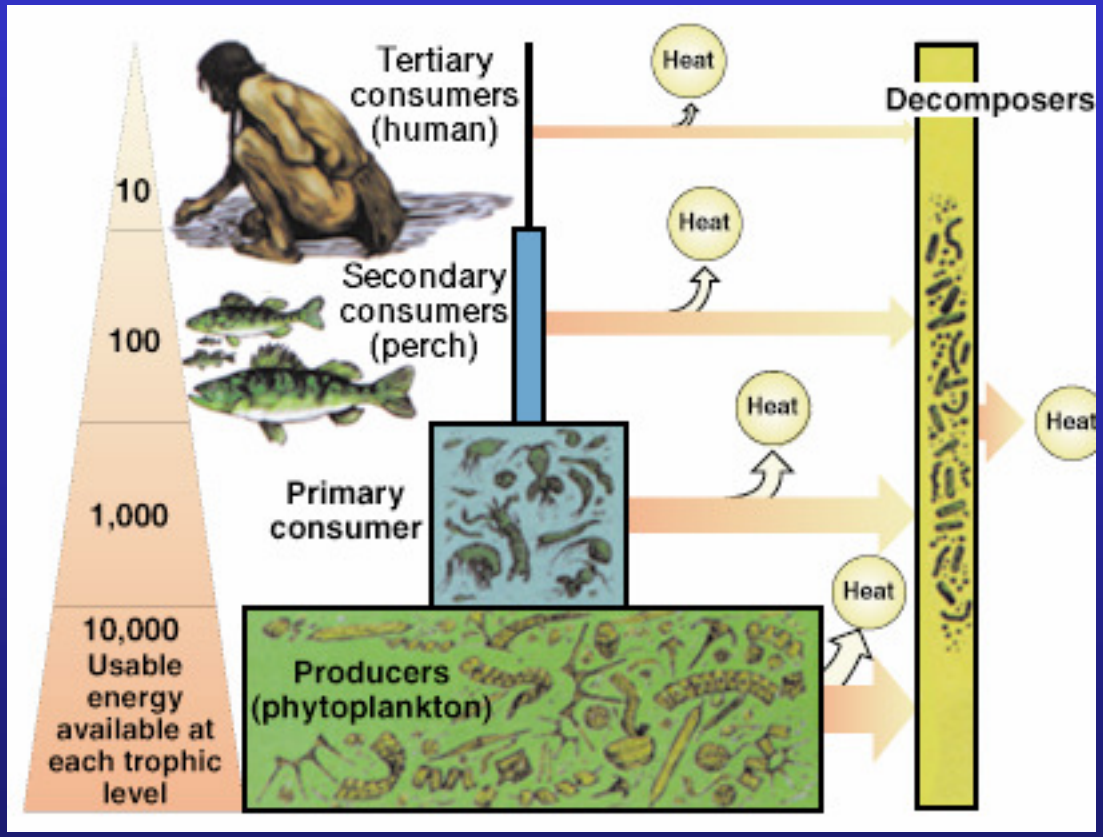


Fig. 4–19

Generalized Energy Pyramid

Annual pyramid of energy flow (in kilocalories per square meter per year) for an aquatic ecosystem in Silver Springs, FL.

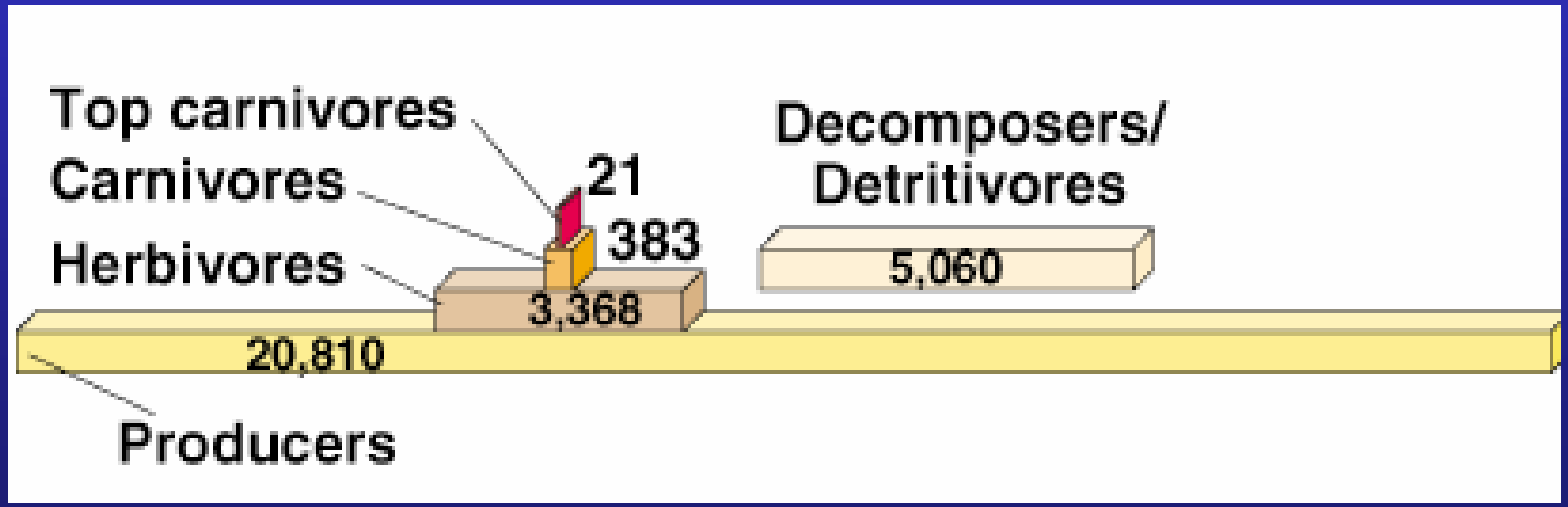


Fig. 4–20

Biomass Pyramids

Biomass pyramids, commonly measured as dry weight per square meter for each trophic level, can either mirror the energy pyramid (as for the abandoned field) or be inverted (as for the ocean). Inverted biomass pyramids result because the producers are eaten by consumers.

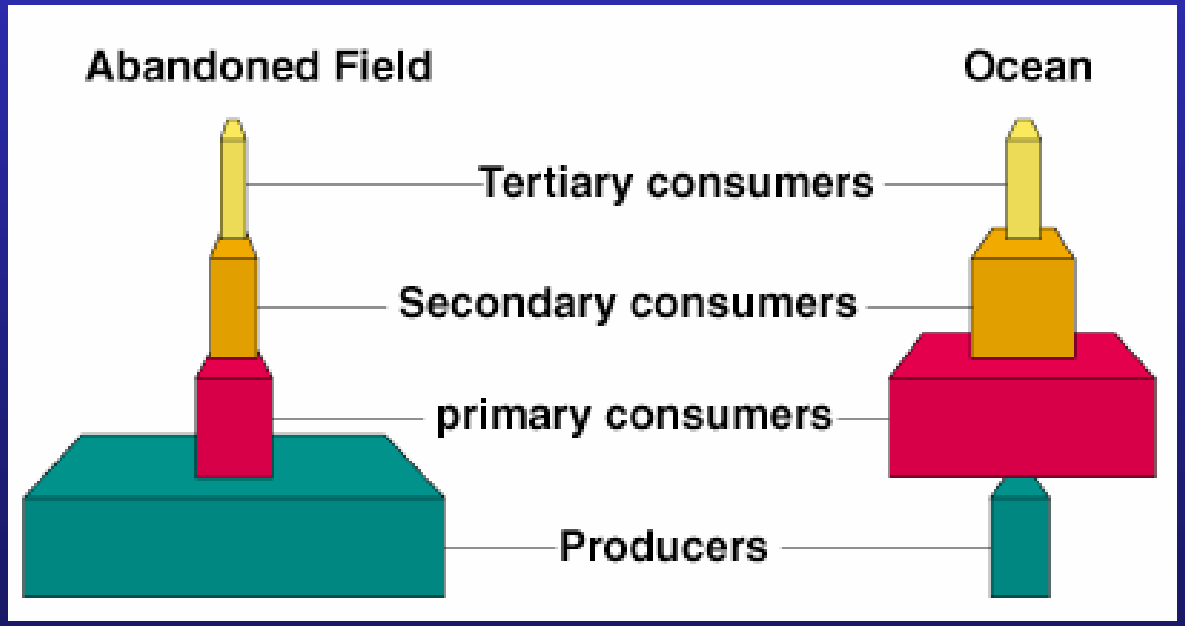


Fig. 4–21

Pyramids of Numbers

Pyramids of numbers depend upon both the size of organisms (e.g., forests have smaller numbers of large producers than do grasslands) & the biomass pyramid.

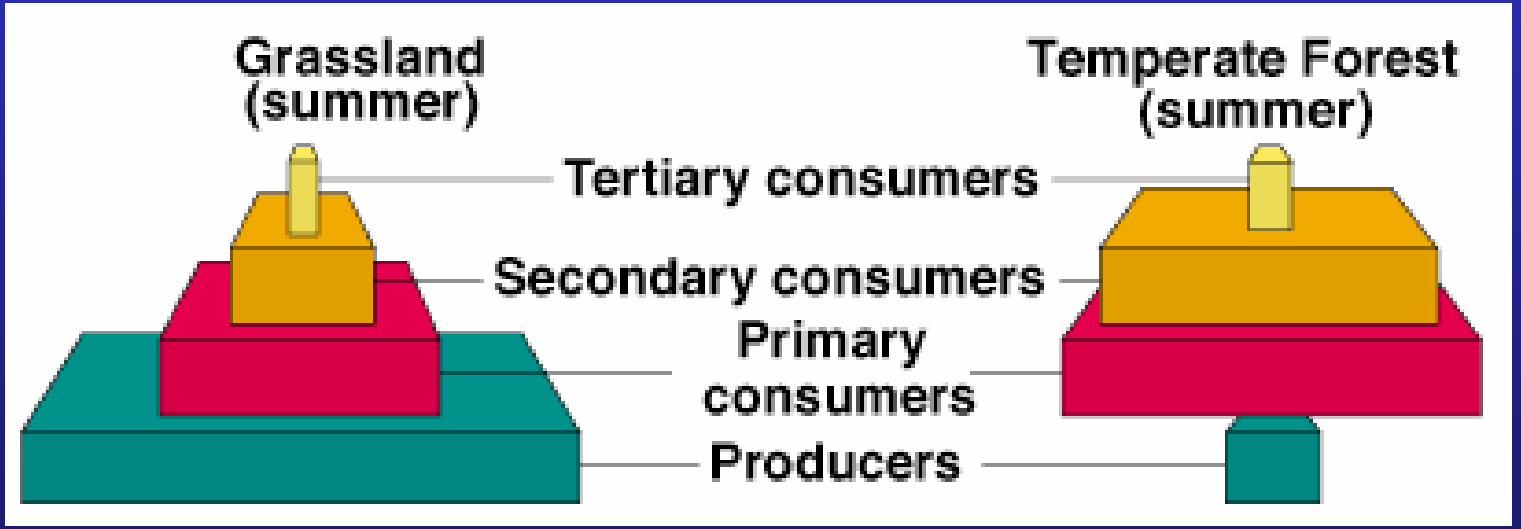


Fig. 4–22

Primary Productivity

gross primary productivity (GPP) is the rate at which an ecosystem's producers convert solar energy into chemical energy as biomass.

net primary productivity (NPP) is the rate at which energy for use by consumers is stored in new biomass.

NPP = GPP – [rate at which producers use biomass]

Primary Productivity

Estimated annual net primary productivity of major biomes & aquatic life zones, expressed as kilocalories per square meter per year.

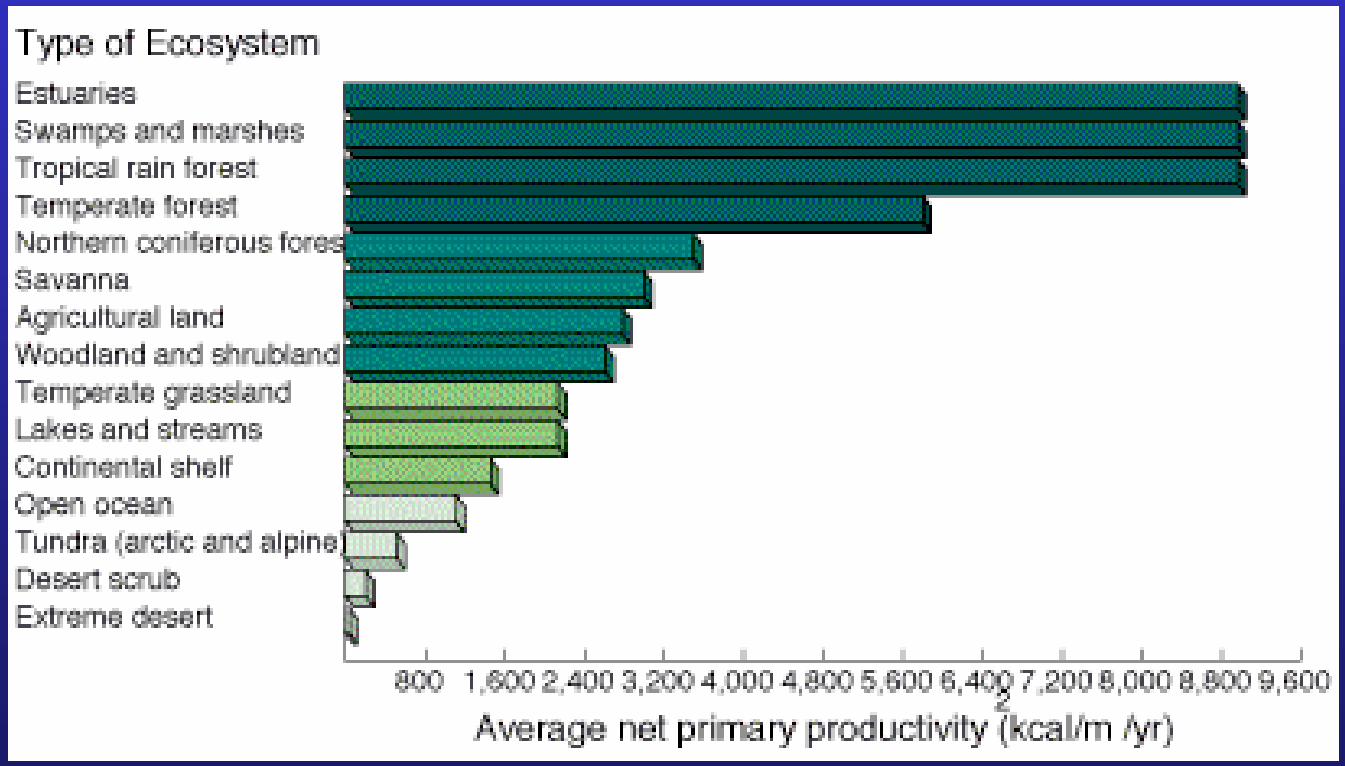


Fig. 4–24

Primary Productivity

Estimated annual contribution of the various types of biomes & aquatic life zones to Earth's overall net primary productivity. Note that the preceding figure gives the average net primary productivity per unit area.

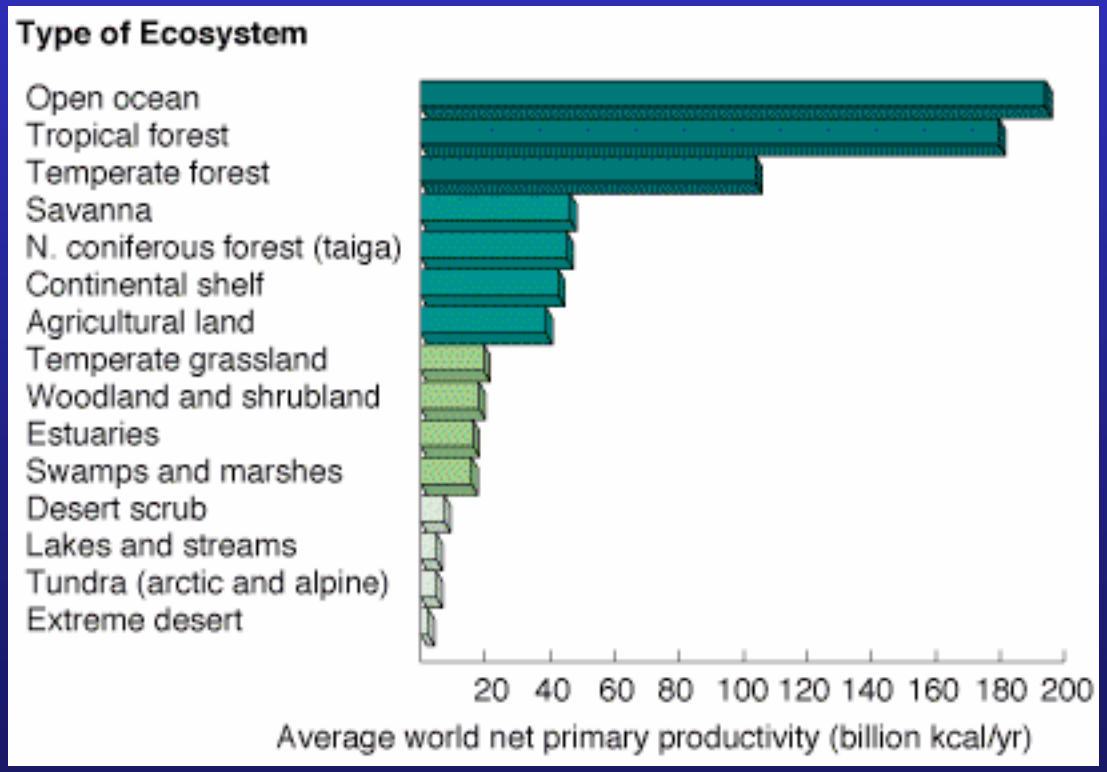


Fig. 4–25

5. Ecosystem Services & Sustainability

ecosystem services: natural benefits that support life on the earth & are essential to the quality of human life & the functioning of the world's economies.

Examples:

- control & moderate climate
- recycle vital nutrients
- provide energy & mineral resources
- furnish food, fiber, medicine, timber, & paper
- pollinate crops & useful native plants
- absorb, dilute, or detoxify pollutants
- control populations of pests & disease organisms
- slow soil erosion & prevent flooding
- provide biodiversity of genes & species

Ecosystem Services & Sustainability

Why is biodiversity an important ecosystem service?

The rich variety of organisms provides material benefits (food, raw materials, energy, & medicine), ecosystem services (purification of air & water, natural pest control…), & aesthetic benefits.

What are two principles of ecosystem sustainability?

Almost all natural ecosystems achieve sustainability by 1) using renewable solar energy as the energy source; & 2) recycling nutrients needed for survival, growth, & reproduction.

6. How Do Ecologist Learn?

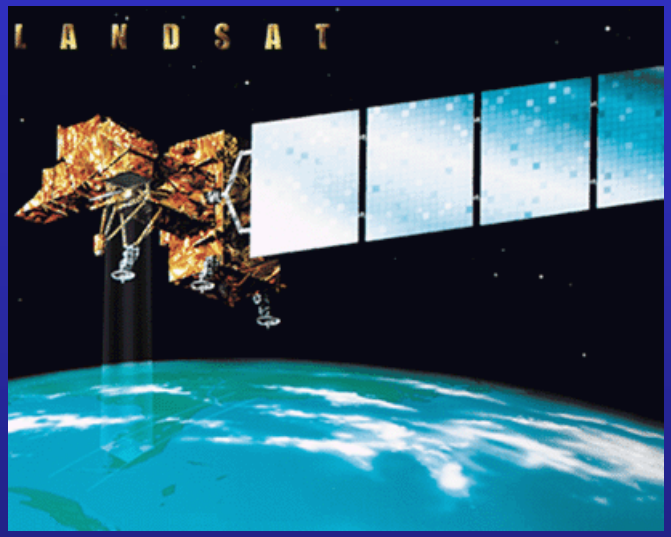
Ecologists learn about ecosystems through a combination of methods:

- field research
- systems analysis
  - system measurement
  - data analysis
  - systems modeling
  - systems simulation
  - systems optimization

Methods for Monitoring & Analysis

New technologies are enabling scientists to collect field information more effectively across broad geographic scales.

A) Remote sensing involves use of sensors to collect information about a system from a distance.



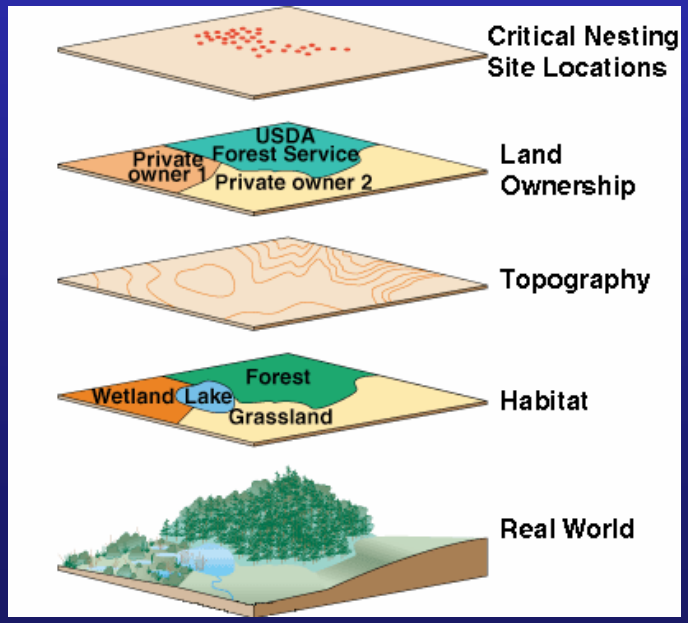


Fig. 4–26

B) Geographic Information Systems (GIS) provide the computer technology for organizing, storing, and analyzing complex map data.