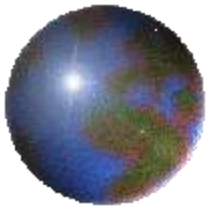


Ecosystems: Components, Energy Flow, and Matter Cycling

"All things come from earth, and to earth they all return"—Menander

Ecosystem Organization

- Organisms
  - Made of cells
  - Eukaryotic vs Prokaryotic
- Species
  - Groups of organisms that resemble one another in appearance, behavior, and genetic make up
  - Sexual vs Asexual reproduction
  - Production of viable offspring in nature
  - 1.5 million named; 10-14 million likely
- Populations
  - Genetic diversity
- Communities
- Ecosystems
- Biosphere

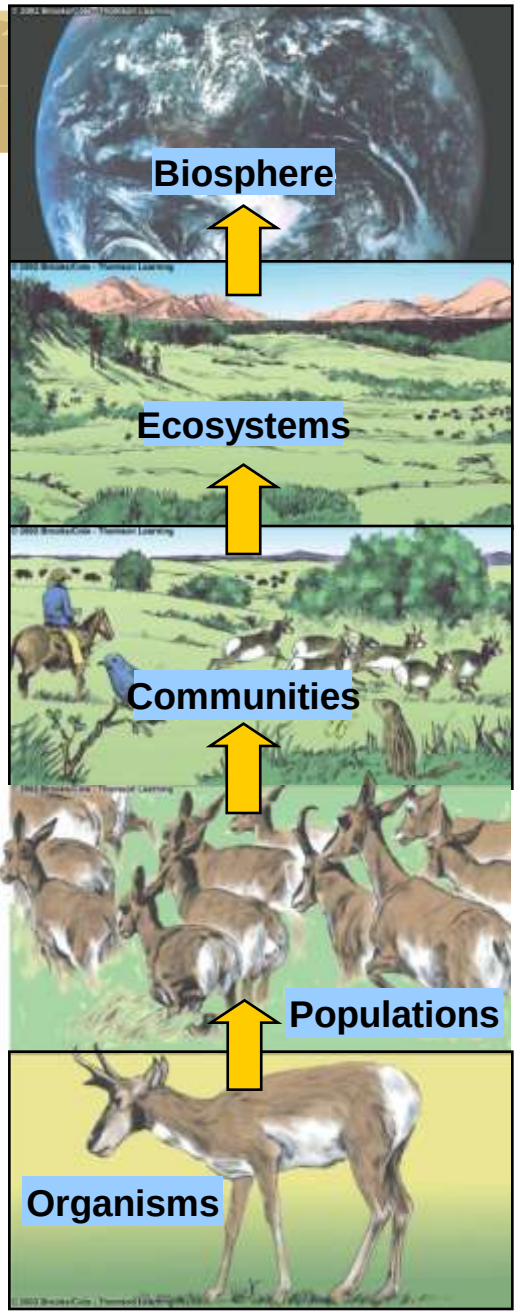
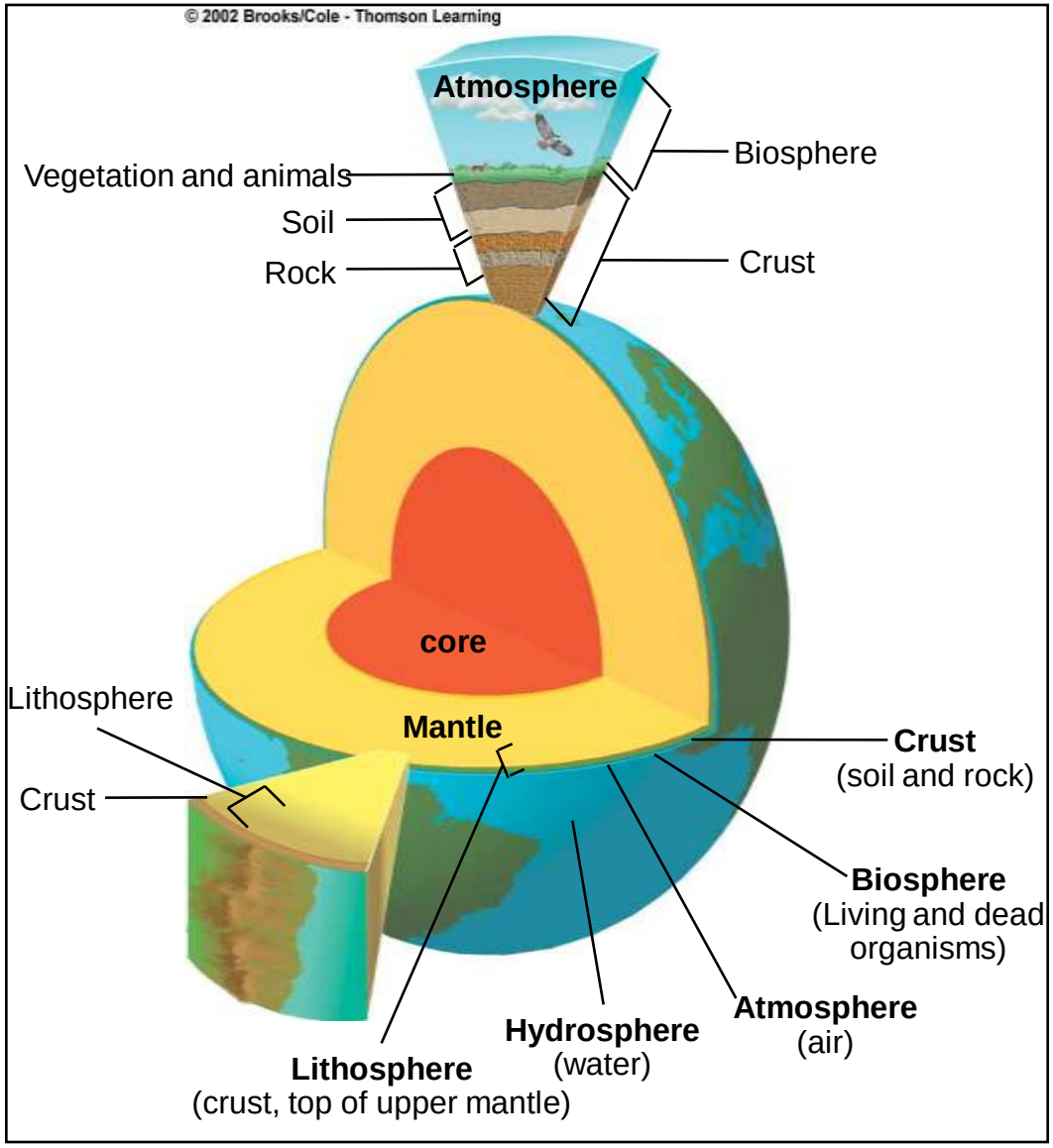


Fig. 4.2, p. 66

Earth's Life Support Systems

- Troposphere
  - To 11 miles
  - Air is here
- Stratosphere
  - 11 to 30 miles
  - Ozone layer
- Hydrosphere
  - Solid, liquid, and gaseous water
- Lithosphere
  - Crust and upper mantle
  - Contains non-renewable res.

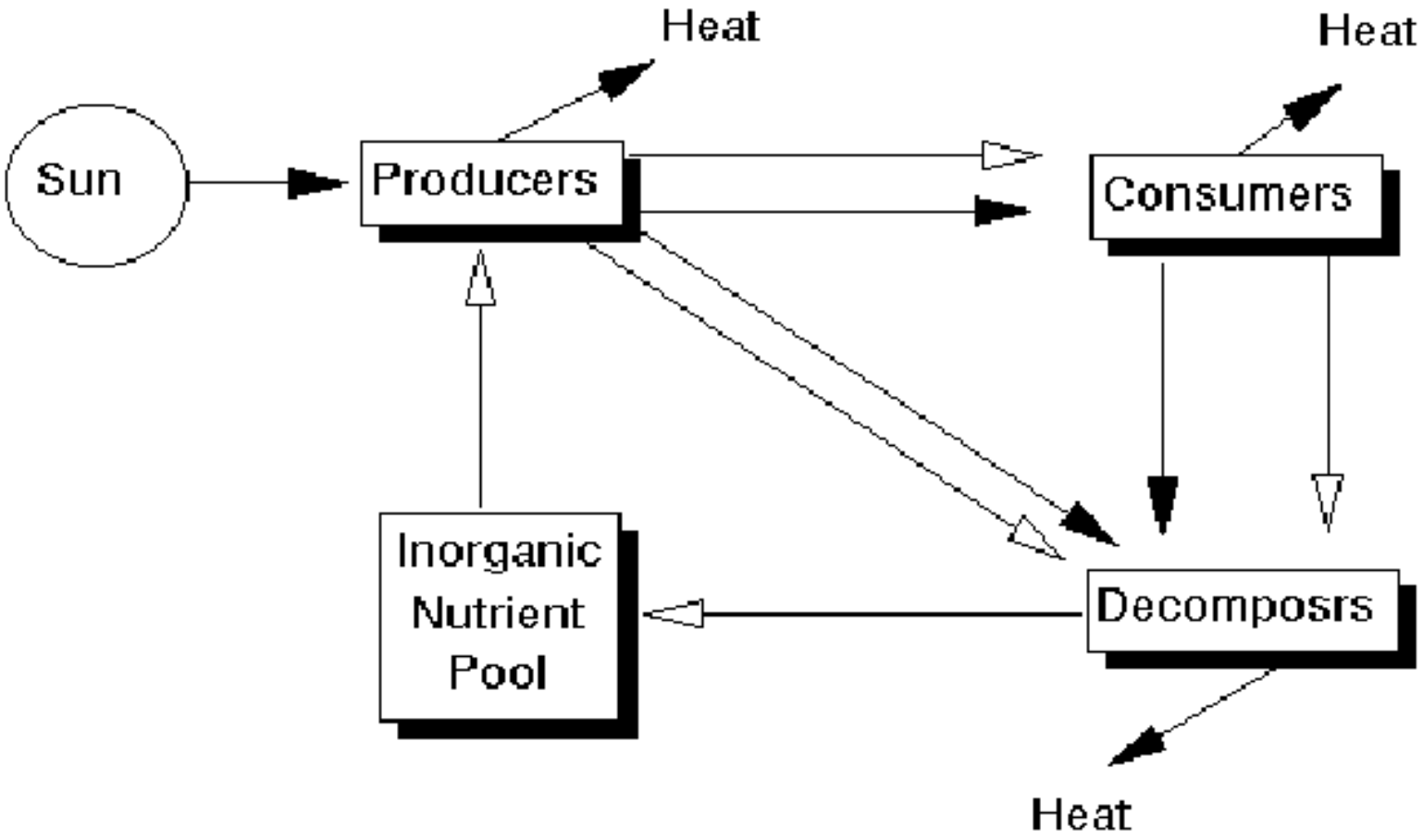


Major Ecosystem Components

- Abiotic Components
  - Water, air, temperature, soil, light levels, precipitation, salinity
  - Sets tolerance limits for populations and communities
  - Some are limiting factors that structure the abundance of populations
- Biotic Components
  - Producers, consumers, decomposers
  - Plants, animals, bacteria/fungi
  - Biotic interactions with biotic components include predation, competition, symbiosis, parasitism, commensalism etc.

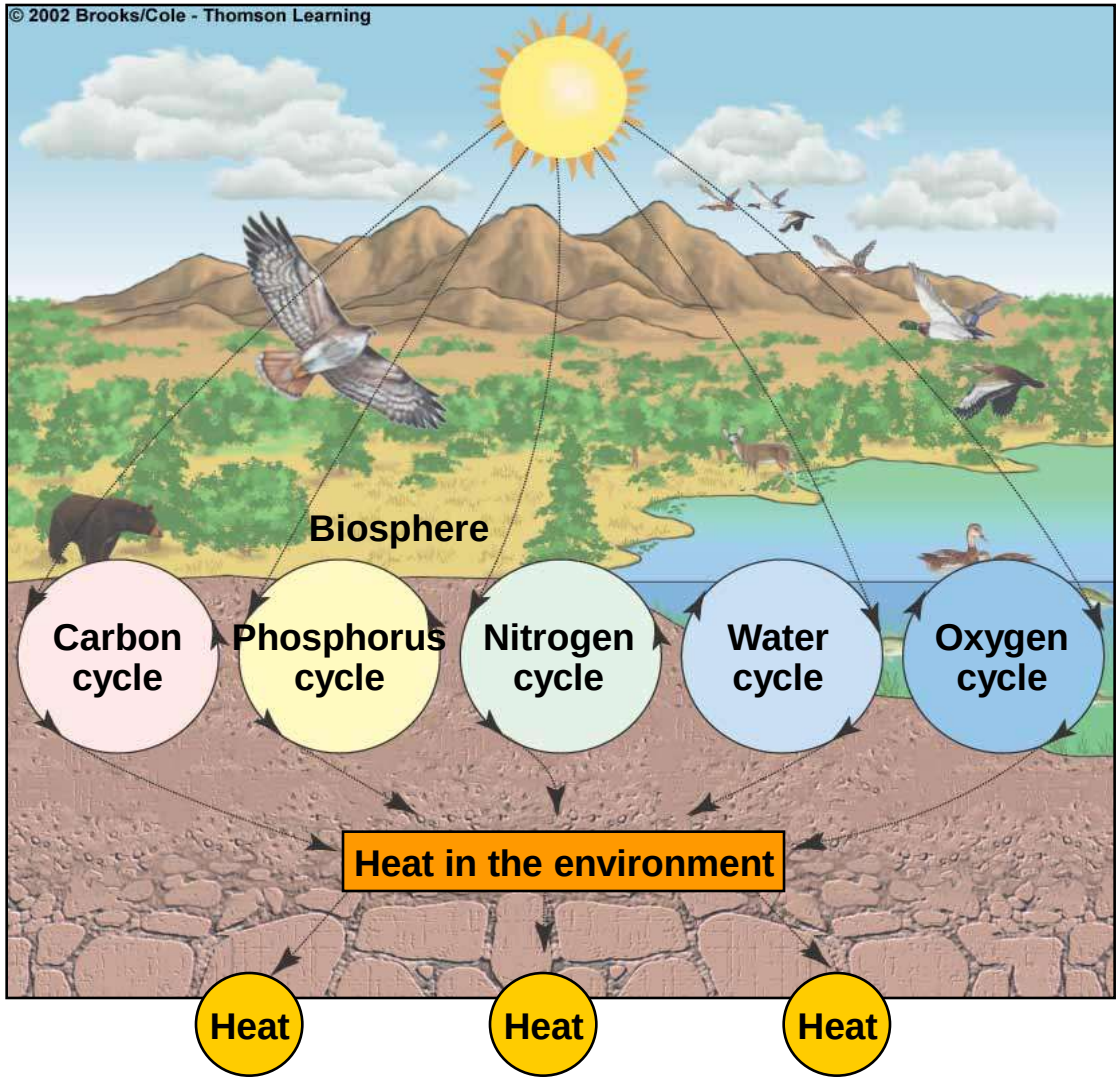
Limiting Factors on Land & in H_2O

- Terrestrial
  - Sunlight
  - Temperature
  - Precipitation
  - Soil nutrients
  - Fire frequency
  - Wind
  - Latitude
  - Altitude
- Aquatic/Marine
  - Light penetration
    - Water clarity
  - Water currents
  - Dissolved nutrient concentrations
    - Esp. N, P, Fe
  - Dissolved Oxygen concentration
  - Salinity

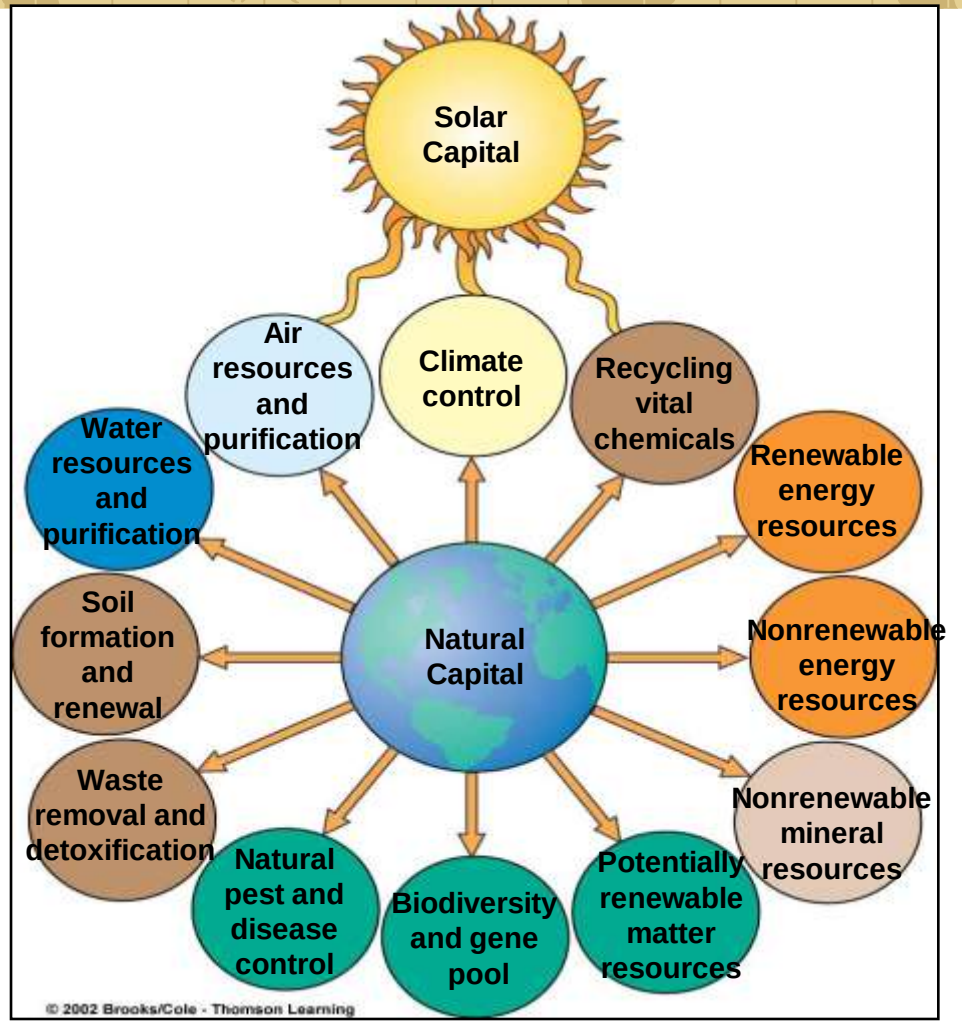

Heat
Heat
Sun
Producers
Consumers
Inorganic
Nutrient
Pool
Decomposrs
Heat

Sustaining Life on Earth…

- One way flow of high quality energy
- The cycling of matter (the earth is a closed system)
- Gravity
  - Causes downward movement of matter



Ecosystem Services and Sustainability



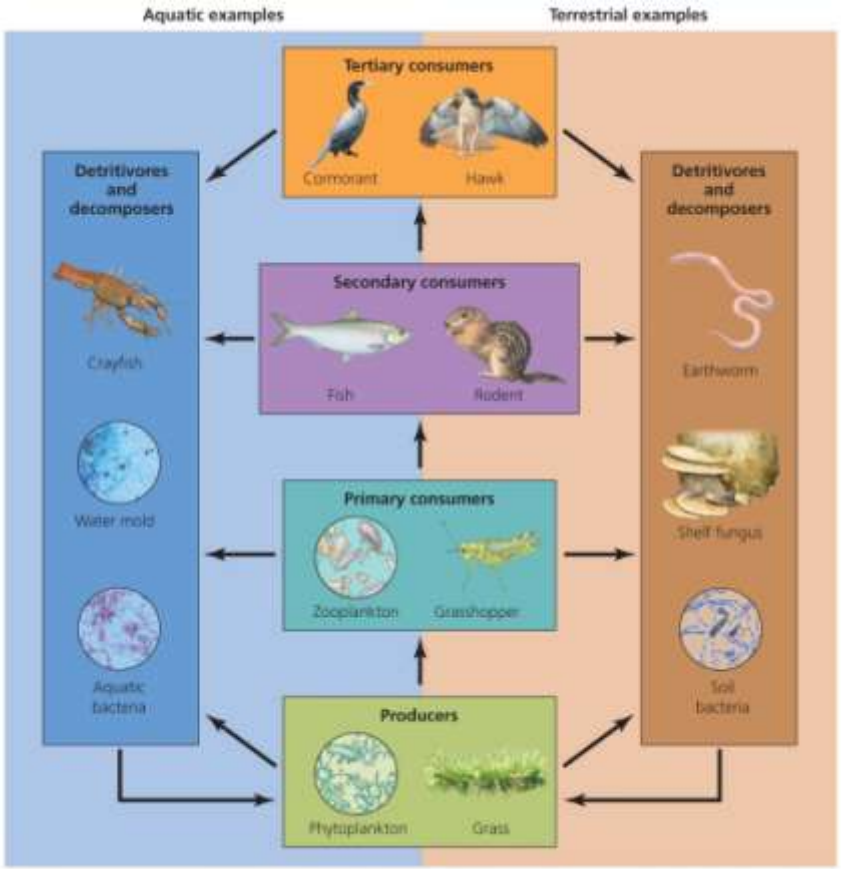
1. Use Renewable Solar Energy As Energy Source
2. Recycle the chemical nutrients needed for life

Ecological communities

- **Community** = an assemblage of species living in the same place at the same time
  - Members interact with each other
  - Interactions determine the structure, function, and species composition of the community
- **Community ecologists** = people interested in how:
  - Species coexist and relate to one another
  - Communities change, and why patterns exist

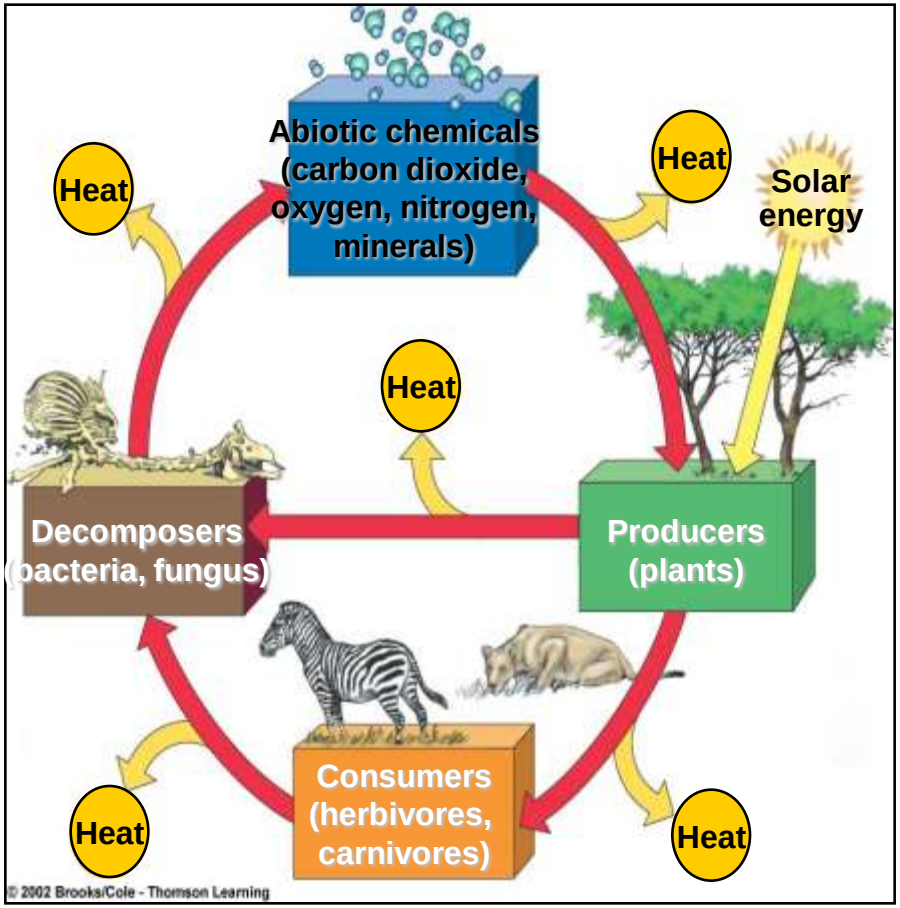
Energy passes through trophic levels

- One of the most important species interactions is who eats whom
- Matter and energy move through the community
- **Trophic levels** = rank in the feeding hierarchy
  - Producers
  - Consumers
  - Detritivores and Decomposers



Biotic Components of Ecosystems

- Producers=autotroph
  - Source of all food
  - Photosynthesis
- Consumers=heterotroph
  - Aerobic respiration
  - Anaerobic respiration
    - Methane, H_2S
- Decomposers
  - Matter recyclers…
  - Release organic compounds into soil and water where they can be used by producers

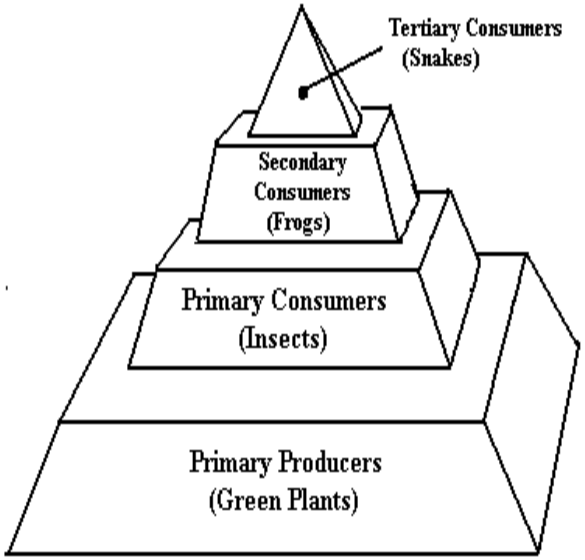


Producers: the first trophic level

- **Autotrophs** ("self-feeders") = organisms that capture solar energy for photosynthesis to produce sugars
  - Green Plants
  - Cyanobacteria
  - Algae
- **Chemosynthetic bacteria** use the geothermal energy in hot springs or deep-sea vents to produce their food

Consumers: organisms that consume producers

- **Primary consumers** = second trop level
  - Organisms that consume producers
  - **Herbivores** consume plants
  - Deer, grasshoppers
- **Secondary consumers** = third trophic level
  - Organisms that prey on primary consumers
  - **Carnivores** consume meat
  - Wolves, rodents



Consumers occur at even higher trophic levels

- **Tertiary Consumers** = fourth trophic level
  - Predators at the highest trophic level
  - Consume secondary consumers
  - Are also carnivores
  - Hawks, owls
- **Omnivores** = consumers that eat both plants and animals

Detritivores and decomposers

- Organisms that consume nonliving organic matter
  - Enrich soils and/or recycle nutrients found in dead organisms
- **Detritivores** = scavenge waste products or dead bodies
  - Millipedes
- **Decomposers** = break down leaf litter and other non-living material
  - Fungi, bacteria
  - Enhance topsoil and recycle nutrients

Detritivores vs Decomposers

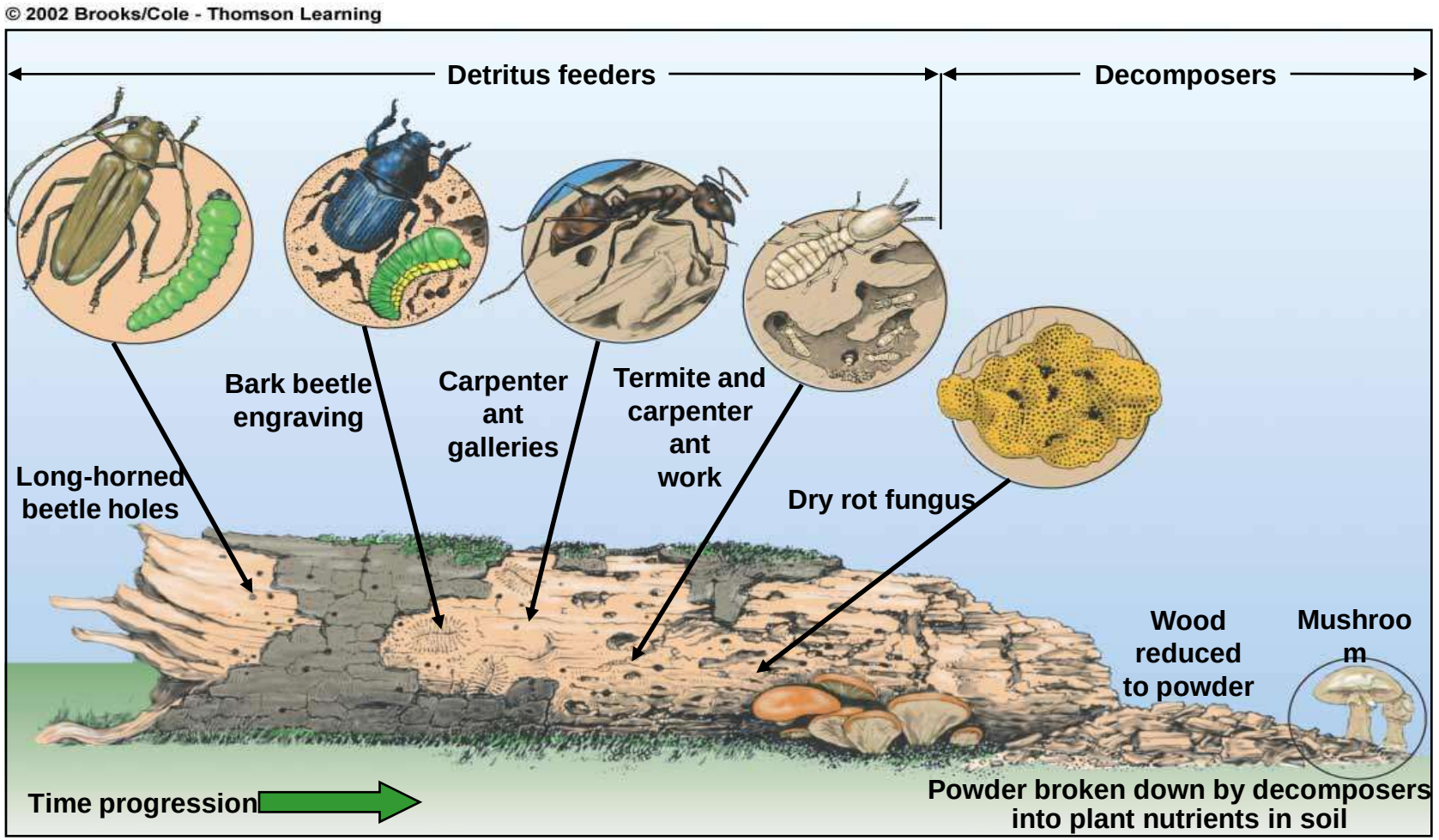
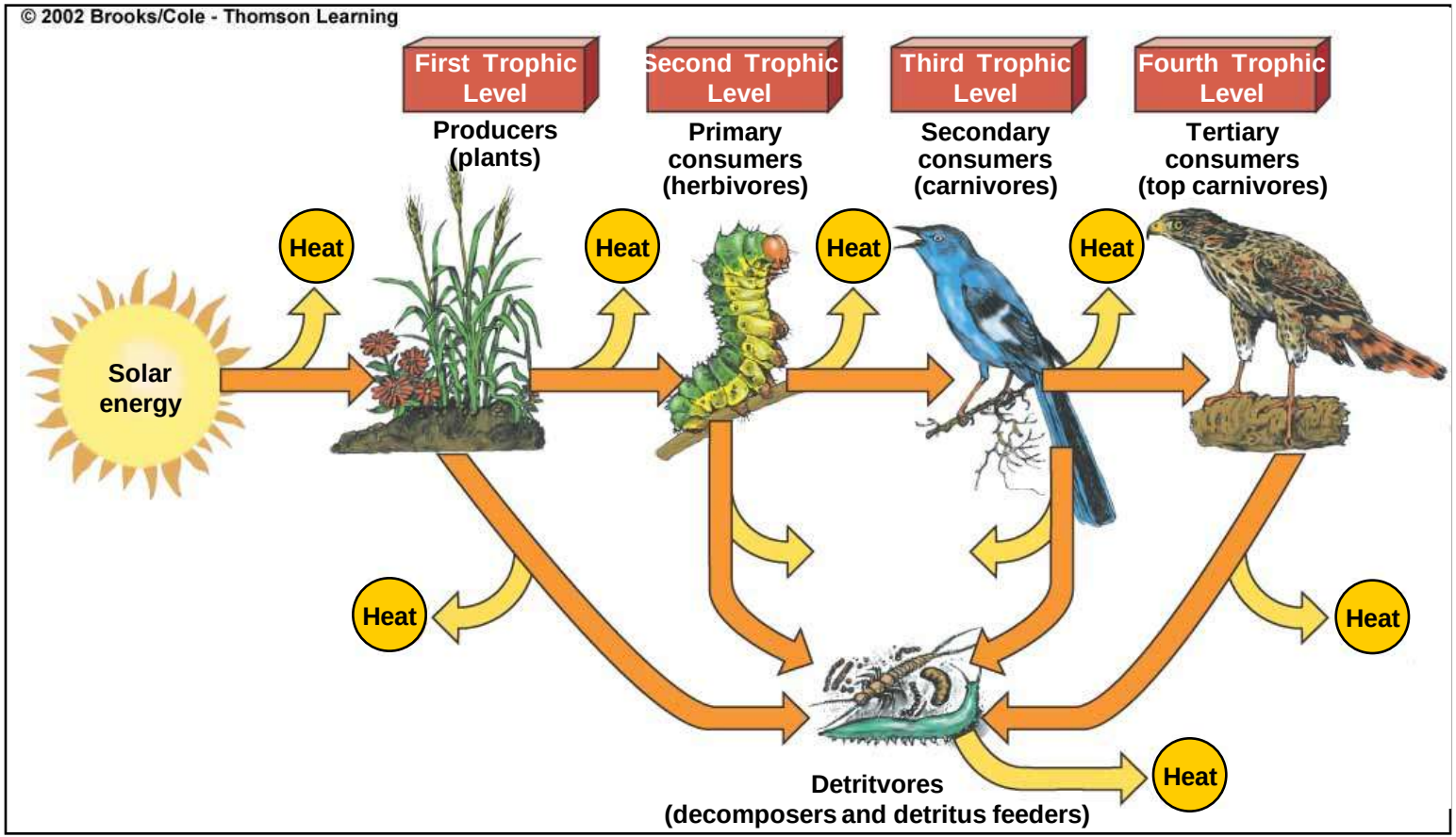


Fig. 4.15, p. 75

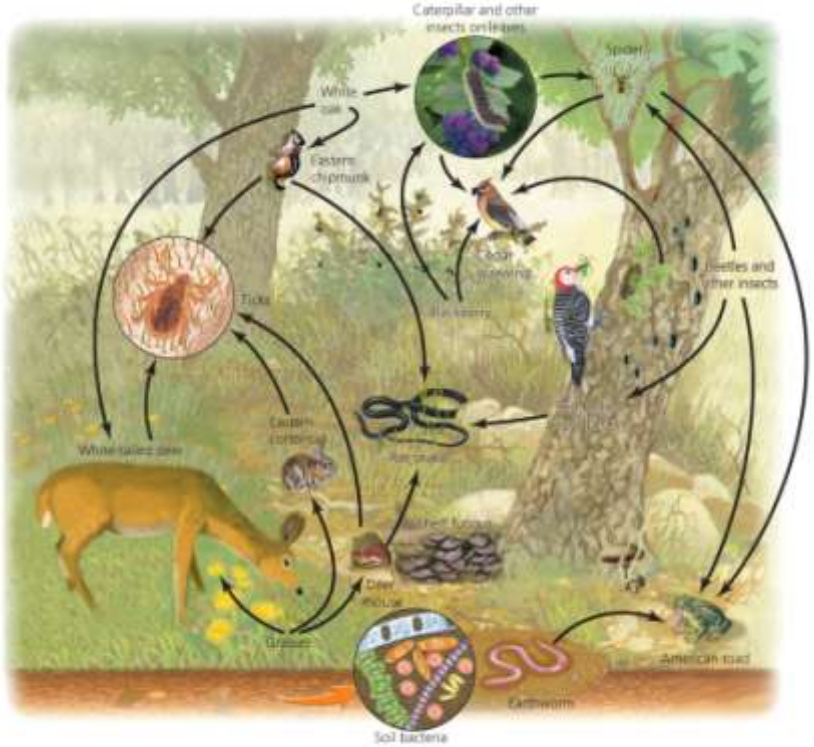
Energy Flow and Matter Cycling in Ecosystems…

- Food Chains vs. Food Webs
- KEY: There is little if no matter waste in natural ecosystems!

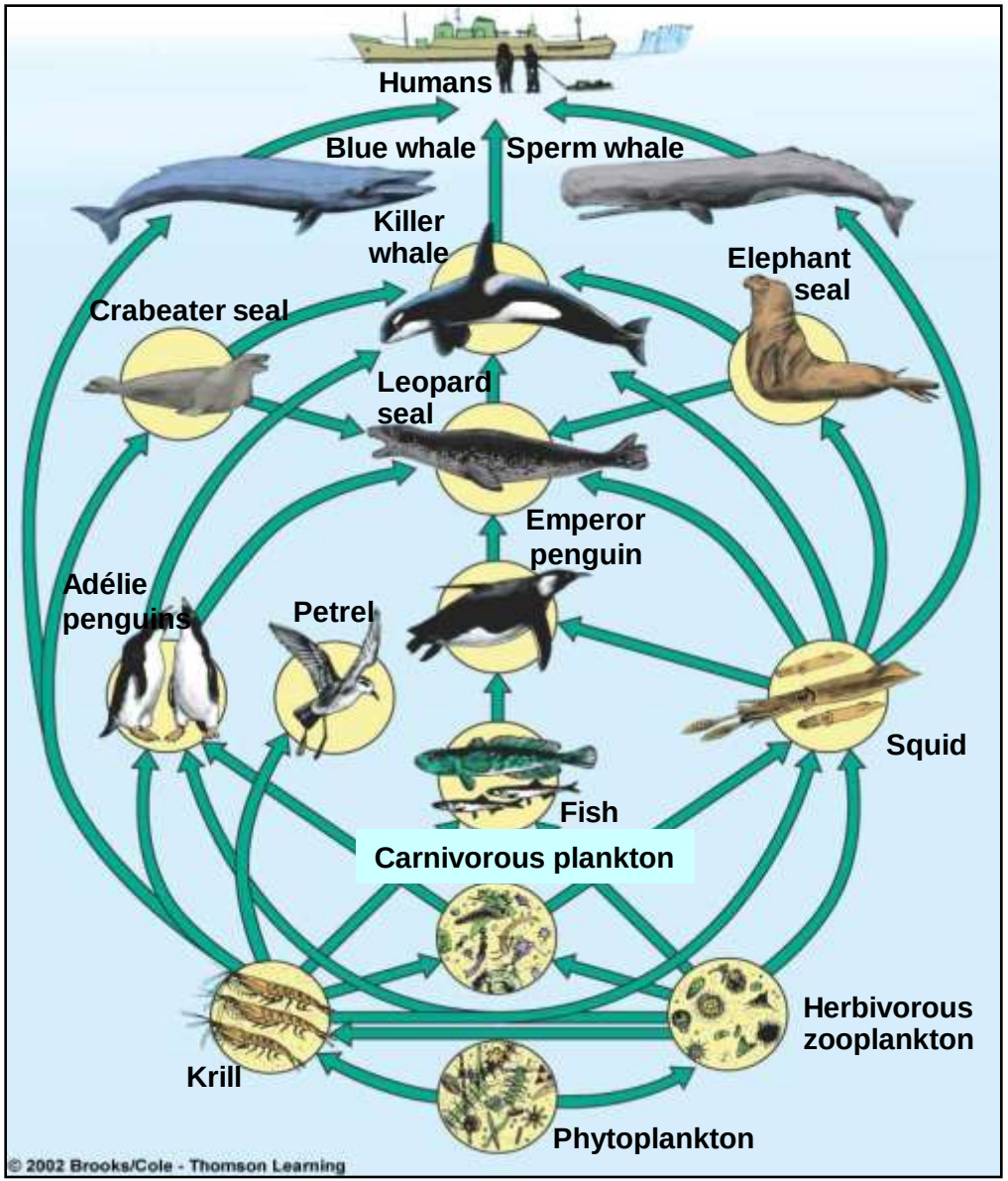


Food webs show relationships and energy flow

- **Food chain** = the relationship of how energy is transferred up the trophic levels
- **Food web** = a visual map of feeding relationships and energy flow
  - Includes many different organisms at all the various levels
  - Greatly simplified; leaves out the majority of species



Generalized Food Web of the Antarctic



Note:
Arrows
Go in direction
Of energy
flow…

Fig. 4.18, p. 77

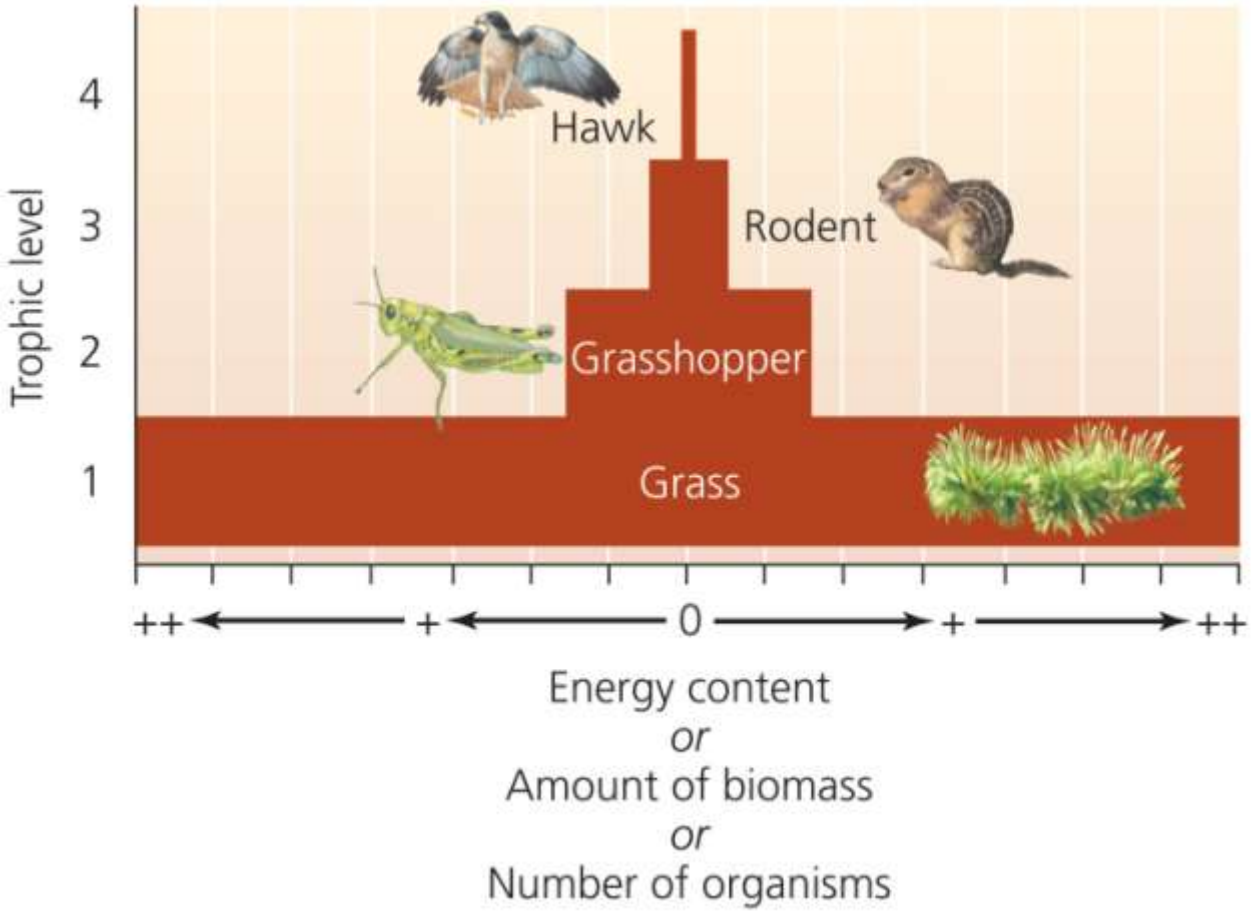
Food Webs and the Laws of matter and energy

- Food chains/webs show how matter and energy move from one organism to another through an ecosystem
- **Each trophic level contains a certain amount of biomass** (dry weight of all organic matter)
  - Chemical energy stored in biomass is transferred from one trophic level to the next
  - With each trophic transfer, some usable energy is degraded and lost to the environment as low quality heat
    - Thus, only a small portion of what is eaten and digested is actually converted into an organisms' bodily material or biomass (WHAT LAW ACCOUNTS FOR THIS?)
- **Ecological Efficiency**:
  - The % of usable energy transferred as biomass from one trophic level to the next (ranges from 5-20% in most ecosystems, use 10% as a rule of thumb)
  - Thus, the more trophic levels or steps in a food chain, the greater the cumulative loss of useable energy…

Energy, biomass, and numbers decrease

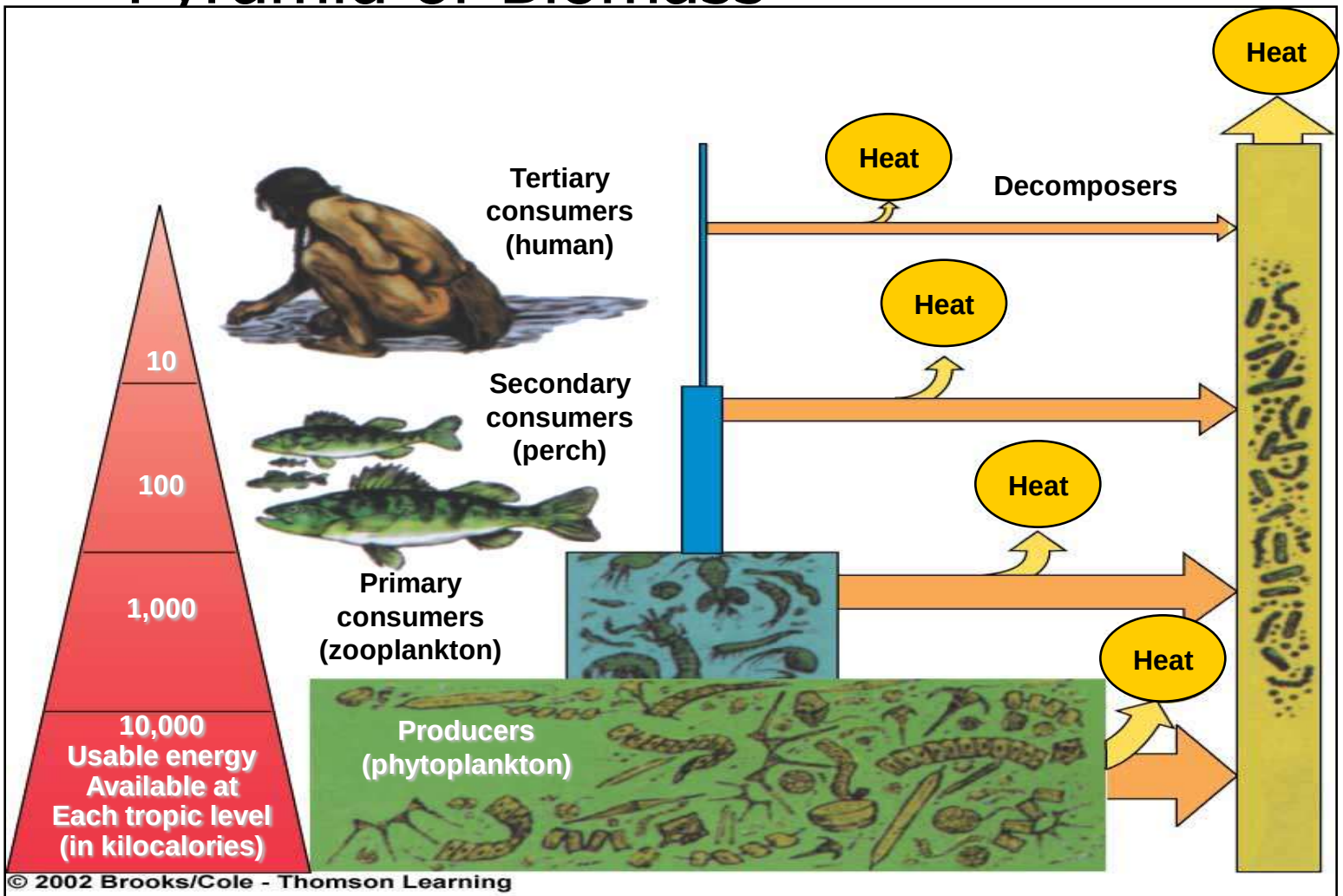
- Most energy organisms use is lost as waste heat through respiration
  - Less and less energy is available in each successive trophic level
  - Each level contains only 10% of the energy of the trophic level below it
- There are far fewer organisms at the highest trophic levels, with less energy available

Pyramids of energy, biomass, and numbers

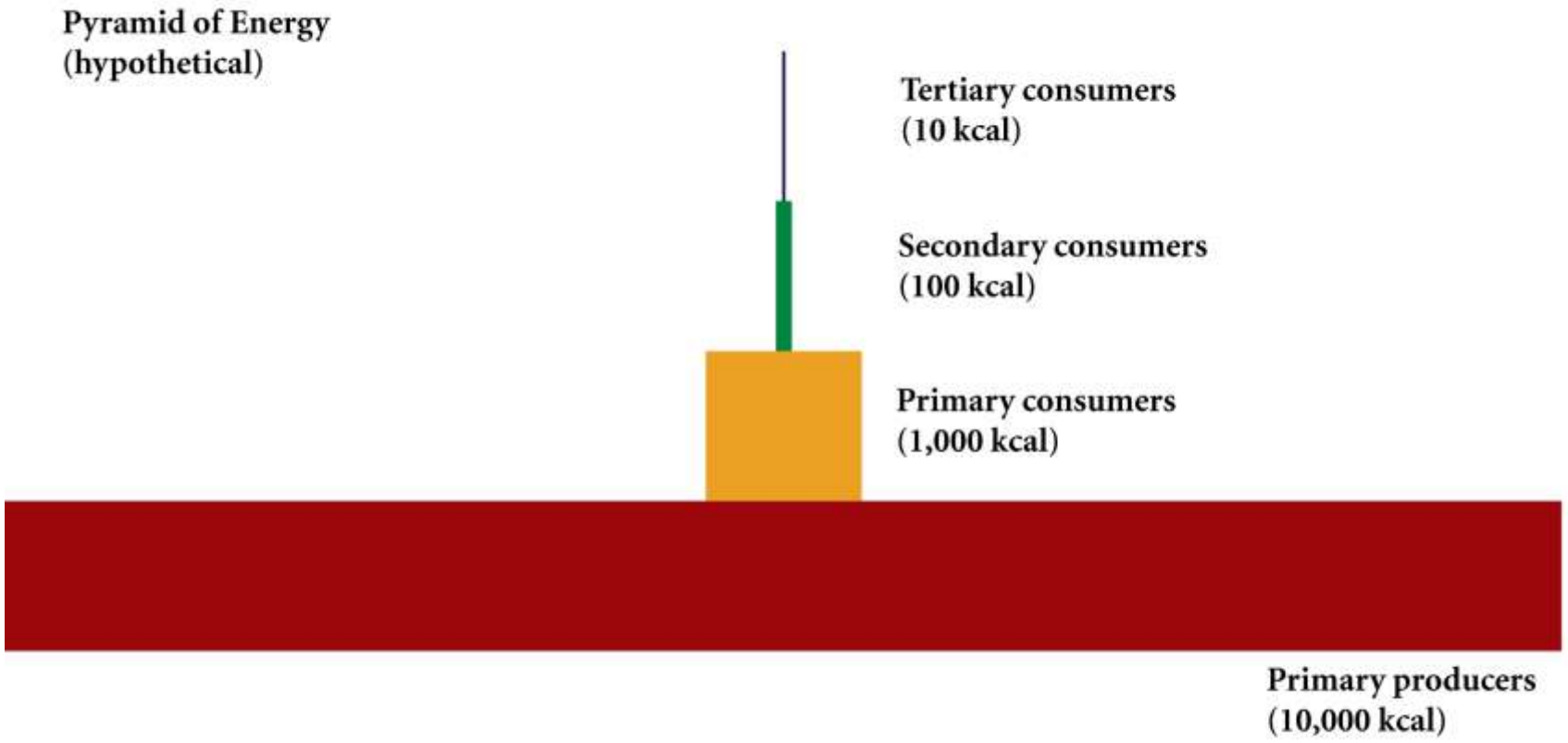


Pyramids of Energy and Matter

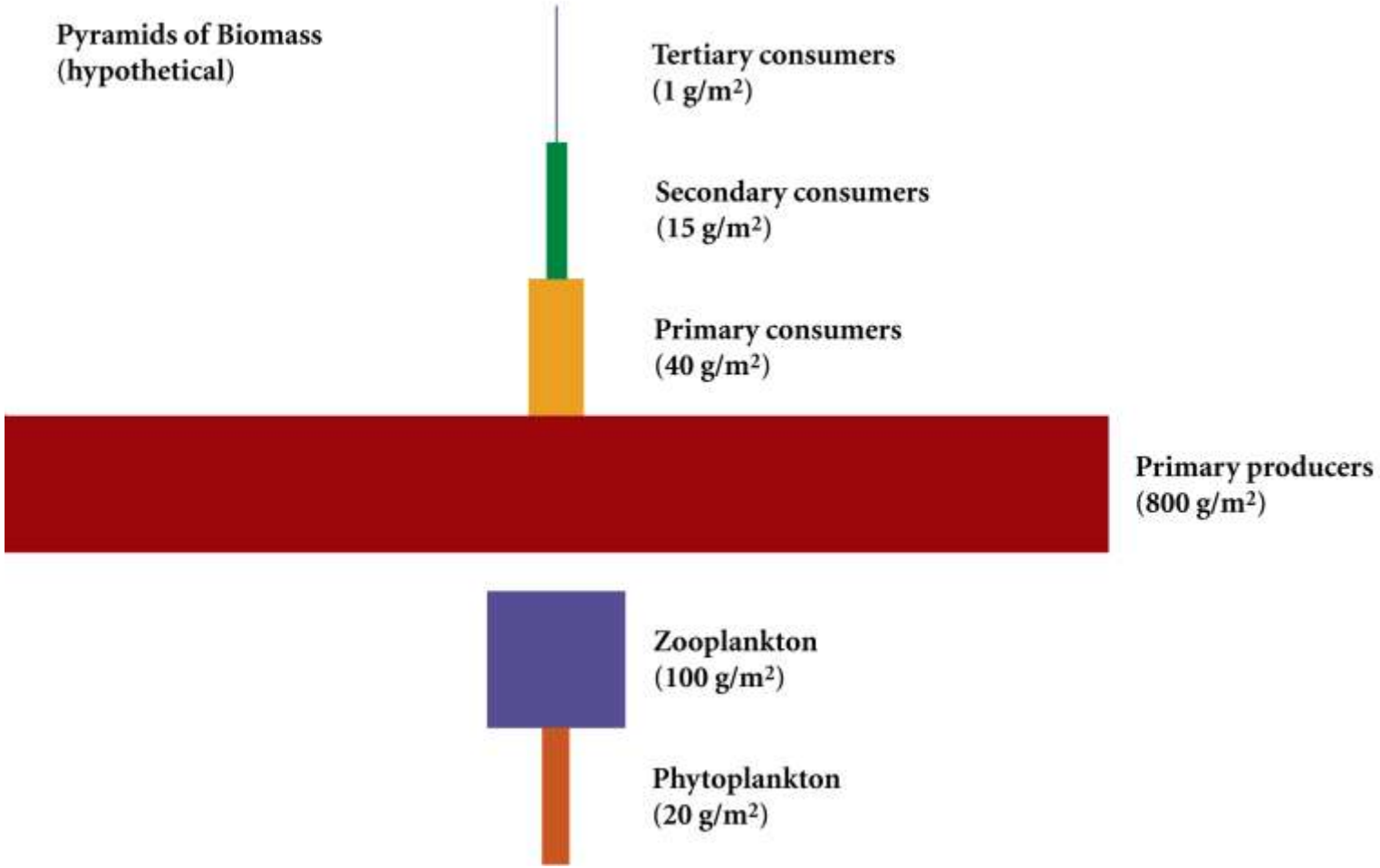
- Pyramid of Energy Flow
- Pyramid of Biomass

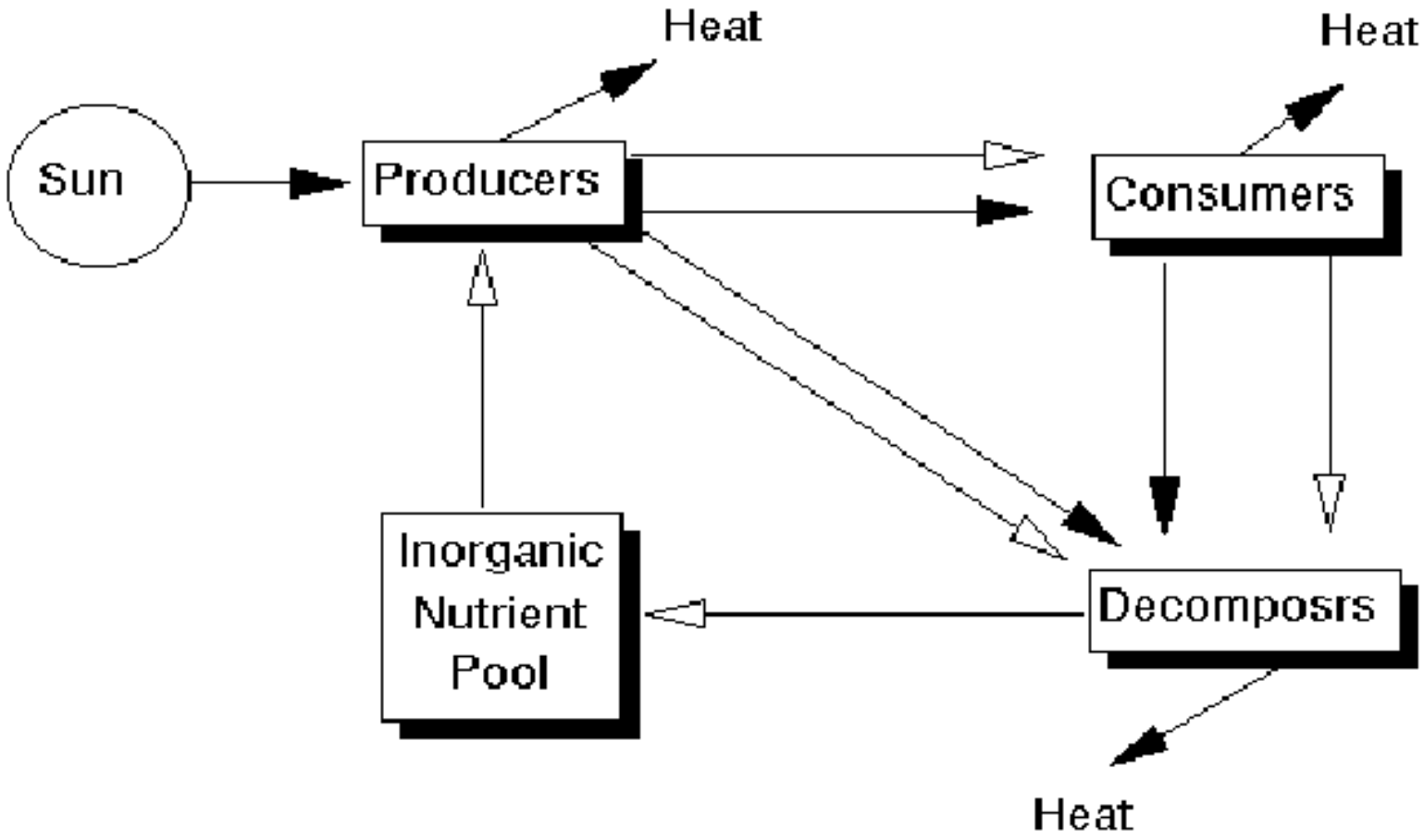


Ecological Pyramids of Energy



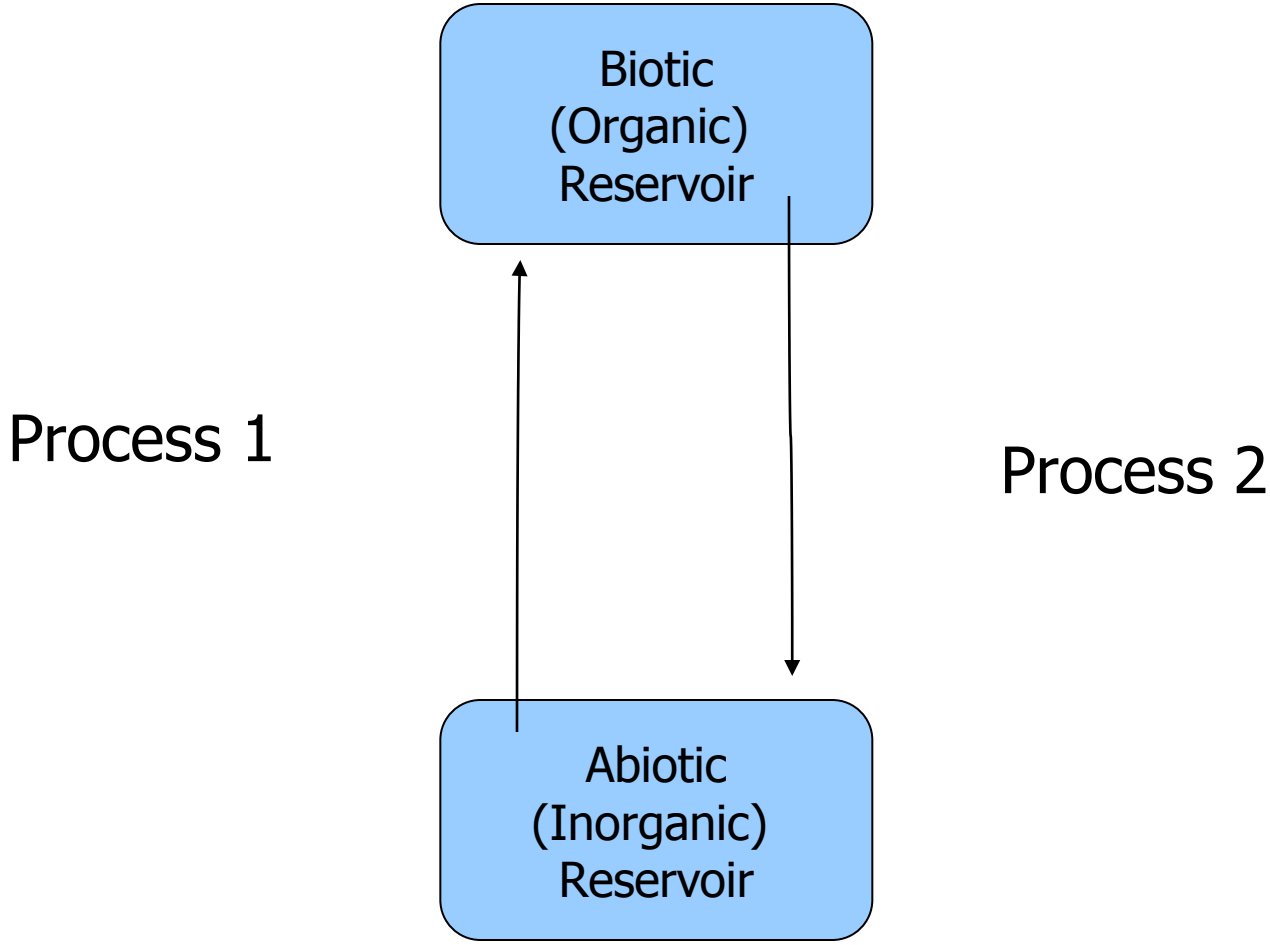
Ecological Pyramids of Biomass



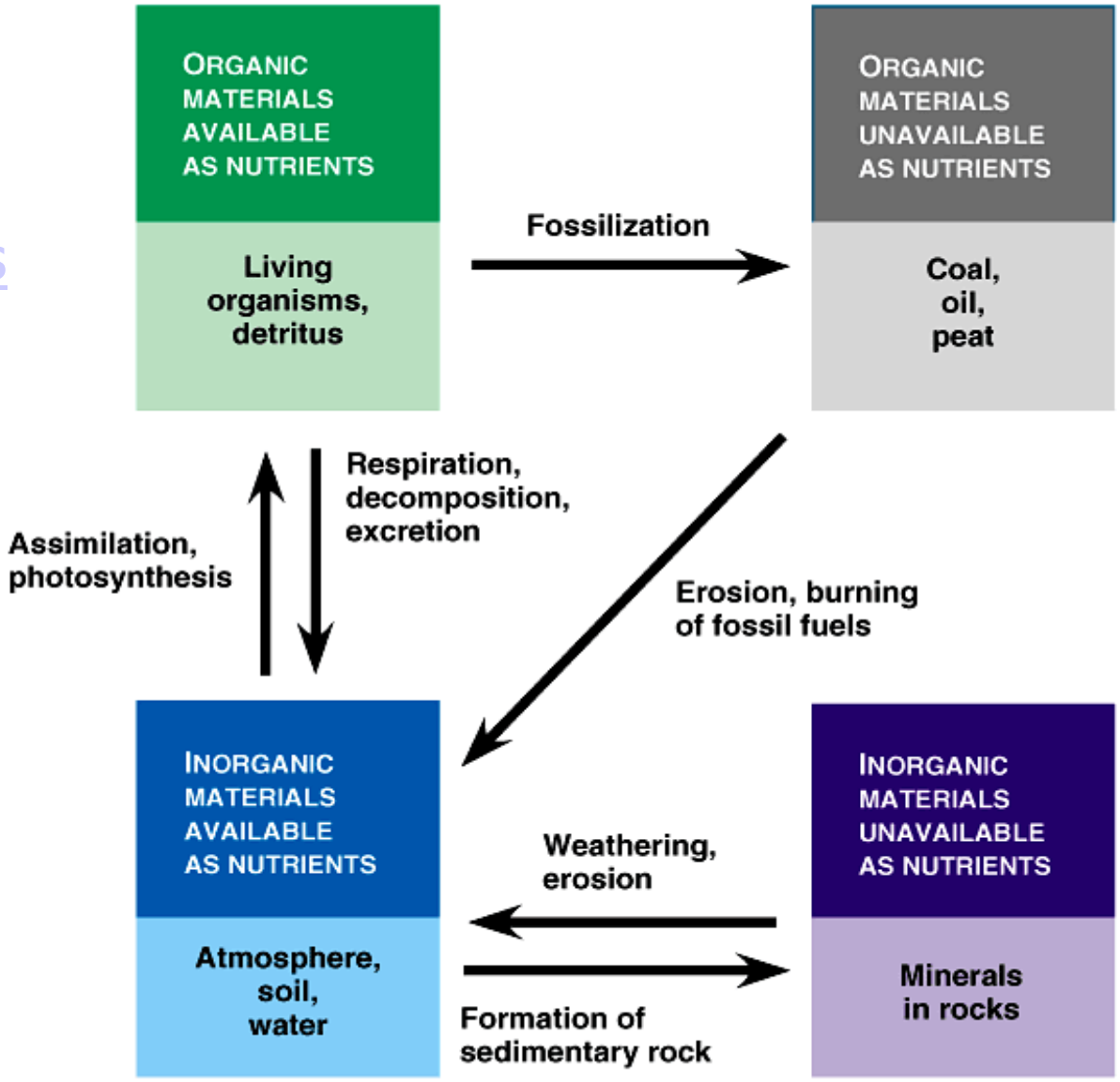

Heat
Heat
Sun
Producers
Consumers
Inorganic
Nutrient
Pool
Decomposrs
Heat

Matter Cycles

Basic Biogeochemical Cycling



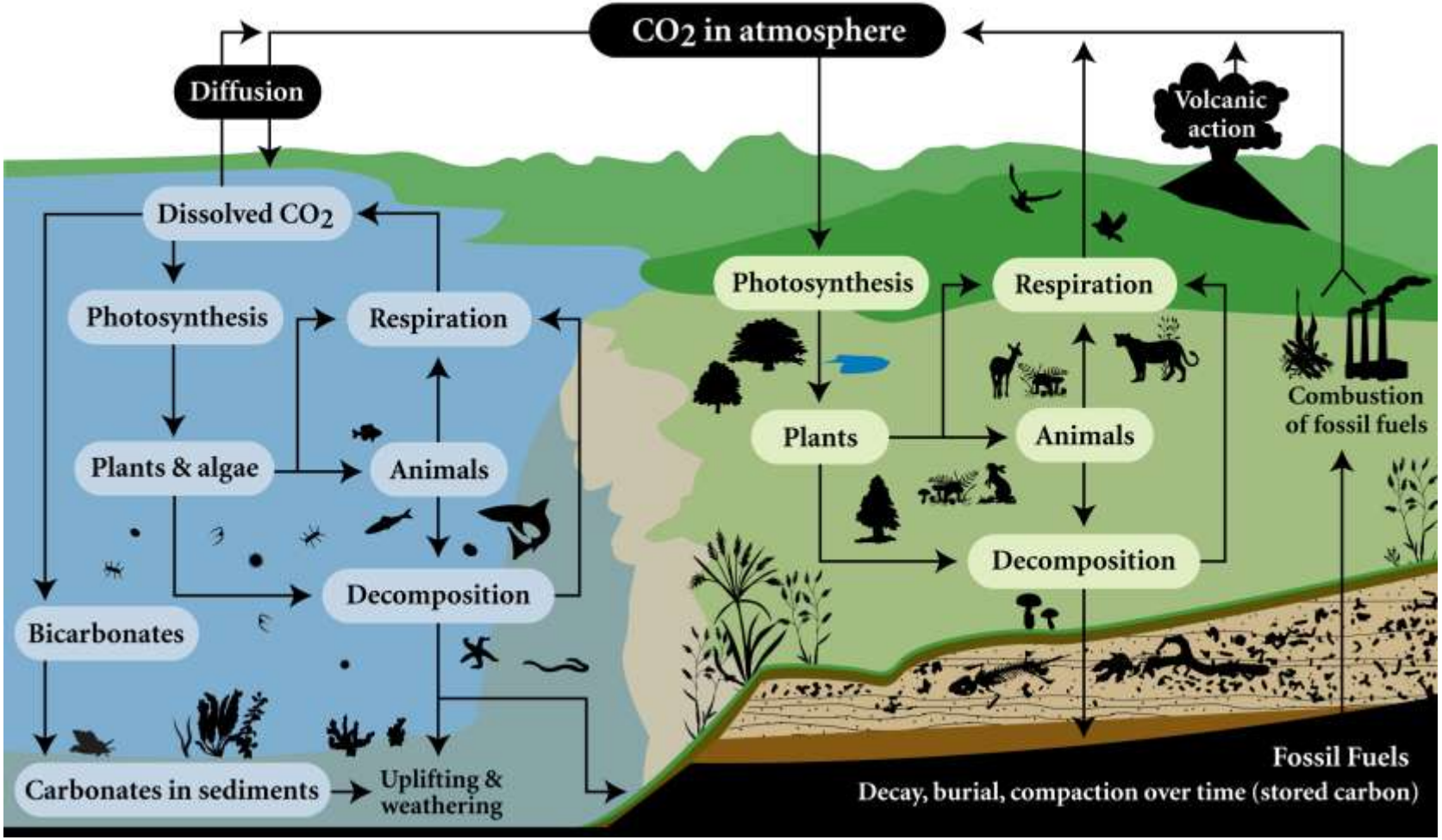
Common Reservoirs and Fluxes



Carbon Cycle

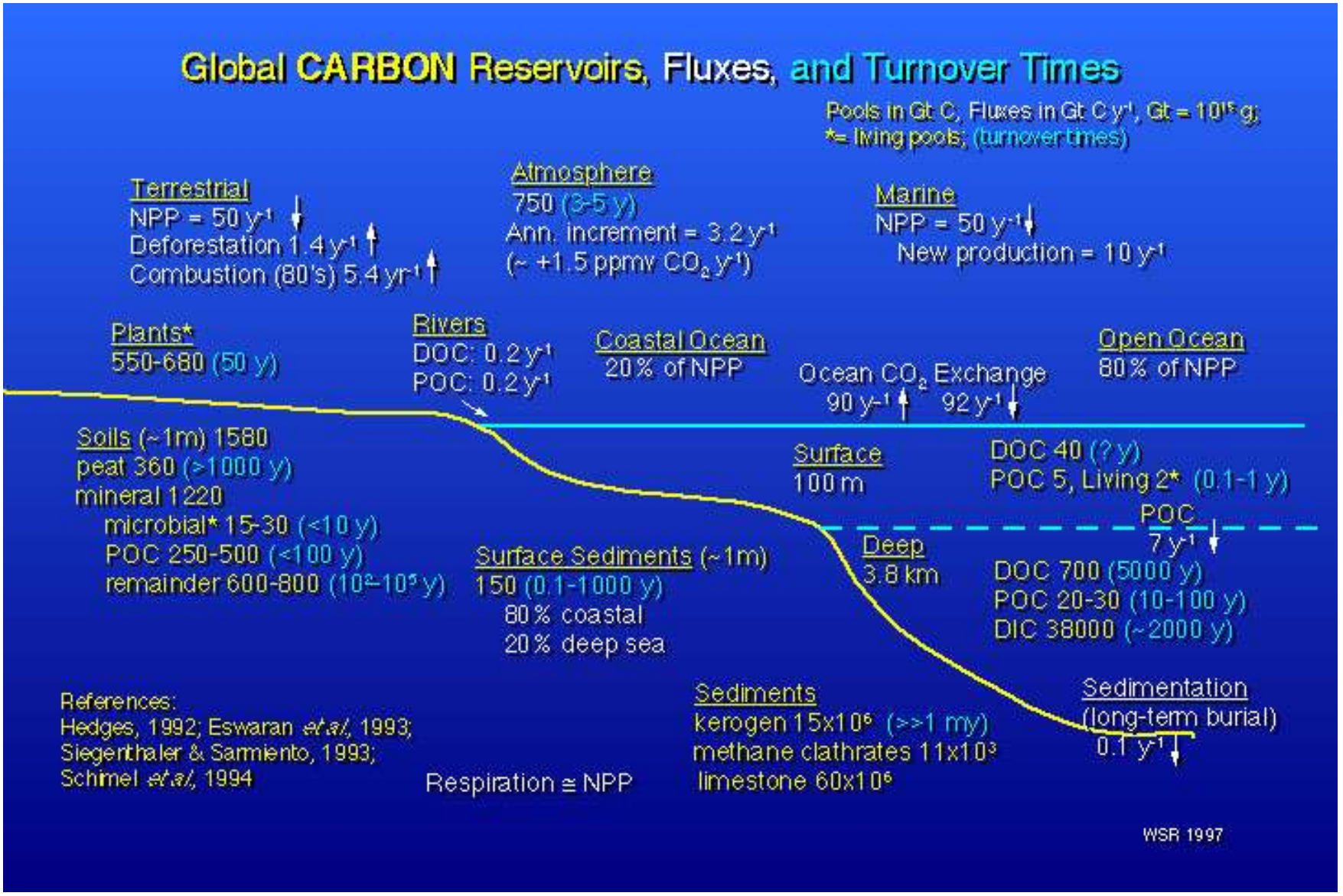
- Can be stored in five major areas:
  1. Living and dead organisms
  2. Atmosphere (carbon dioxide)
  3. Organic matter in soil
  4. Lithosphere as fossil fuels and rock deposits
  5. Oceans as dissolved CO2 and shells

Carbon Cycle



Estimated major stores of carbon on the Earth

Sink	Amounts in Billions of Metric Tons
Atmosphere	766
Soil Organic Matter	1500-1600
Ocean	38,000-40,000
Marine sediments and sedimentary rocks	66,000,000 to 100,000,000
Terrestrial plants	540-610
Fossil Fuel Deposits	4000

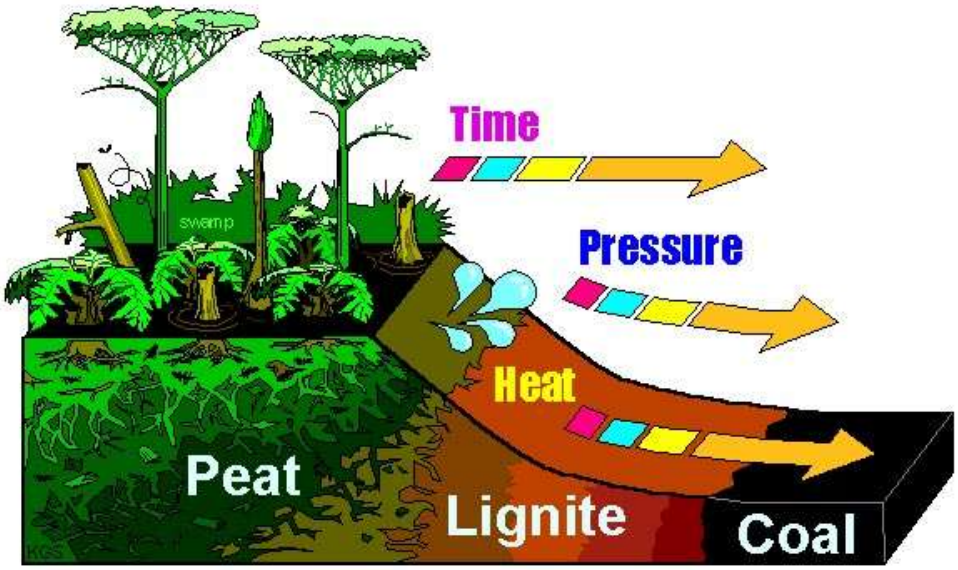

Global CARBON Reservoirs, Fluxes, and Turnover Times
Pools in Gt C, Fluxes in Gt C y-1, Gt = 10^15 g;
*= living pools; (turnover times)
Terrestrial
NPP = 50 y-1
Deforestation 1.4 y-1
Combustion (80's) 5.4 yr-1
Atmosphere
750 (3-5 y)
Ann. increment = 3.2 y-1
(~ +1.5 ppmv CO2 y-1)
Marine
NPP = 50 y-1
New production = 10 y-1
Plants*
550-680 (50 y)
Rivers
DOC: 0.2 y-1
POC: 0.2 y-1
Coastal Ocean
20 % of NPP
Ocean CO2 Exchange
90 y-1
92 y-1
Open Ocean
80 % of NPP
Soils (~1m) 1580
peat 360 (>1000 y)
mineral 1220
microbial* 15-30 (<10 y)
POC 250-500 (<100 y)
remainder 600-800 (10^2-10^3 y)
Surface
100 m
DOC 40 (? y)
POC 5, Living 2* (0.1-1 y)
POC
7 y-1
Deep
3.8 km
DOC 700 (5000 y)
POC 20-30 (10-100 y)
DIC 38000 (~2000 y)
Surface Sediments (~1m)
150 (0.1-1000 y)
80 % coastal
20 % deep sea
References:
Hedges, 1992; Eswaran et al., 1993;
Siegenthaler & Sarmiento, 1993;
Schimel et al., 1994
Respiration ≅ NPP
Sediments
kerogen 15x10^6 (>>1 my)
methane clathrates 11x10^3
limestone 60x10^6
Sedimentation
(long-term burial)
0.1 y-1
WSR 1997

Carbon in Oceans

- Enters through diffusion (creates carbonic acid)
- Some sea life use bicarbonate to produce shells and body parts (coral, clams, some algae)

Carbon cycle in the lithosphere

- Inorganic: coal, oil, natural gas, oil shale, limestone
- Created from organisms (both plant and animal) that died a long time ago and accumulated on the bottom of oceans or lakes



Carbon cycle in the soil

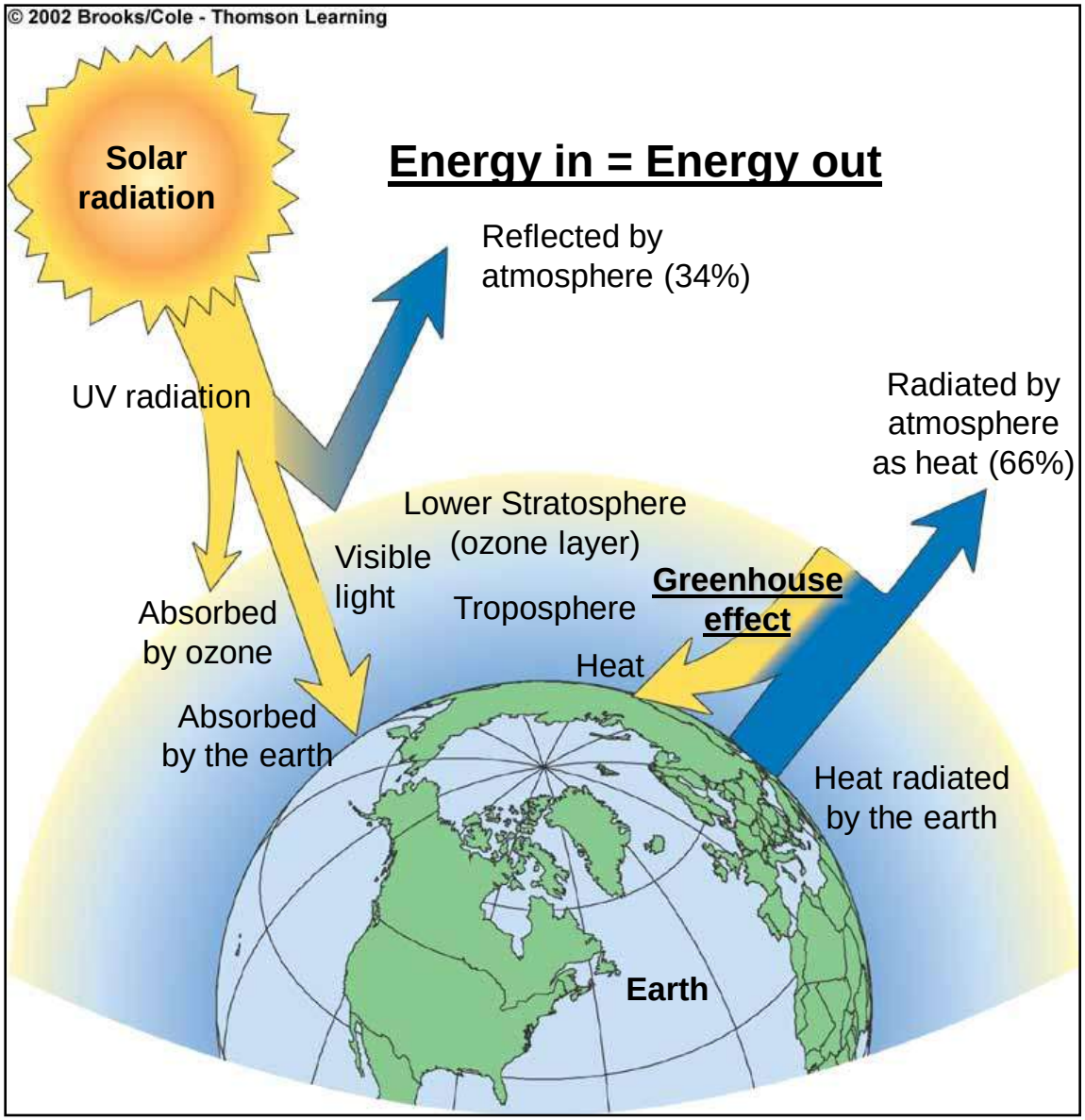
- Organic: litter, humic substances found in soil

Humans and the Carbon Cycle

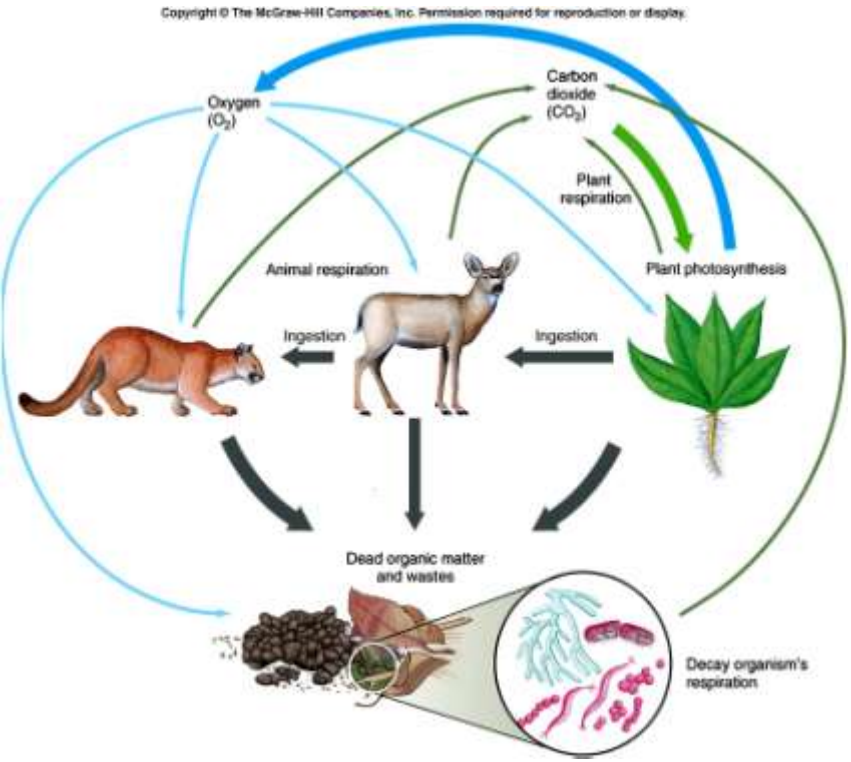
- Until recently: none
- Now: 6.5 billion metric tons of carbon are transferred from fossil fuel storage pool to the atmosphere

The Source of High Quality Energy

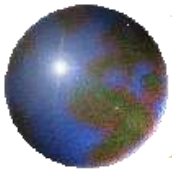
- Energy of sun lights and warms the planet
- Supports photosyn.
- Powers the cycling of matter
- Drives climate and weather that distribute heat and H_2O



Carbon in Ecosystems: Photosynthesis and Respiration



- Forms of C: CO_2, organic C compounds like glucose
- Processes
  - Photosynthesis: Carbon dioxide + water + solar energy $\xrightarrow{\text{chlorophyll}}$ glucose (sugar) + oxygen
  - Respiration: Glucose + oxygen $\Rightarrow$ Carbon dioxide + water + E

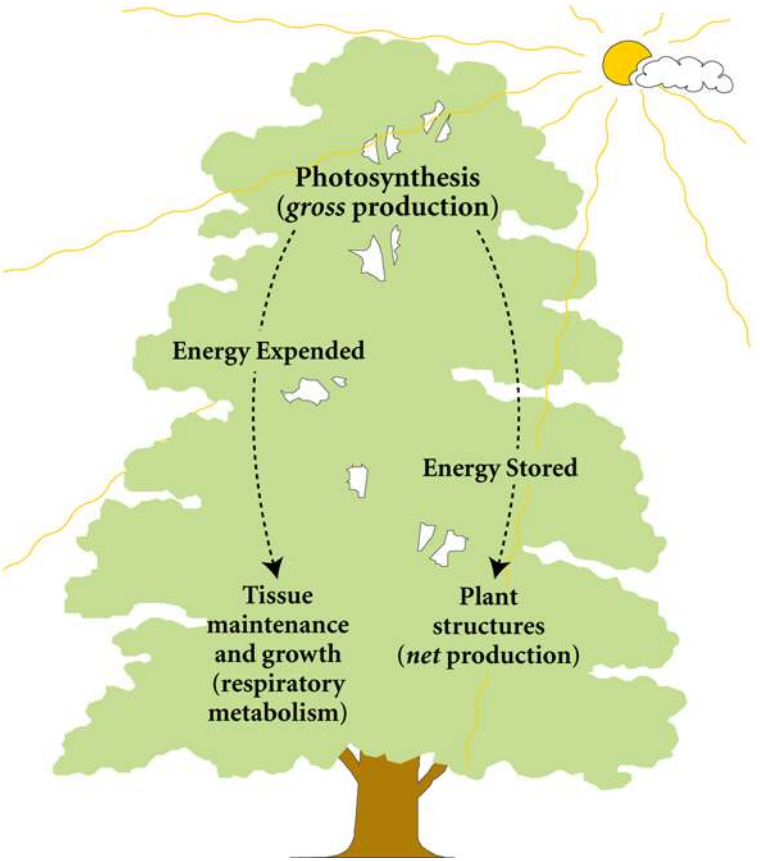


Fate of Solar Energy…

- Earth gets 1/billionth of sun's output of nrg
- 34% is reflected away by atmosphere
- 66% is absorbed by chemicals in atm = re-radiated into space
- Visible light, Infrared radiation (heat), and a small amount of UV not absorbed by ozone reaches the atmosphere
- Energy warms troposphere and land
  - Evaporates water and cycles it along with gravity
  - Generates winds
  - A tiny fraction is captured by photosynthesizing organisms
- Natural greenhouse effect vs. Global Warming

Primary Productivity

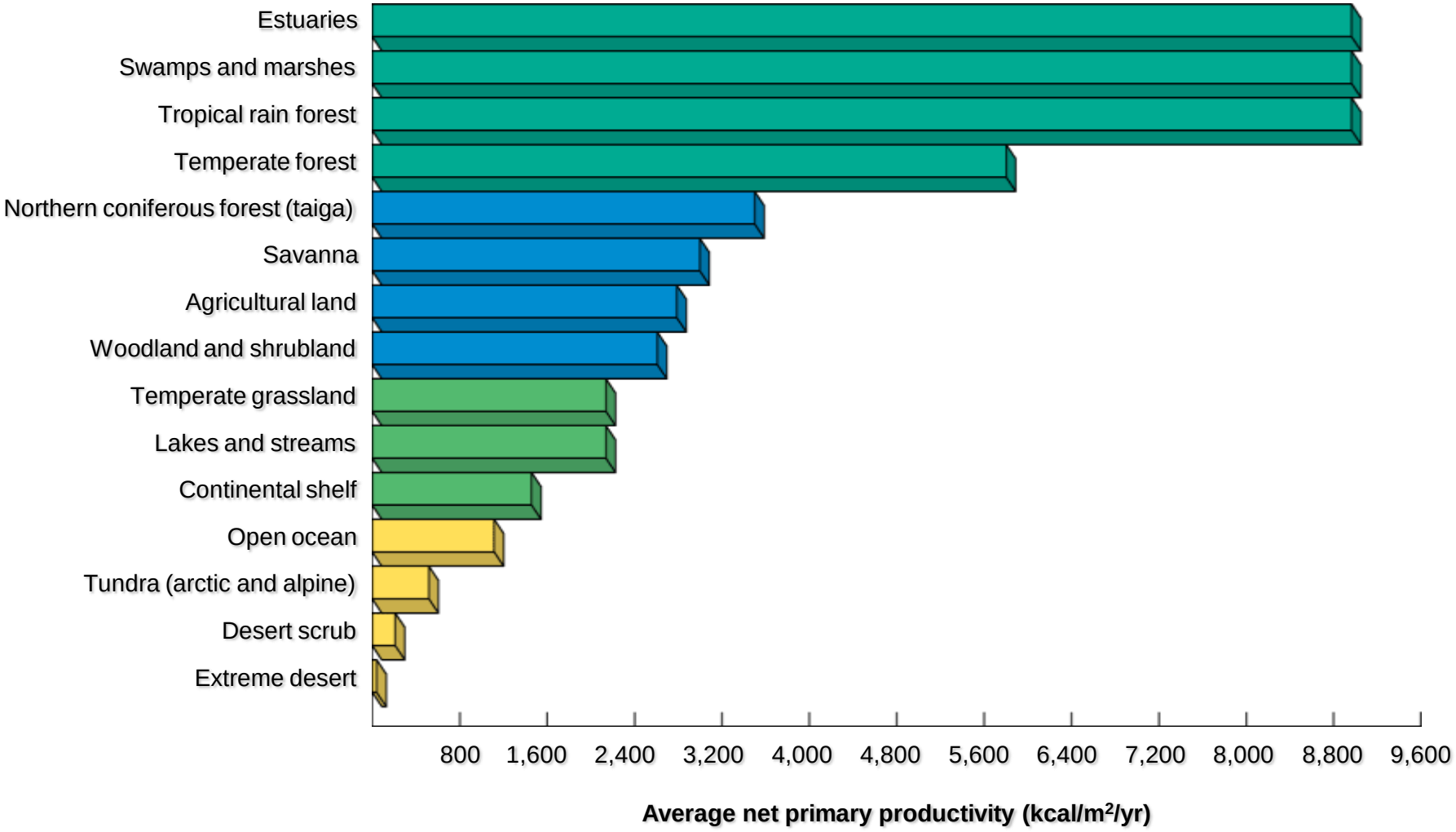
- The conversion of light energy to chemical energy is called "gross primary production."
- Plants use the energy captured in photosynthesis for maintenance and growth.
- The energy that is accumulated in plant biomass is called "net primary production."



Primary Productivity

- NPP=GPP-respiration rate
- GPP= RATE at which producers convert solar energy into chemical energy as biomass
  - Rate at which producers use photosynthesis to fix inorganic carbon into the organic carbon of their tissues
  - These producers must use some of the total biomass they produce for their own respiration
- NPP= Rate at which energy for use by consumers is stored in new biomass (available to consumers)
- Units Kcal/m^2/yr or g/m^2/yr
- How do you measure it? AP Lab Site
- Most productive vs. least productive

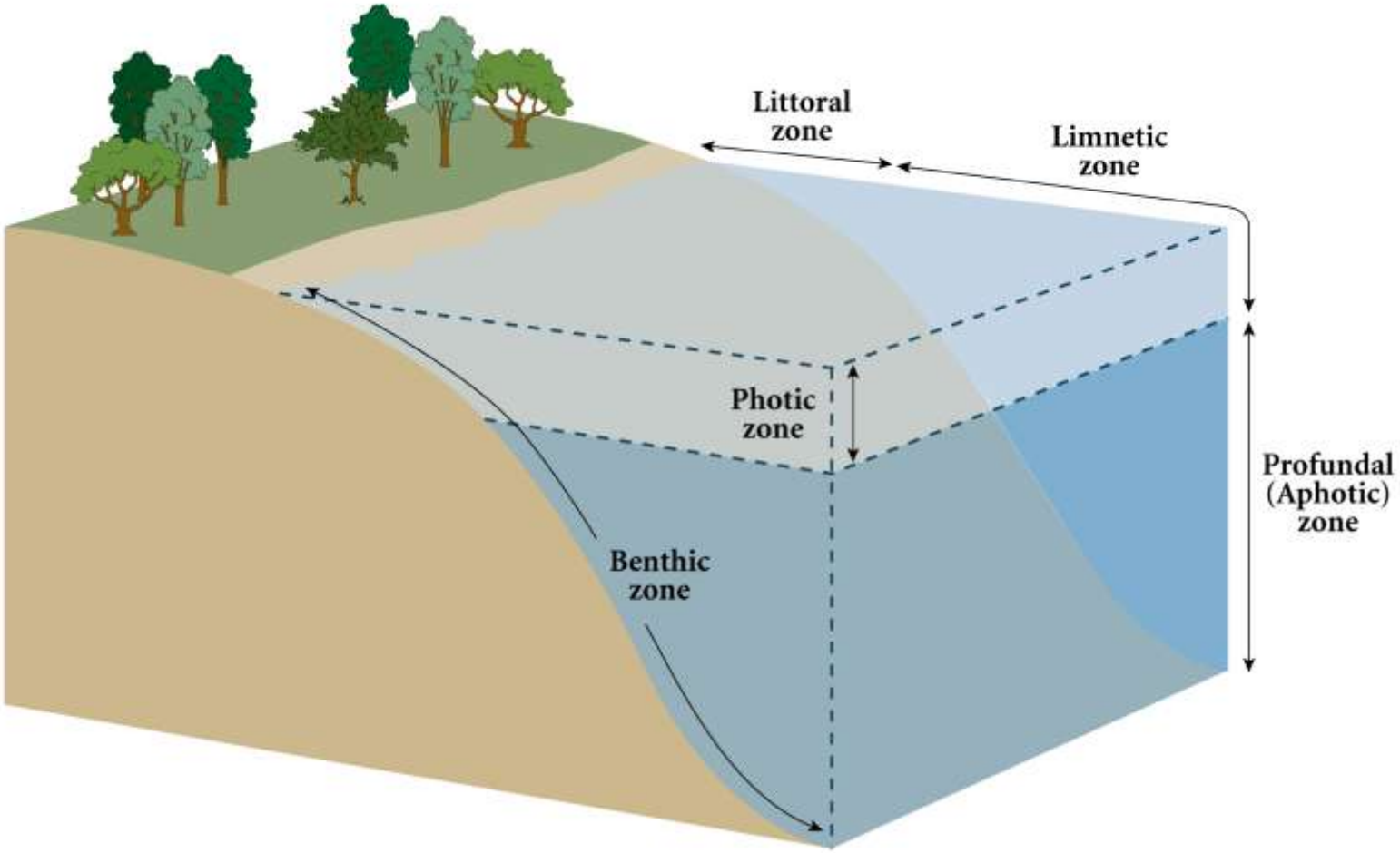
What are the most productive Ecosystems?



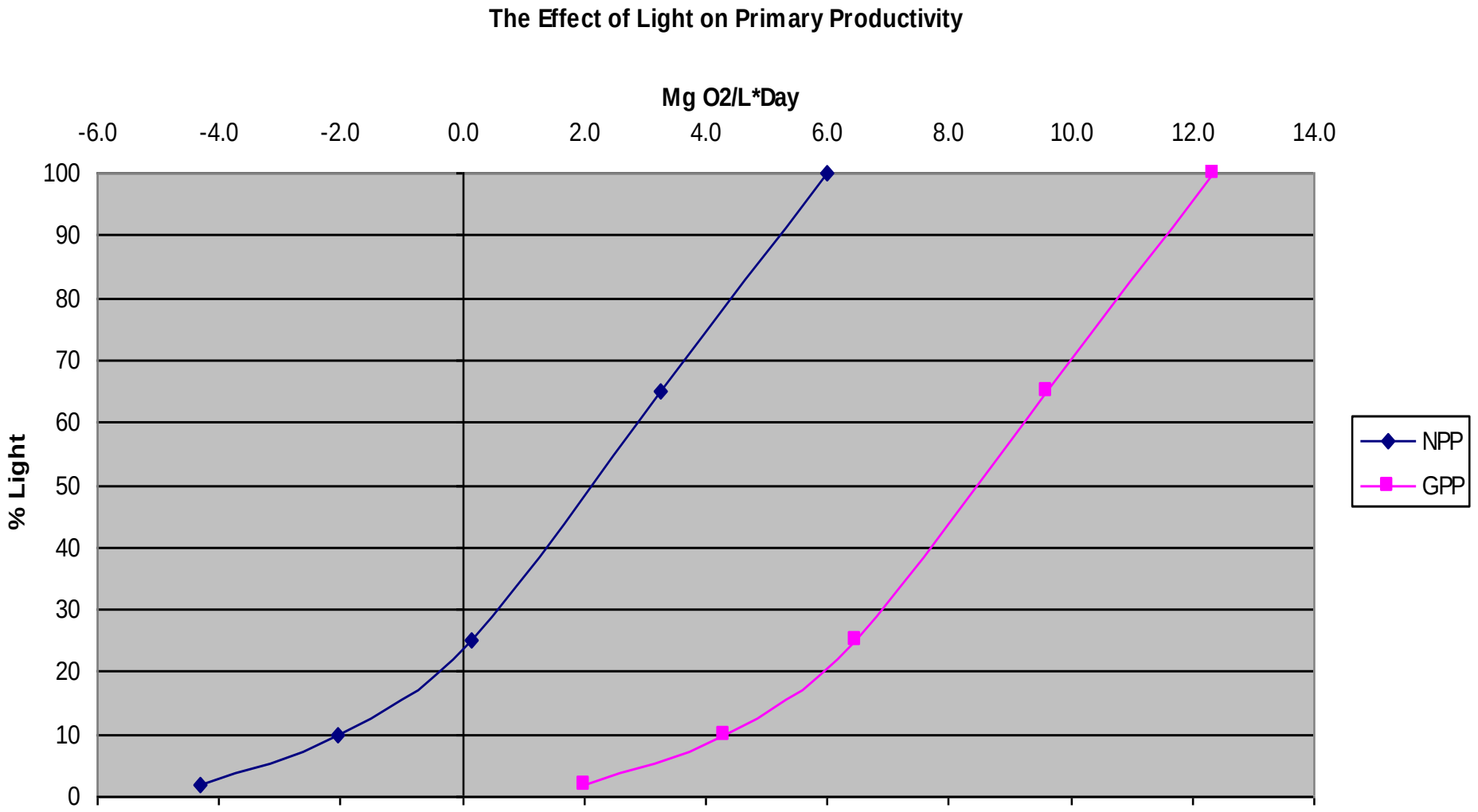
Lakes and ponds are ecologically diverse

- Lakes and ponds are bodies of open, standing water
- **Littoral zone** = region ringing the edge of a water body
- **Benthic zone** = extends along the entire bottom of the water body
  - Home to many invertebrates
- **Limnetic zone** = open portions of the lake or pond where the sunlight penetrates the shallow waters
- **Profundal zone** = water that sunlight does not reach
  - Supports fewer animals because there is less oxygen

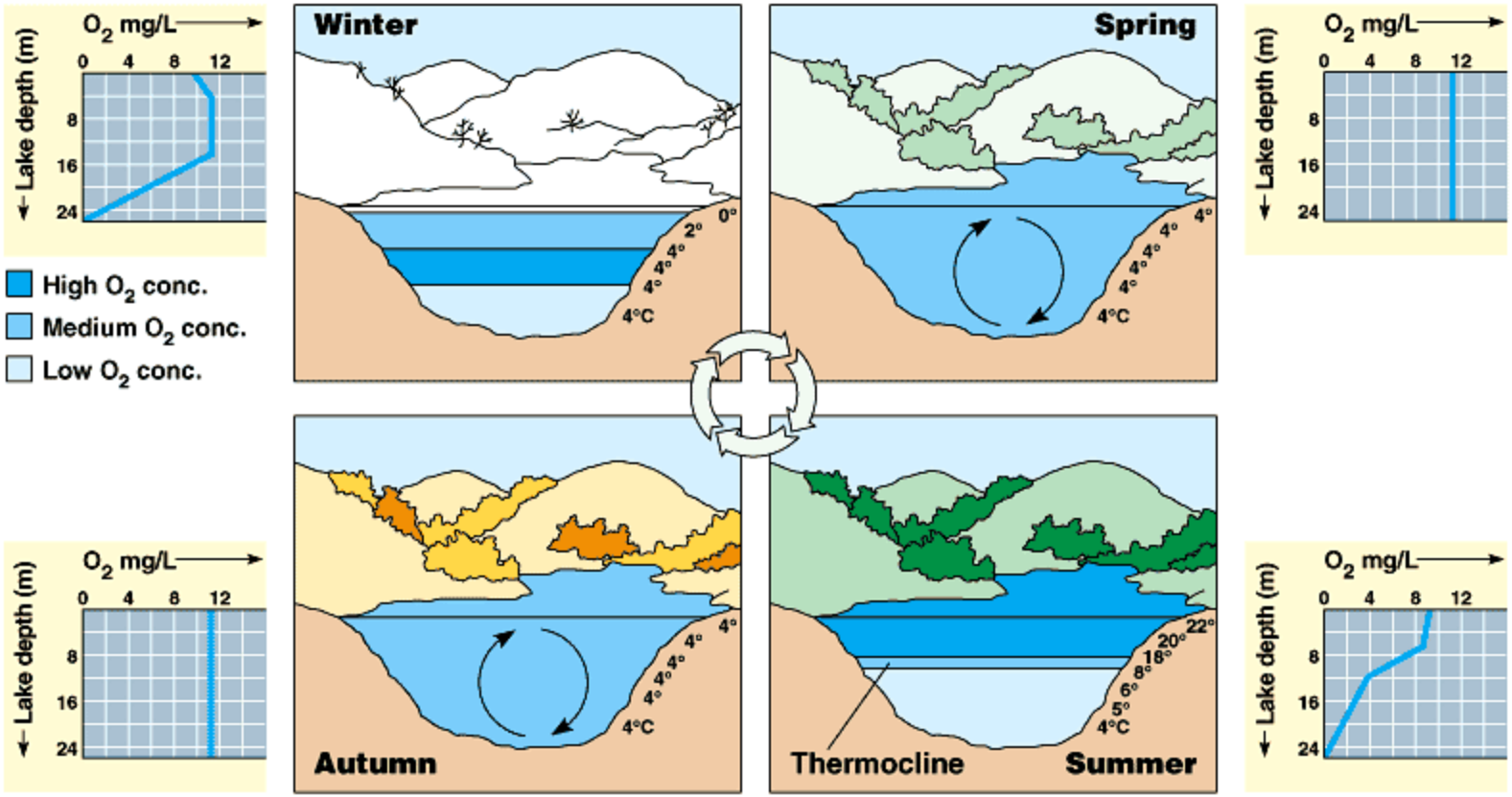
Zonation in Lakes



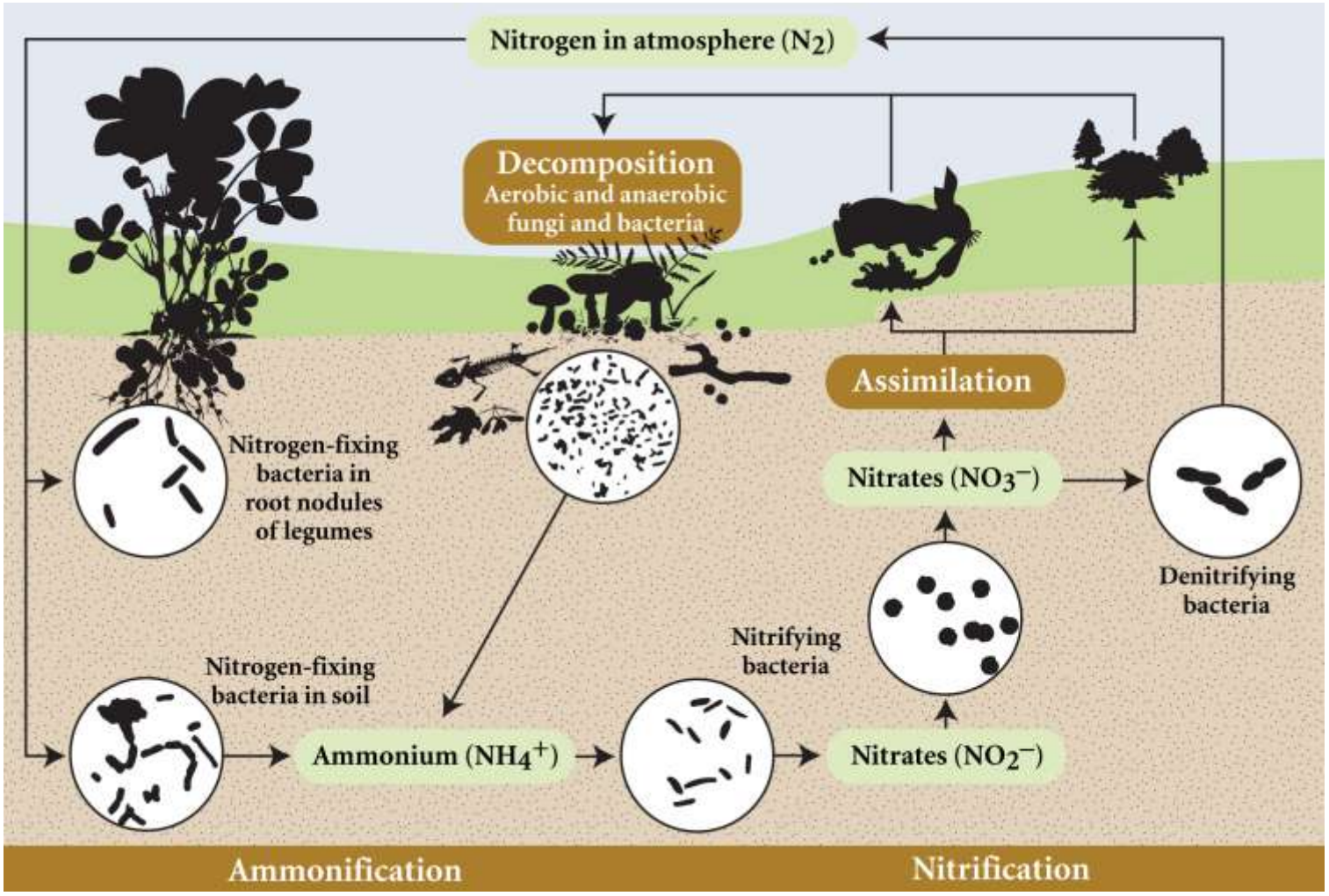
NPP as a function of Depth:Phs and Resp



Thermal Stratification in Lakes



Nitrogen Cycle



Nutrient pollution

- **Pollution** = the release of matter or energy into the environment that causes undesirable impacts on the health and well-being of humans or other organisms

Lakes vary in their nutrients and oxygen

- Nutrient pollution from fertilizers, farms, sewage, lawns, golf courses
  - Leads to eutrophication
  - **Oligotrophic** lakes and ponds = have low nutrient and high oxygen conditions
  - **Eutrophic** lakes and ponds = have high nutrient and low oxygen conditions

Eutrophication is a natural process, but…

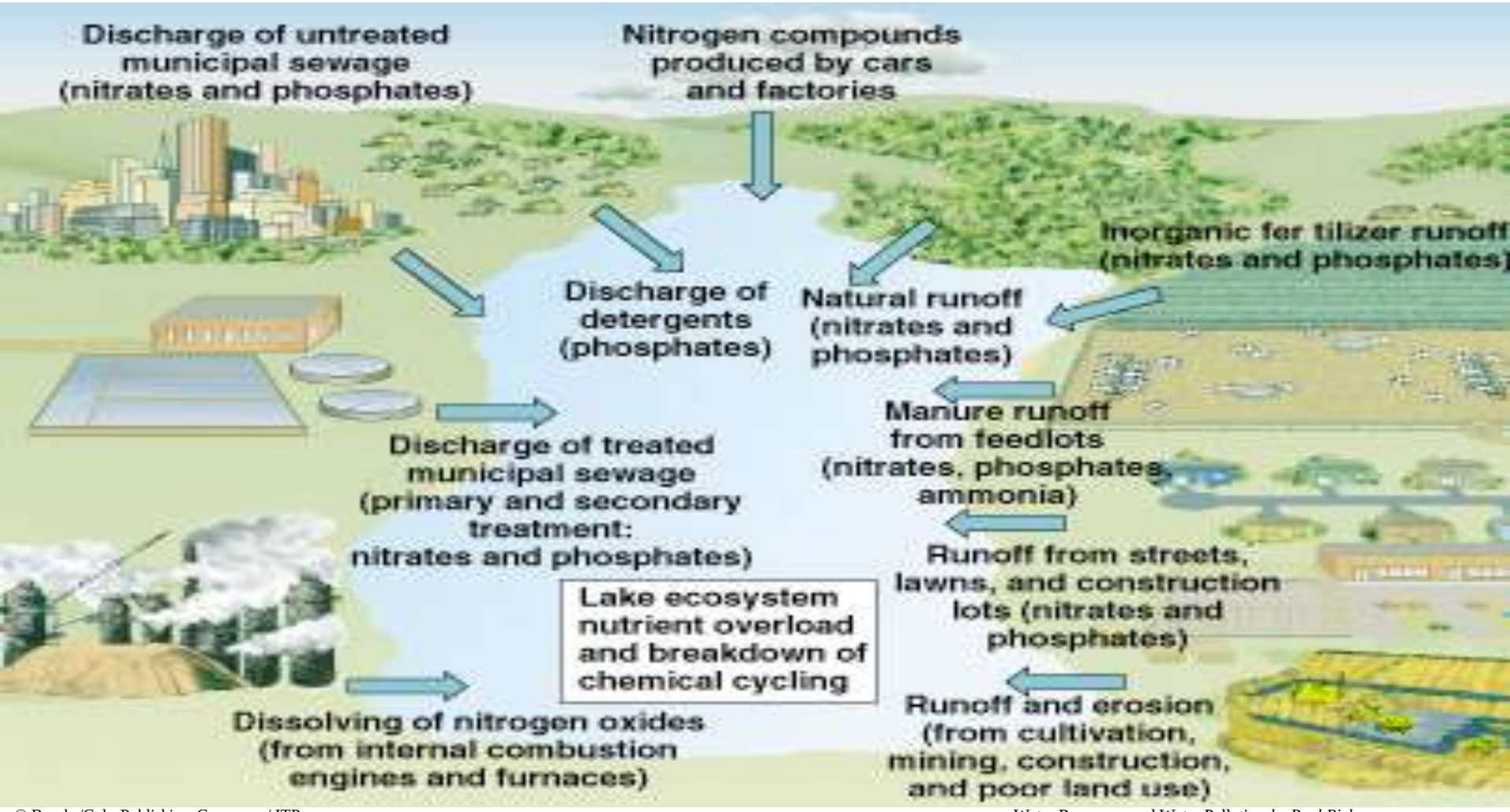
- Human activities dramatically increase the rate at which it occurs

(a) Oligotrophic water body

(b) Eutrophic water body

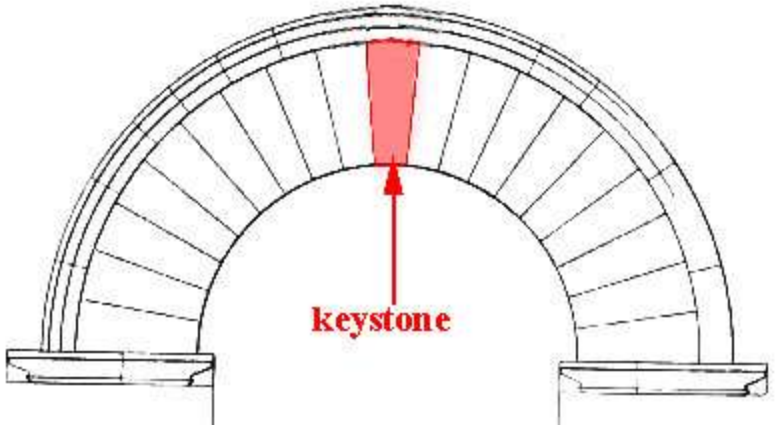
Eutrophication

Accelerated results with human input of nutrients to a lake



Some organisms play big roles

- **Keystone Species** = has a strong or wide-reaching impact far out of proportion to its abundance
- Removal of a keystone species has substantial ripple effects
  - Alters the food chain

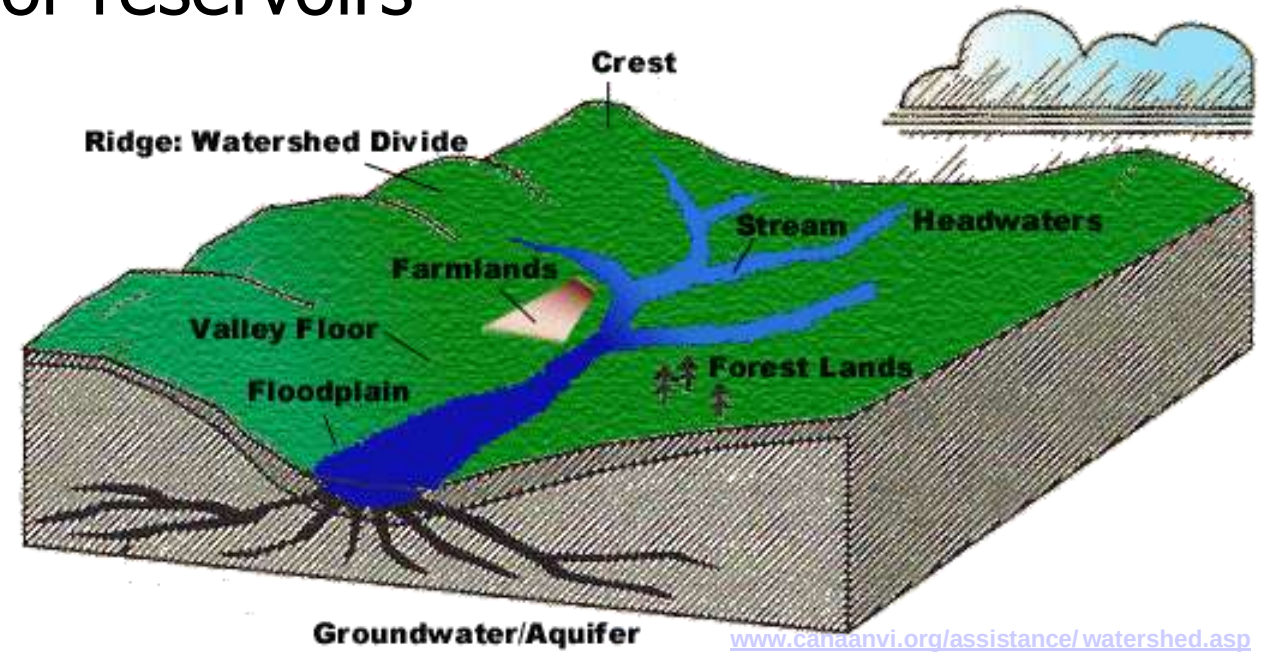


Species can change communities

- **Trophic Cascade** = predators at *high trophic levels* can indirectly affect populations of organisms at *low trophic levels* by keeping species at *intermediate trophic* levels in check
  - Extermination of wolves led to increased deer populations, which led to overgrazed vegetation and changed forest structure
- Ecosystem engineers = **ecosystem engineer** is an organism that modifies, creates or destroys habitat and directly or indirectly modulates the availability of resources to other species, causing physical state changes in biotic or abiotic materials

Surface Water

- Surface runoff flows into streams, lakes, wetlands and reservoirs
- A watershed or drainage basin
  - Region that drains into a streams, lakes, wetlands or reservoirs



www.canaanvi.org/assistance/ watershed.asp

Rivers and streams wind through landscapes

- Water from rain, snowmelt, or springs forms streams, creeks, or brooks
- These merge into rivers, and eventually reaches the ocean
  - **Tributary** = a smaller river slowing into a larger one
  - **Watershed** = the area of land drained by a river and its tributaries

A river may shift course

- Floodplain = areas nearest to the river's course that are flooded periodically
  - Discharge and Sediment Load
  - Frequent deposition of silt makes floodplain soils fertile
- **Riparian =** riverside areas that are productive and species-rich
- Water of rivers and streams hosts diverse ecological communities

Rivers shape the landscape

- If there is a large bend in the river, the force of the water cuts through the land
  - **Oxbow** = an extreme bend in a river
  - **Oxbow lake** = the bend is cut off and remains as an isolated, U-shaped body of water

Wetlands include marshes, swamps, and bogs

- **Wetlands** = systems that combine elements of freshwater and dry land
- **Freshwater marshes** = shallow water allows plants to grow above the water's surface
- **Swamps** = shallow water that occurs in forested areas
  - Can be created by beavers
- **Bogs** = ponds covered in thick floating mats of vegetation
  - A stage in aquatic succession

Wetlands are valuable

- Wetlands are extremely valuable for wildlife
- They slow runoff
  - Reduce flooding
  - Recharge aquifers
  - Filter pollutants
- People have drained wetlands, mostly for agriculture
  - Southern Canada and the U.S. have lost more than half of their wetlands