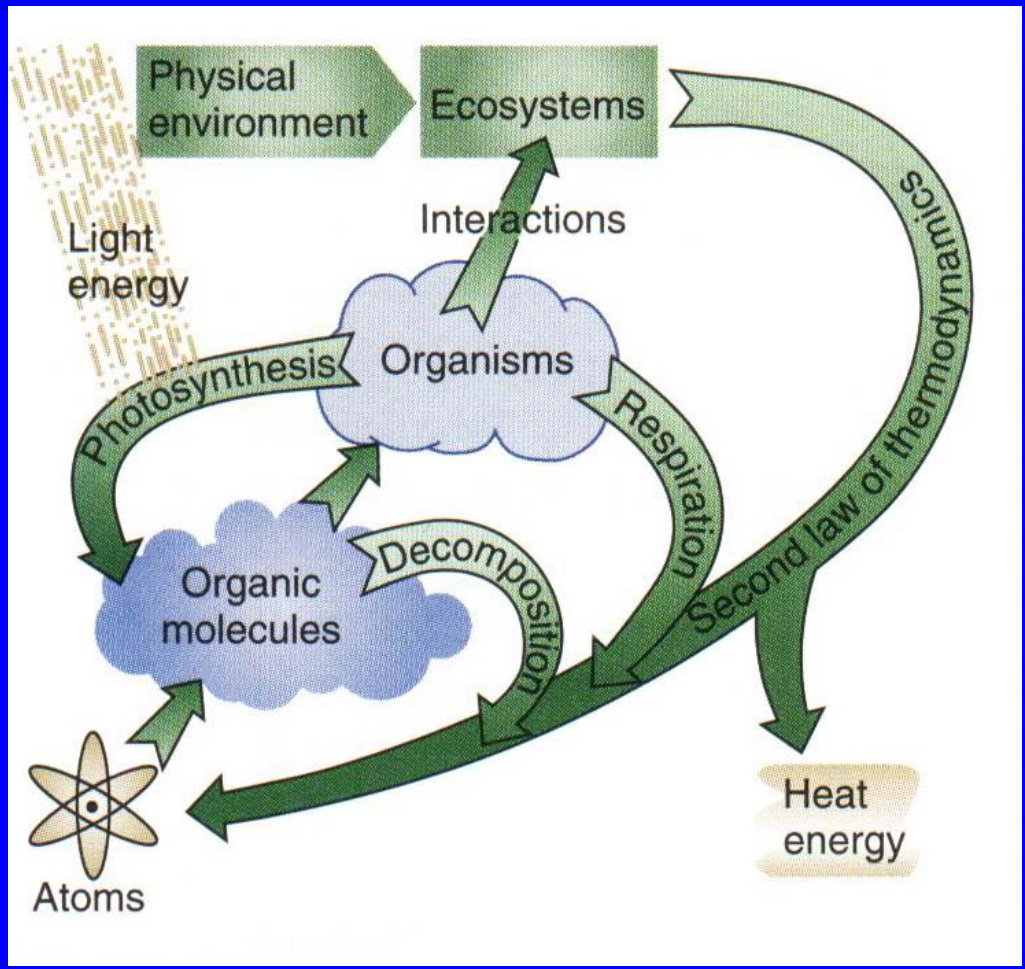
Environments, Organisms and Ecosystems

Unit 3: 环境、生物与生态系统

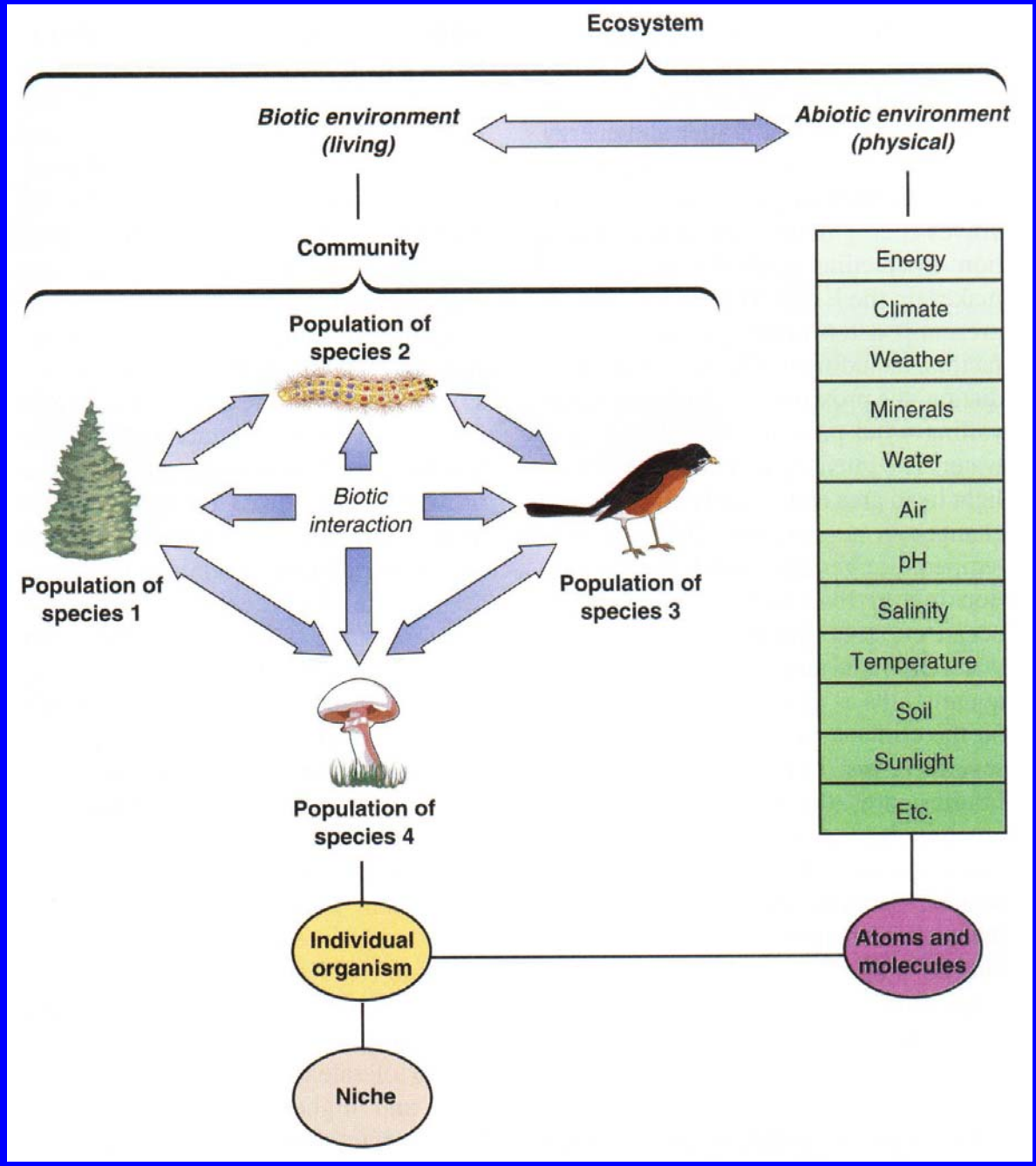


Ecological Concepts

- Ecology: Study of how organisms interact with each other and with their non-living surroundings.
- Environment: Everything that affects an organism during its lifetime.
  - biotic: living component
  - abiotic: non-living component

Levels of Organization in Ecology

The study of ecology can take place at several different levels as shown in the figure.

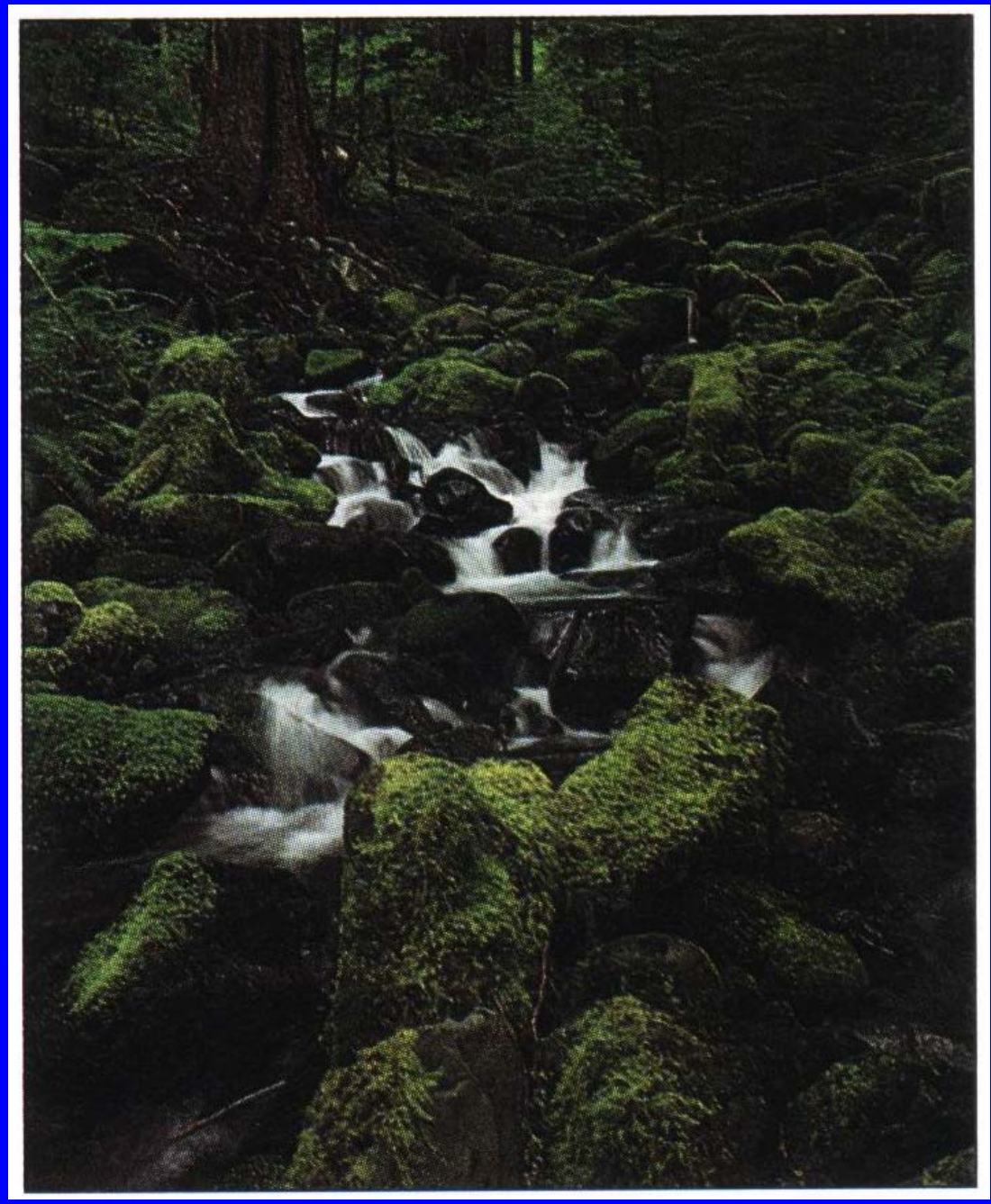


Ecological Concepts

- Limiting Factors: Any factor whose shortage or absence restricts species success.
- Habitat: Space an organism inhabits - defined by biological requirements of each particular organism.
- Niche: Includes all ways an organism affects organisms with which it interacts as well as how it modifies its physical surroundings.
- Species: Category of organisms in which individuals within the group can potentially interbreed and produce viable offspring.

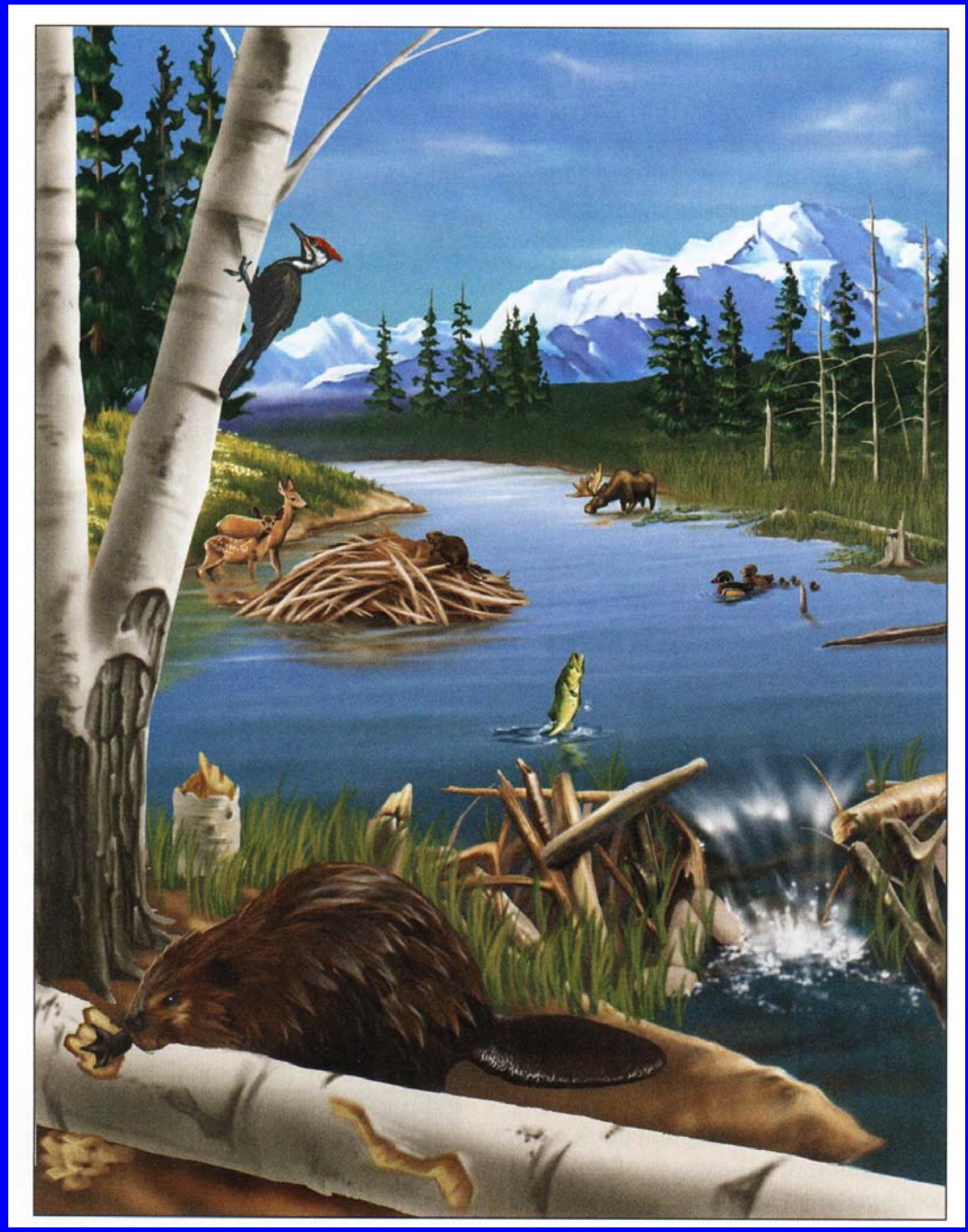
Moss Habitat

The habitat of mosses is typically cool, moist, and shady. Mosses must also have a thin layer of water present.



Ecological Niche

The ecological niche of an organism is a complex set of interactions between an organism and its surroundings. For example, a beaver's ecological niche includes building dams and flooding forested areas, killing trees, providing habitat for the ducks and other animals, serving as food for predators.



The Niche of a Dandelion A dandelion serves as food to various herbivores, supplies nectar to bees, and can regrow quickly from its root if its leaves are removed

Role of Natural Selection and Evolution

- Genes, Populations, and Species: Three interrelated concepts –
  - Genes: Genes are distinct pieces of DNA (deoxyribonucleic acid) that determine the characteristics an individual displays.
  - Population: A population is considered to be all the organisms of the same kind found within a specific geographic region.
  - Species: A species is a population of all the organisms potentially capable of reproducing naturally among themselves and having offspring that also reproduce.
    - An individual organism is not a species but a member of a species.

Natural Selection

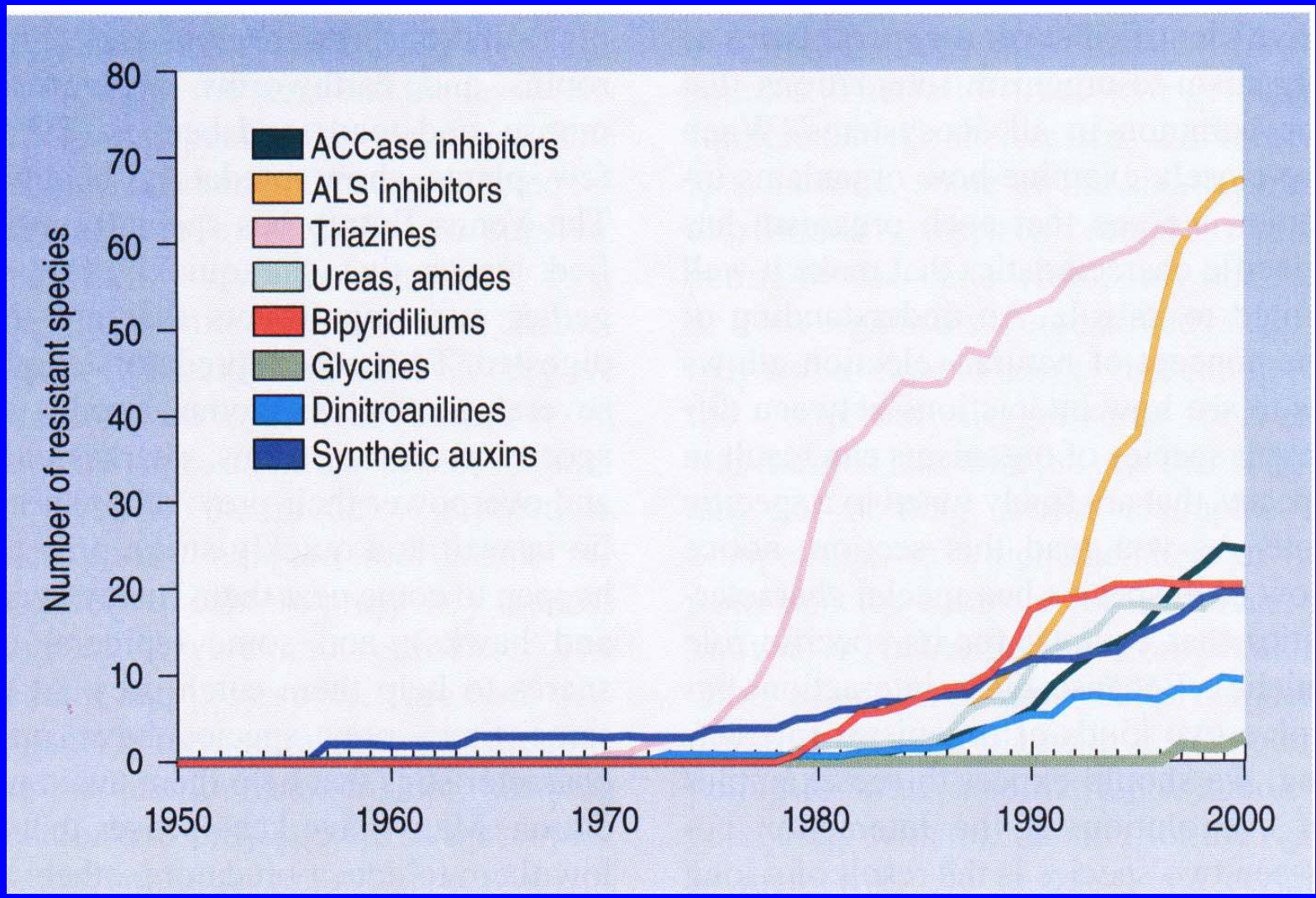
- Natural Selection: Process that determines which individuals within a species will reproduce and pass their genes to the next generation.
- Evolution: The changes in the genes and the characteristics displayed by successive generations of a population of organisms over time.
  - Natural selection is the mechanism that causes evolution to occur.
- Conditions Involved in the Process of Natural Selection:
  - Individuals within a species show variation.
  - Organisms within a species typically produce huge numbers of offspring, most of which die.

Natural Selection

- Conditions Involved in the Process of Natural Selection:
  - Excess number of individuals results in a shortage of specific resources.
  - Due to individual variation, some individuals have a greater chance of obtaining needed resources and thus have a greater likelihood of survival and reproduction.
  - As time passes, percentage of individuals showing favorable variations will increase and percentage showing unfavorable variations will decrease.

Evolutionary Patterns

- Speciation: Production of new species from previously existing species.
  - Speciation is thought to occur as a result of a species dividing into two isolated subpopulations.
- Extinction: Loss of entire species.
  - Of estimated 500 million species of organisms believed to have ever existed on earth, 98-99% have gone extinct.
- Coevolution: Two or more species can reciprocally influence the evolutionary direction of the other.



Evolutionary Change: Populations of weed plants that have been subjected repeatedly to herbicides often develop resistant populations.

Kinds of Organism Interactions

- Predation: One animal kills and/or eats another.
  - Predator benefits from food.
    - Prey adaptation is higher reproduction rate.
  - Prey species benefits by eliminating non-adaptive genes from the gene pool.
    - Poorly adapted predators are less likely to obtain food and thus pass on non-adaptive genes.

Predator-Prey Relationship: Lions are predators of zebra. The quicker lions are more likely to get food, and the slower, sickly or weaker zebra are more likely to become prey.

Kinds of Organism Interactions

- Competition: Two organisms compete to obtain the same limited resource, and both are harmed to some extent.
  - Intraspecific: members of same species competing for resources.
  - Interspecific: members of different species competing for resources.
    - The more similar the competing species, the more intense the competition.

Kinds of Organism Interactions

- Competition
  - Principle of Competitive Exclusion: No two species can occupy the same ecological niche in the same place at the same time.
    - Less fit species must evolve into a slightly different niche.

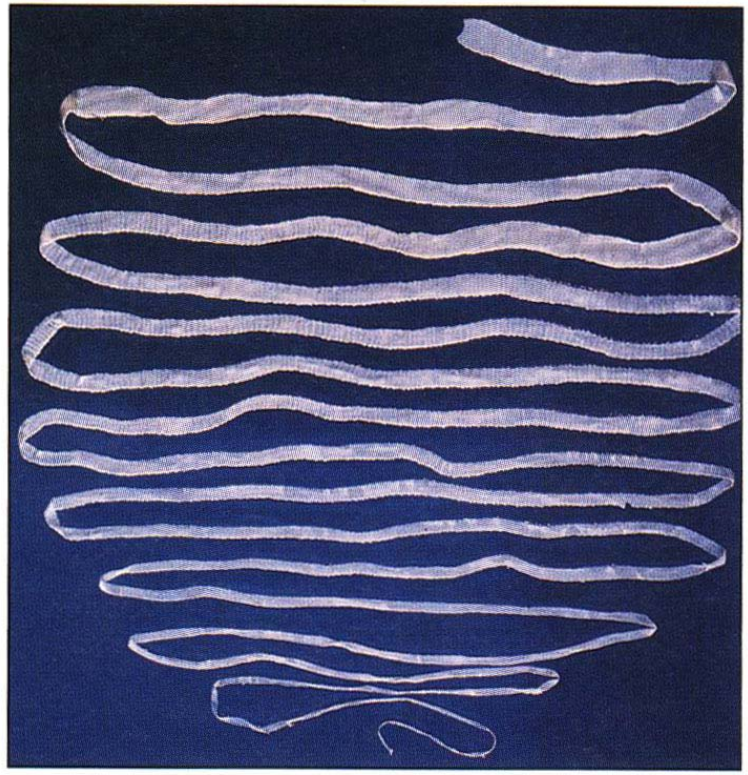
Competition: Several vultures competing for a food source.
Whenever a needed resource is in limited supply, organisms compete for it. This competition may be between members of the same species (intraspecific), or it may be between different species (interspecific).

Symbiotic Relationships

- Symbiosis: Close, physical relationship between two different species. At least one species derives benefit from the interaction.
- Parasitism: One organism (parasite) living in or on another organism (host), from which it derives nourishment.
  - Ectoparasites: Live on host's surface.
    - Fleas
  - Endoparasites: Live inside host.
    - Tapeworms

Parasitism

Ectoparasites: Fleas are small insects that live in the feathers of birds or the fur of mammals, where they bite their hosts to obtain blood.

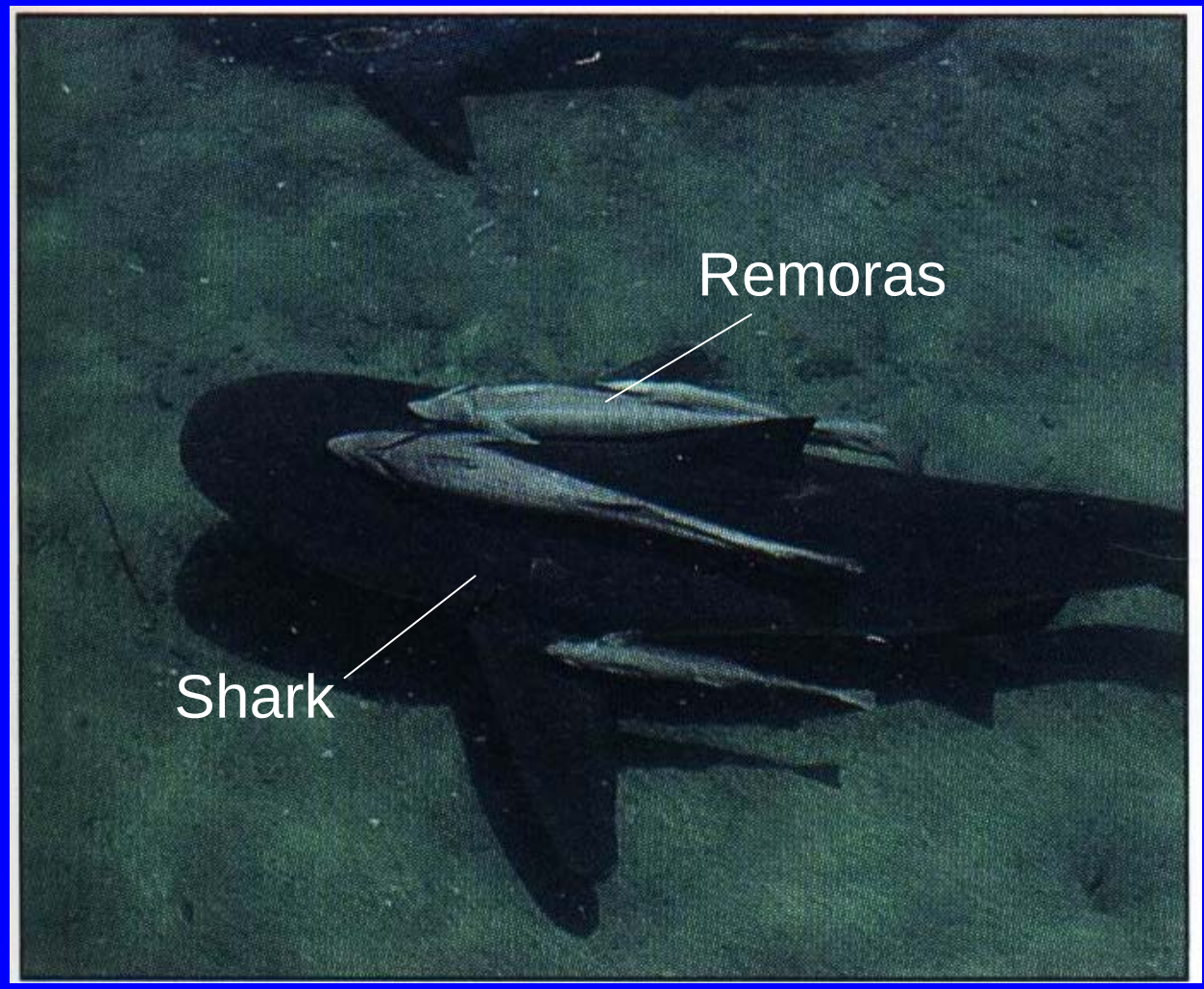


Endoparasites: Tapeworms live inside the intestines of their hosts, where they absorb food from their hosts' intestines.

Symbiotic Relationships

- Commensalism: One organism benefits while the other is not affected. (Remoras and Sharks)
- Mutualism: Both species benefit – Obligatory in many cases as neither can exist without the other. (Yuccas and Yucca Moths)

Commensalism: Remoras hitchhike a ride on sharks and feed on the scraps of food lost by the sharks.



Mutualism:

The growths on the roots of this plant contain beneficial bacteria that make nitrogen available to the plant. The relationship is also beneficial to the bacteria, since the bacteria obtain necessary raw materials from the plant.

Community and Ecosystem Interactions

- Community: Assemblage of all interacting species of organisms in an area.
- Ecosystem: System of all interacting organisms, including their non-living surroundings.

Community and Ecosystem Interactions

- Major Roles of Organisms in Ecosystems
  - Producers: Organisms able to use sources of energy to make complex organic molecules from simple inorganic molecules in the environment.
    - Photosynthesis:

$$6CO_2+6H_20 \text{ ---> } C_6H_{12}O_6 +6O_2$$

Community and Ecosystem Interactions

- Major Roles of Organisms in Ecosystems
  - Consumers: Consume organic matter to provide themselves with energy and organic matter necessary for growth and survival.
    - Primary Consumers - Herbivores (plants)
    - Secondary Consumers - Carnivores (meat)
    - Omnivores (plants and meat)

Community and Ecosystem Interactions

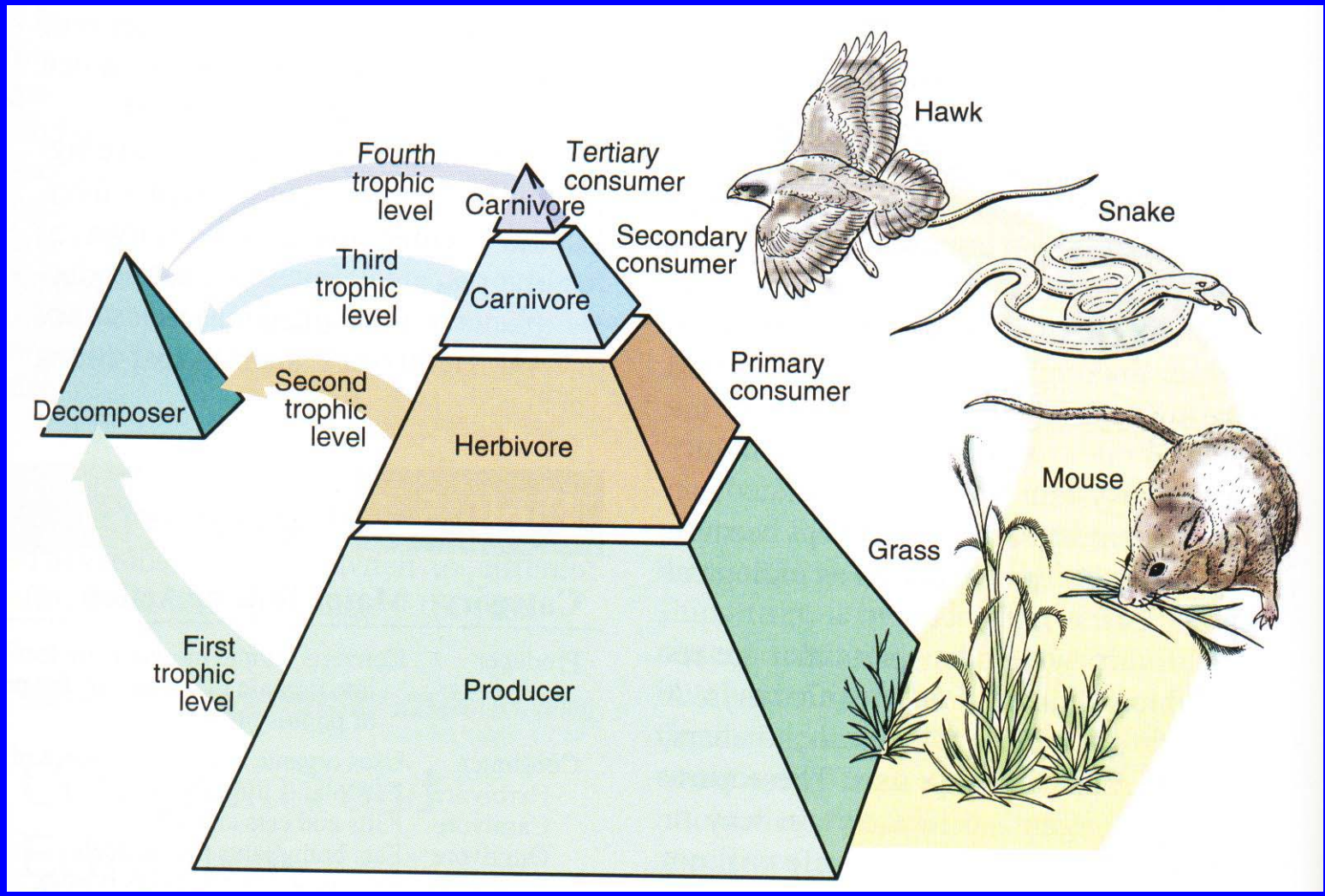
- Major Roles of Organisms in Ecosystems
  - Decomposers
    - Digest organic molecules in detritus into simpler organic compounds, and absorb soluble nutrients. (Bacteria and fungi)
      - Use non-living organic matter as source of energy.

Table 5.1 Roles in an Ecosystem

Category	Major Role or Action	Examples
Producer	Converts simple inorganic molecules into organic molecules by the process of photosynthesis	Trees, flowers, grasses, ferns, mosses, algae
Consumer	Uses organic matter as a source of food	Animals, fungi, bacteria
Herbivore	Eats plants directly	Grasshopper, elk, human vegetarian
Carnivore	Kills and eats animals	Wolf, pike, dragonfly
Omnivore	Eats both plants and animals	Rats, raccoons, most humans
Scavenger	Eats meat but often gets it from animals that died by accident or illness, or were killed by other animals	Coyote, vulture, blowflies
Parasite	Lives in or on another living organism and gets food from it	Tapeworm, many bacteria, some insects
Decomposer	Returns organic material to inorganic material; completes recycling of atoms	Fungi, bacteria, some insects and worms

Community and Ecosystem Interactions

- Keystone Species
  - Play critical role in maintenance of specific ecosystems.
- Energy Flow Through Ecosystems
  - Each step in the flow of energy through an ecosystem is known as a trophic level.
  - As energy moves from one trophic level to the next, most of the useful energy (90%) is lost as heat. (2^{nd} Law of Thermodynamics)
  - Because energy is difficult to track, biomass (weight of living material) is often used as a proxy.



Energy Flow Through an Ecosystem: Energy passes through several trophic levels each containing a certain amount of energy. Each time energy flows to another trophic level, about 90% of the useful energy is lost. Therefore, higher trophic levels often contain less energy and fewer organisms.

Community and Ecosystem Interactions

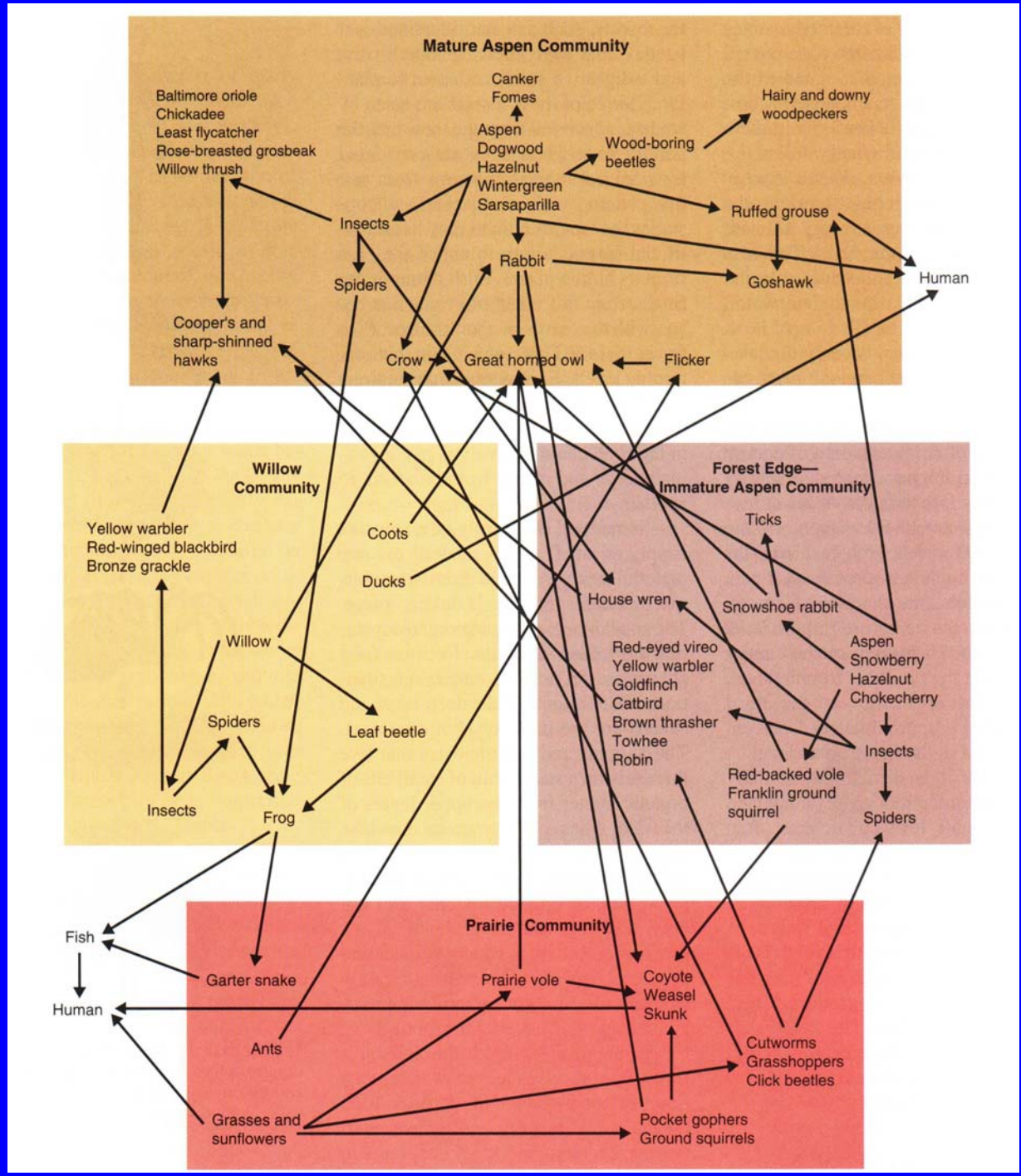
- Food Chains and Food Webs
  - Food Chain: Passage of energy from one trophic level to the next due to one organism consuming another.
    - Some chains rely on detritus.
  - Food Web: series of multiple food chains. (A single predator can have multiple prey species at the same time)

Food Chain

As one organism feeds on another organism, energy flows through the series.

Food Web

The many kinds of interactions among organisms in an ecosystem constitute a food web. In this network of interactions, several organisms would be affected if one key organism were reduced in number.



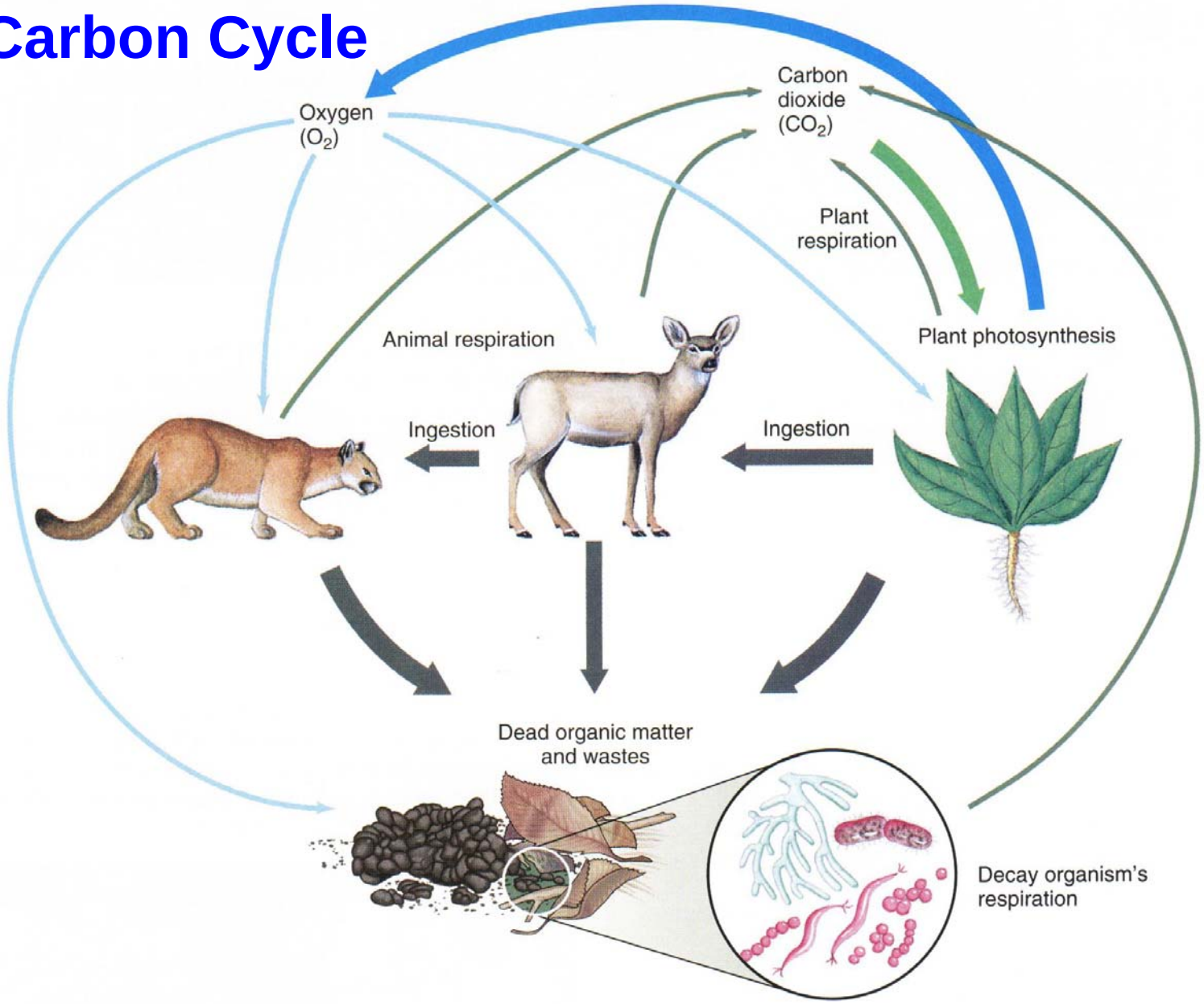
Community and Ecosystem Interactions

- Nutrient Cycles in Ecosystems
  - Organisms are composed of molecules and atoms that are cycled between living and nonliving portions of an ecosystem.
  - The activities involved in the cycling include biological, geological, and chemical processes, and are therefore called biogeochemical cycles.
    - Carbon, nitrogen, oxygen, hydrogen, and phosphorus in important organic molecules.

Nutrient Cycles in Ecosystems

- Carbon Cycle
  - Carbon and Oxygen combine to form Carbon Dioxide.
  - Plants use Carbon Dioxide during photosynthesis to produce sugars.
  - Plants use sugars for plant growth.
  - Herbivores eat plants, and incorporate molecules into their structure.
  - Respiration breaks down sugars releasing CO_2 and water back into the atmosphere.

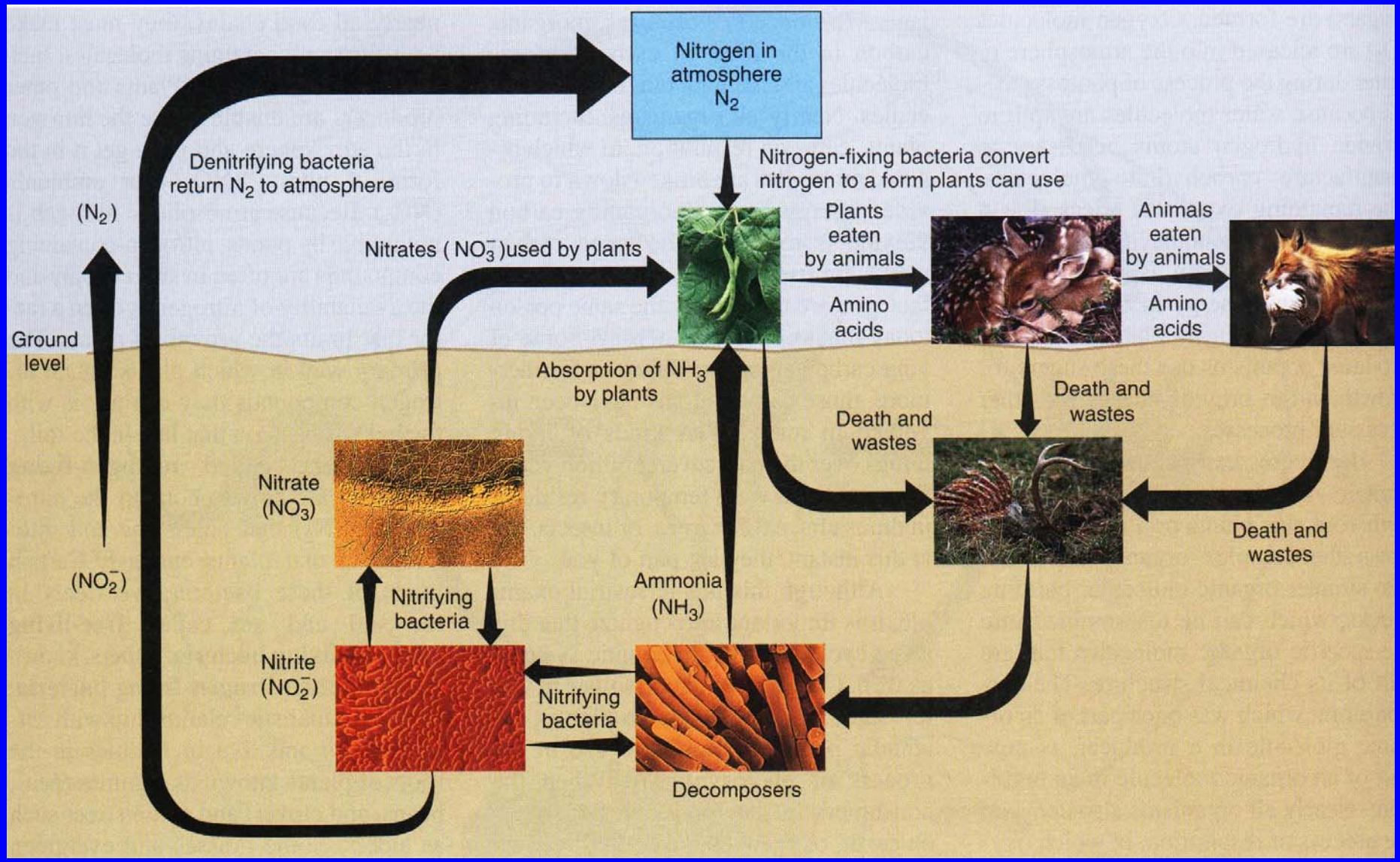
Carbon Cycle



Nutrient Cycles in Ecosystems

- Nitrogen Cycle
  - Cycling of nitrogen atoms between abiotic and biotic ecosystem components.
    - Producers unable to use atmospheric N.
      - Must get nitrate NO_3^- or ammonia NH_3.
    - Nitrogen-fixing bacteria converts nitrogen gas N_2 into ammonia.
      - Plants construct organic molecules.
        - Eaten by animals.
    - Decomposers also break down nitrogen-containing molecules releasing ammonia.

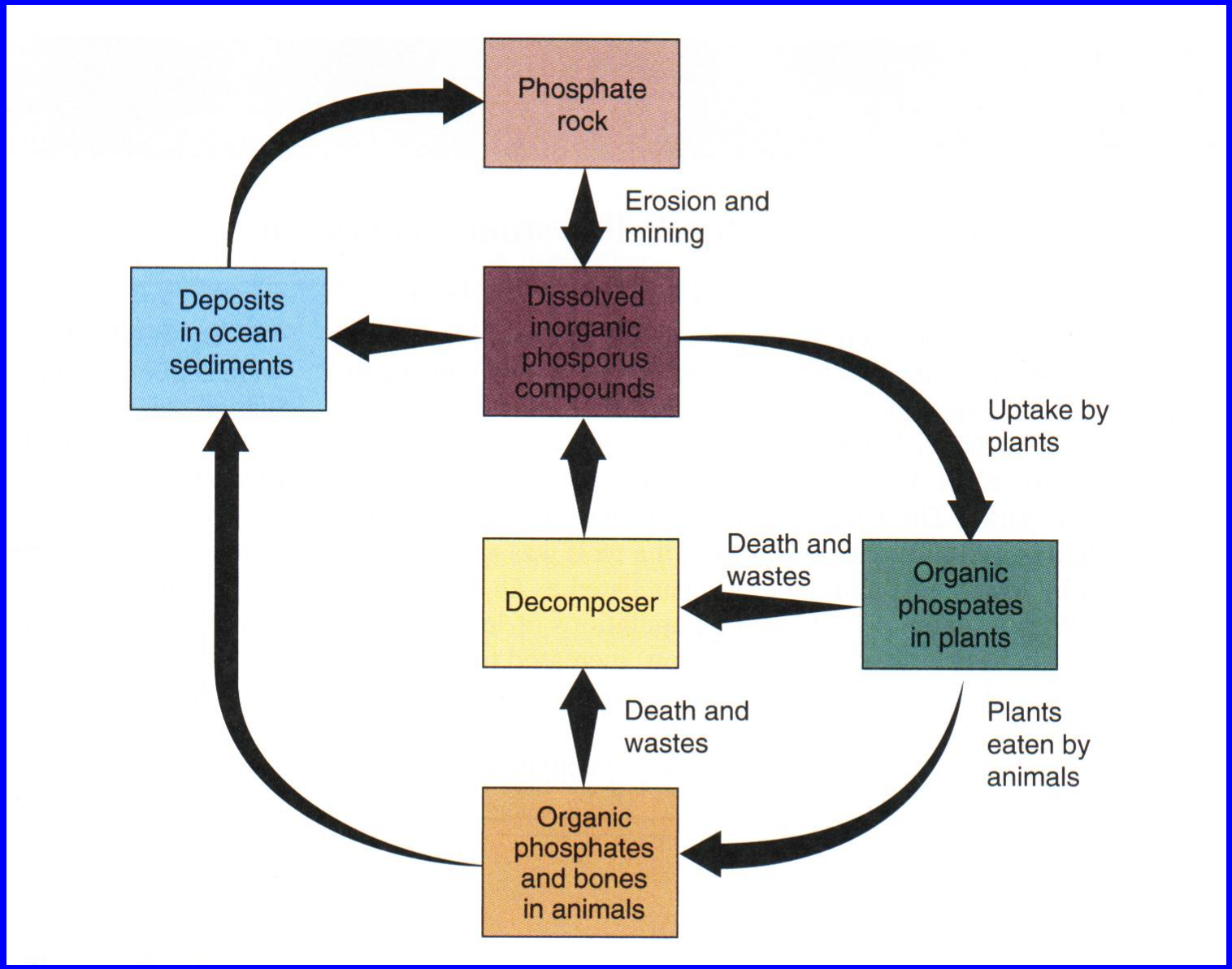
Nitrogen Cycle



Nutrient Cycles in Ecosystems

- Phosphorus Cycle
  - Phosphorus compounds released by erosion and become dissolved in water.
  - Plants use phosphorus to construct necessary molecules.
  - Animals gain necessary P via herbivory.
  - Decomposers recycle into soil.

Phosphorus Cycle

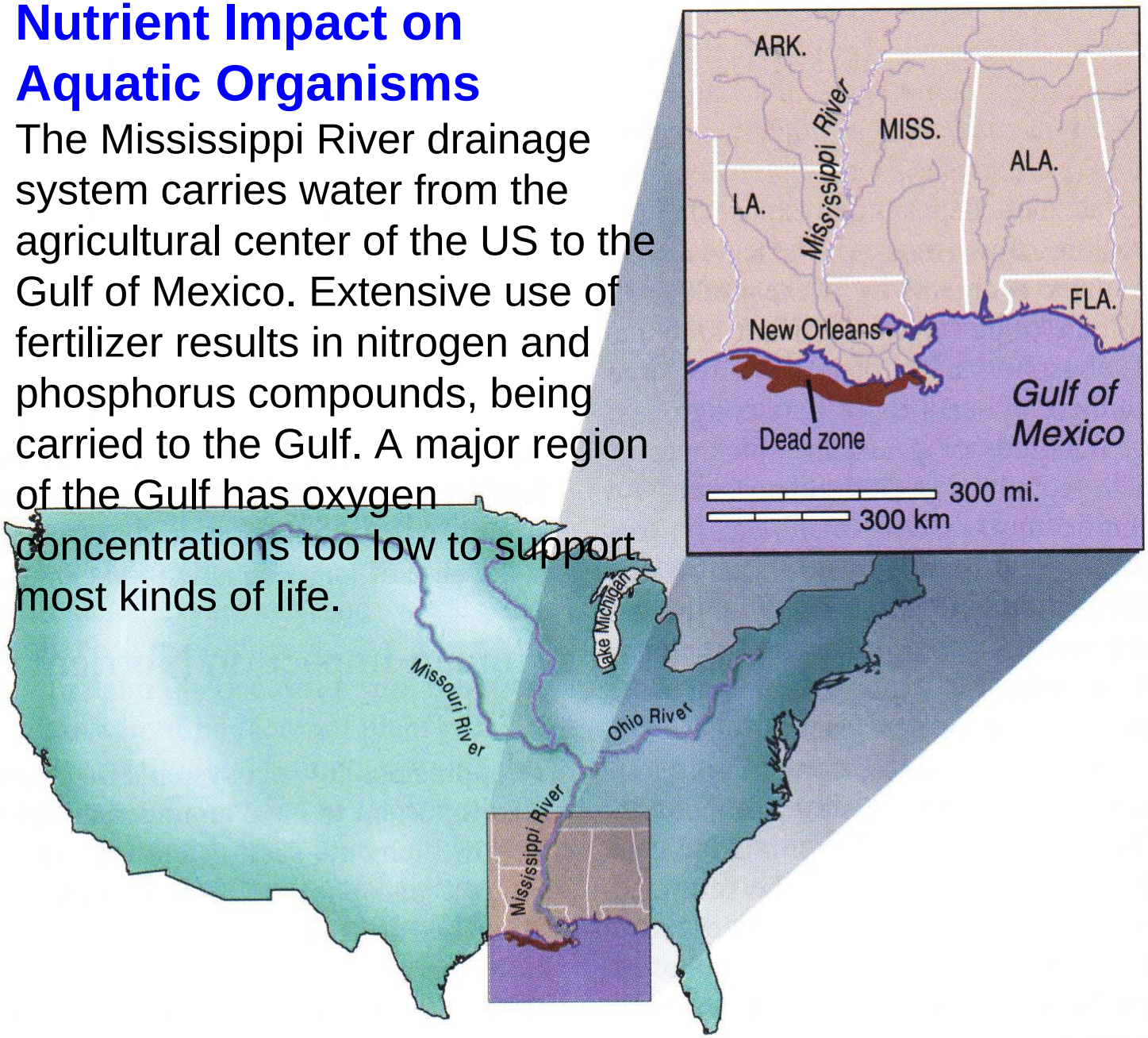


Human Impact on Nutrient Cycles

- Two activities caused significant changes in carbon cycle:
  - Burning Fossil Fuels
  - Converting forests to agricultural land.
- Fossil fuel burning also Increased amount of nitrogen available to plants.
- Fertilizer carried into aquatic ecosystems.
  - Increase aquatic plant growth rate.
    - Lowered oxygen concentrations.

Nutrient Impact on Aquatic Organisms

The Mississippi River drainage system carries water from the agricultural center of the US to the Gulf of Mexico. Extensive use of fertilizer results in nitrogen and phosphorus compounds, being carried to the Gulf. A major region of the Gulf has oxygen concentrations too low to support most kinds of life.



Succession

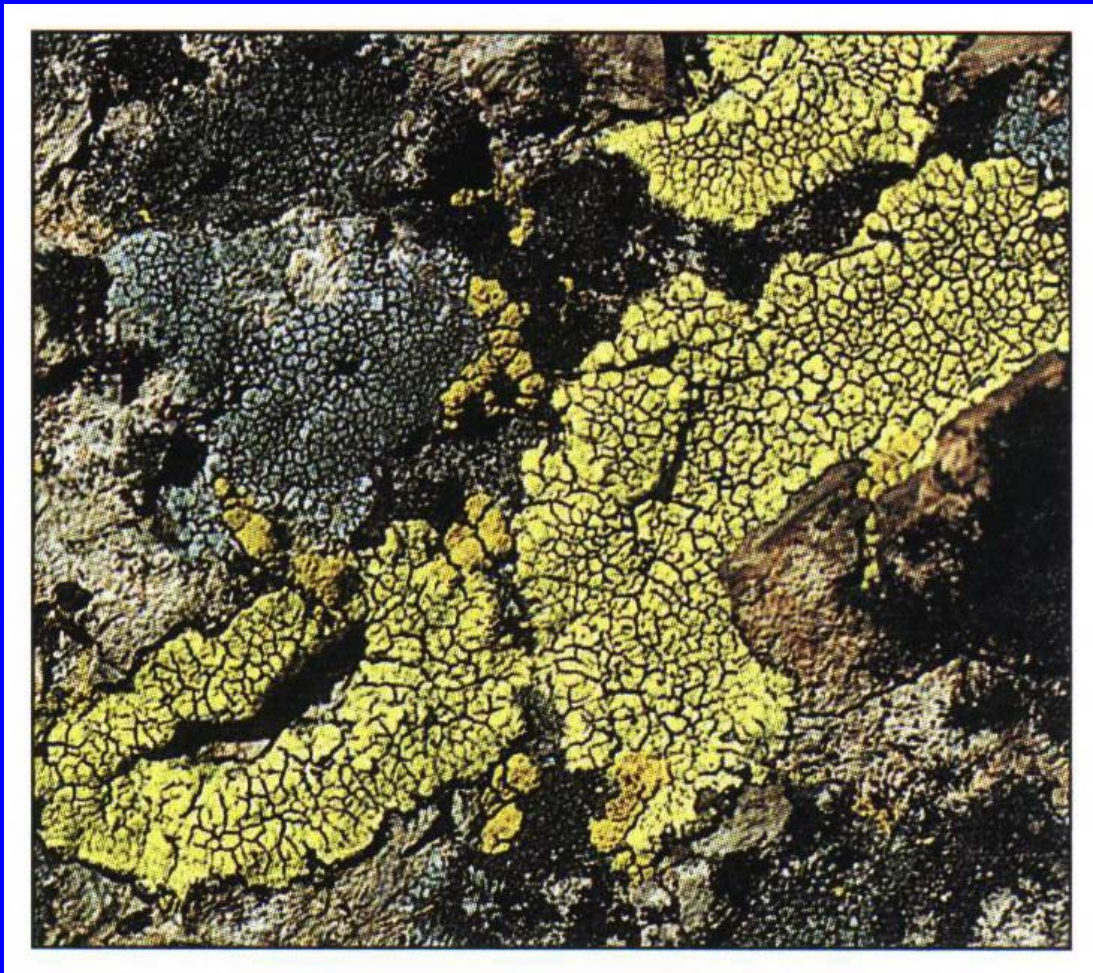
- Succession - A series of regular, predictable changes in the structure of a community over time.
  - Occurs because activities of organisms change their surroundings and make the environment suitable for other kinds of organisms.
    - Climax community - stable, long-lasting community, primarily determined by climate.

Succession

- Primary Succession - Begins with bare mineral surfaces or water and total lack of organisms.
- Secondary Succession - Begins with disturbance of an existing ecosystem.

Primary Succession

- Terrestrial Primary Succession
  - Pioneer Community: Collection of organisms able to colonize bare rock (i.e. lichens).
  - Lichens help breakdown rock, and accumulate debris helping to form a thin soil layer.
  - Soil layer begins to support small life forms.



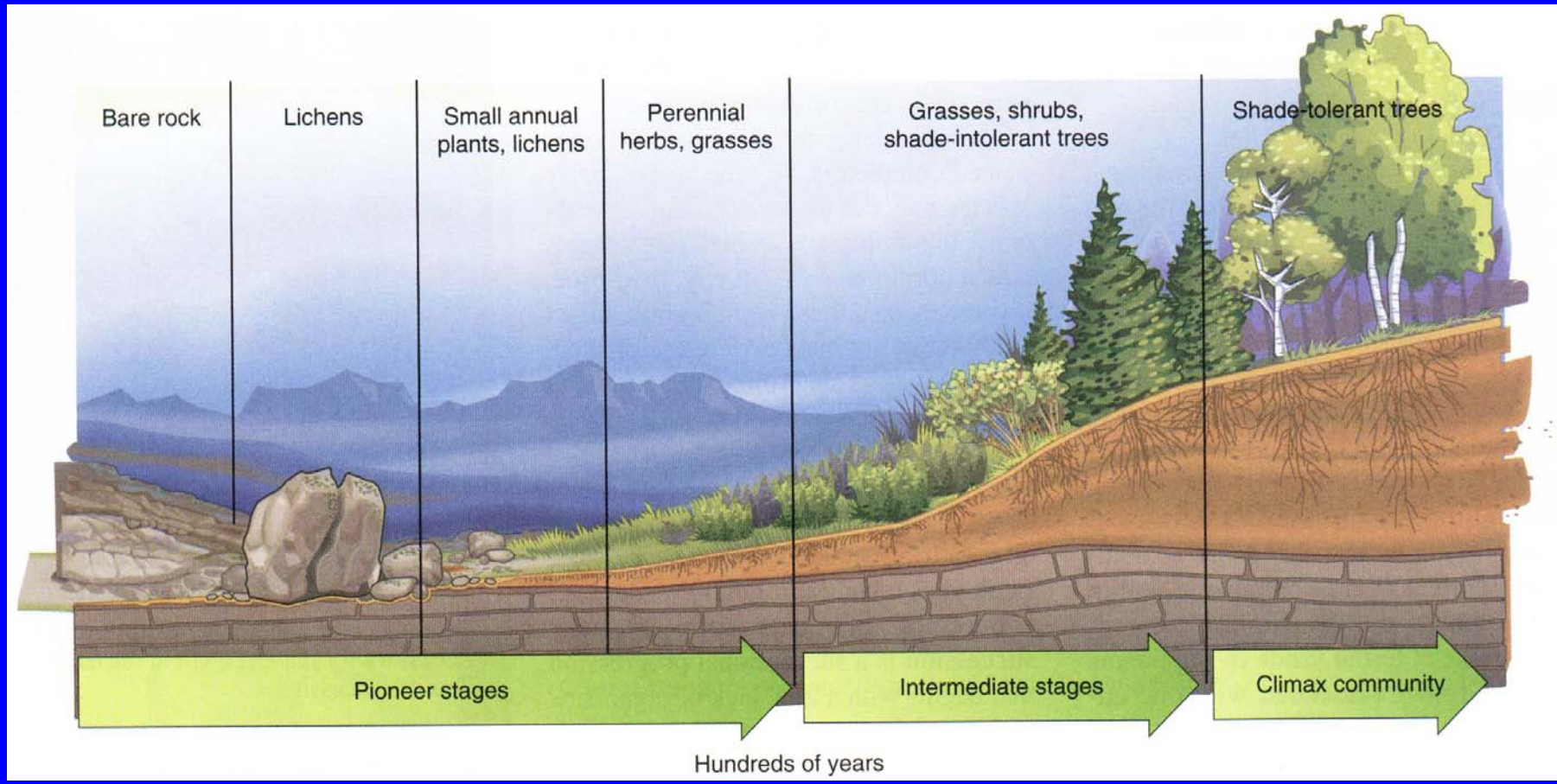
Pioneer Organism: The lichen growing on this rock is able to accumulate bits of debris, carry on photosynthesis, and aid in breaking down the rock. All of these activities contribute to the formation of a thin layer of soil, which is necessary for plant growth in the early stages of succession.

Terrestrial Primary Succession

- Life forms replace lichen community.
- New community replaced by perennial plant community.
- Perennial plant community replaced by shrubs.
- Shrubs replaced by shade intolerant trees.
- Shade intolerant trees replaced by shade tolerant trees.
- Eventually a climax community is reached - Stable, long-lasting.

Terrestrial Primary Succession

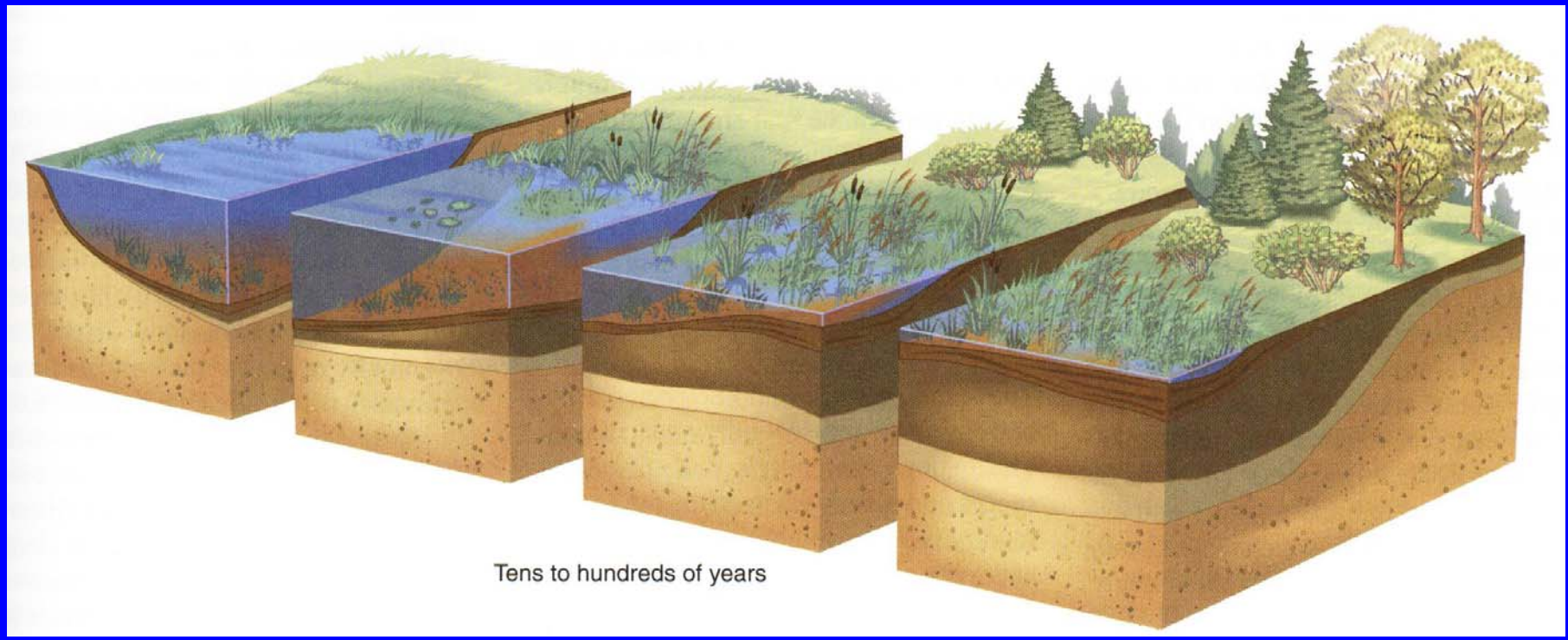
- In general, climax communities are more stable and have larger, more diverse populations of species than earlier stages of succession.
- Successional (seral) stage - each step in the process.



Primary Succession on Land: The formation of soil is a major step in primary succession. Until soil is formed, the area is unable to support large amounts of vegetation, which modify the harsh environment. Once soil formation begins, the site proceeds through an orderly series of stages toward a climax community.

Aquatic Primary Succession

- Except for oceans, most aquatic systems are considered temporary.
- All aquatic systems receive inputs of soil particles and organic matter from surrounding land.
  - Gradual filling of shallow bodies of water.
    - Roots and stems below water accumulate more material.
      - Wet soil established.



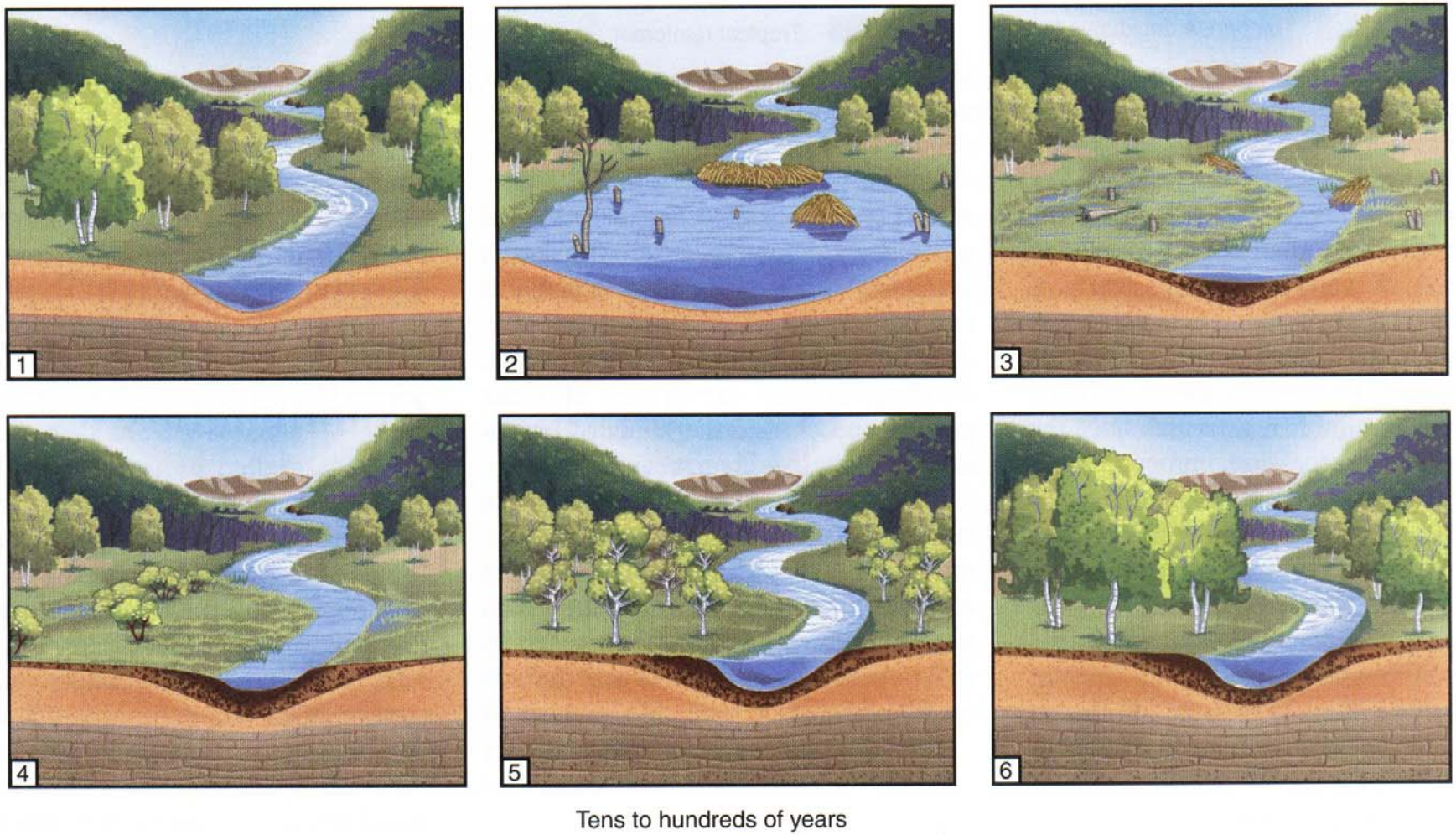
Primary Succession from a Pond to a Wet Meadow: A shallow pond will fill slowly with organic matter from producers in the pond. Eventually, a wet soil will form and grasses will become established. In many areas, this will be succeeded by a climax forest.

Secondary Succession

- Occurs when an existing community is disturbed or destroyed.
- With most disturbances, most of the soil remains, and many nutrients necessary for plant growth may be available for reestablishment of the previous ecosystem.
  - Nearby undamaged communities can serve as sources of seeds and animals.
- Tends to be more rapid than primary growth.

Mature oak/hickory forest destroyed	Farmland abandoned	Annual plants	Grasses and biennial herbs	Perennial herbs and shrubs begin to replace grasses and biennials	Pines begin to replace shrubs	Young oak and hickory trees begin to grow	Pines die and are replaced by mature oak and hickory trees	Mature oak/hickory forest
		1–2 years	**3–4 years**	**4–15 years**	**5-15 years**	**10–30 years**	**50–75 years**	

Secondary Succession on Land: A plowed field in the southeastern United States shows a parade of changes over time, involving plant and animal associations. The general pattern is for annual weeds to be replaced by grasses and other perennial herbs, which are replaced by shrubs, which are replaced by trees. As the plant species changes, so do the animal species.



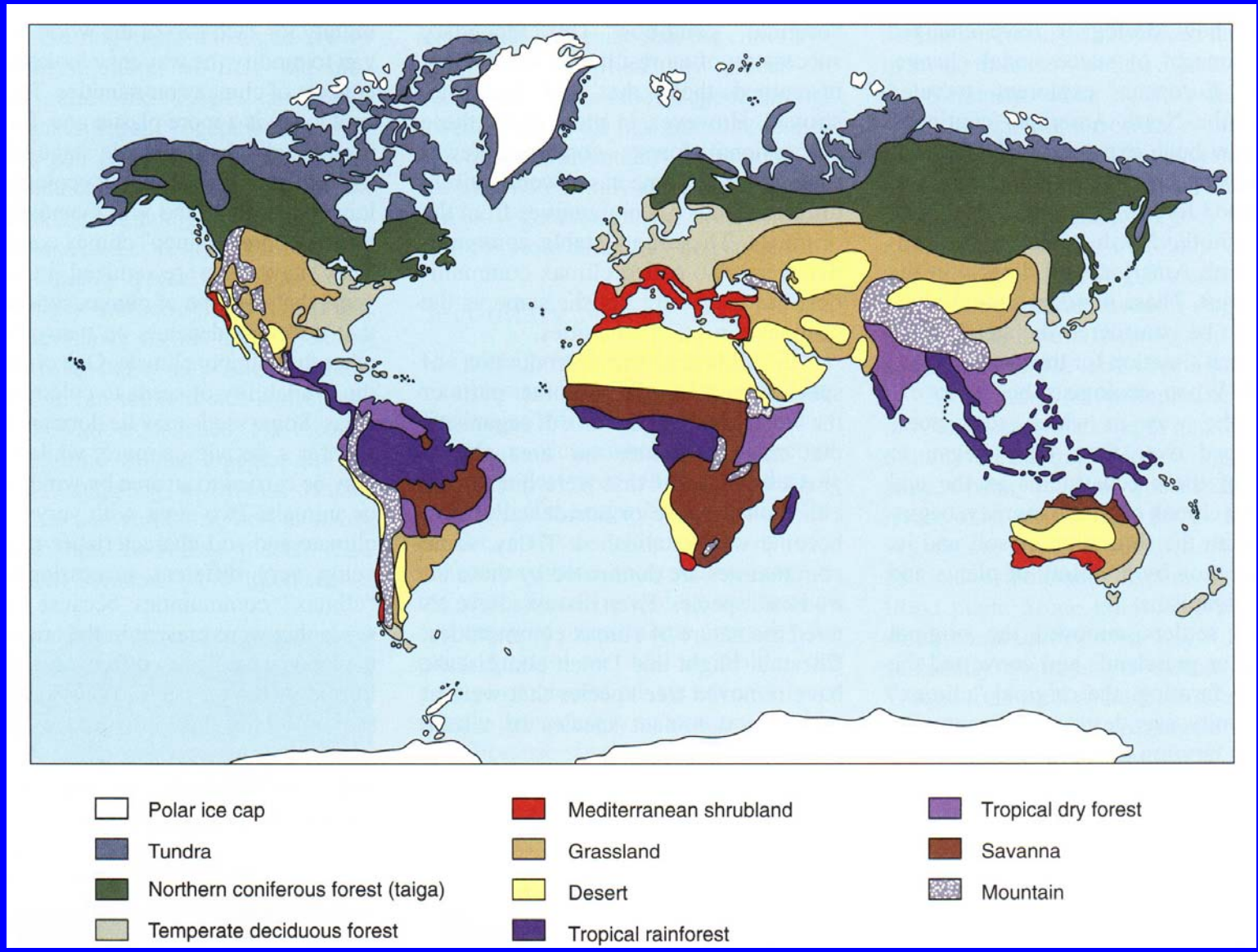
Secondary Succession from a Beaver Pond: A colony of beavers can dam up streams and kill trees by the flooding that occurs and by using trees for food. Once the site is abandoned, it will slowly return to the original forest community by a process of succession.

Modern Concepts of Succession and Climax

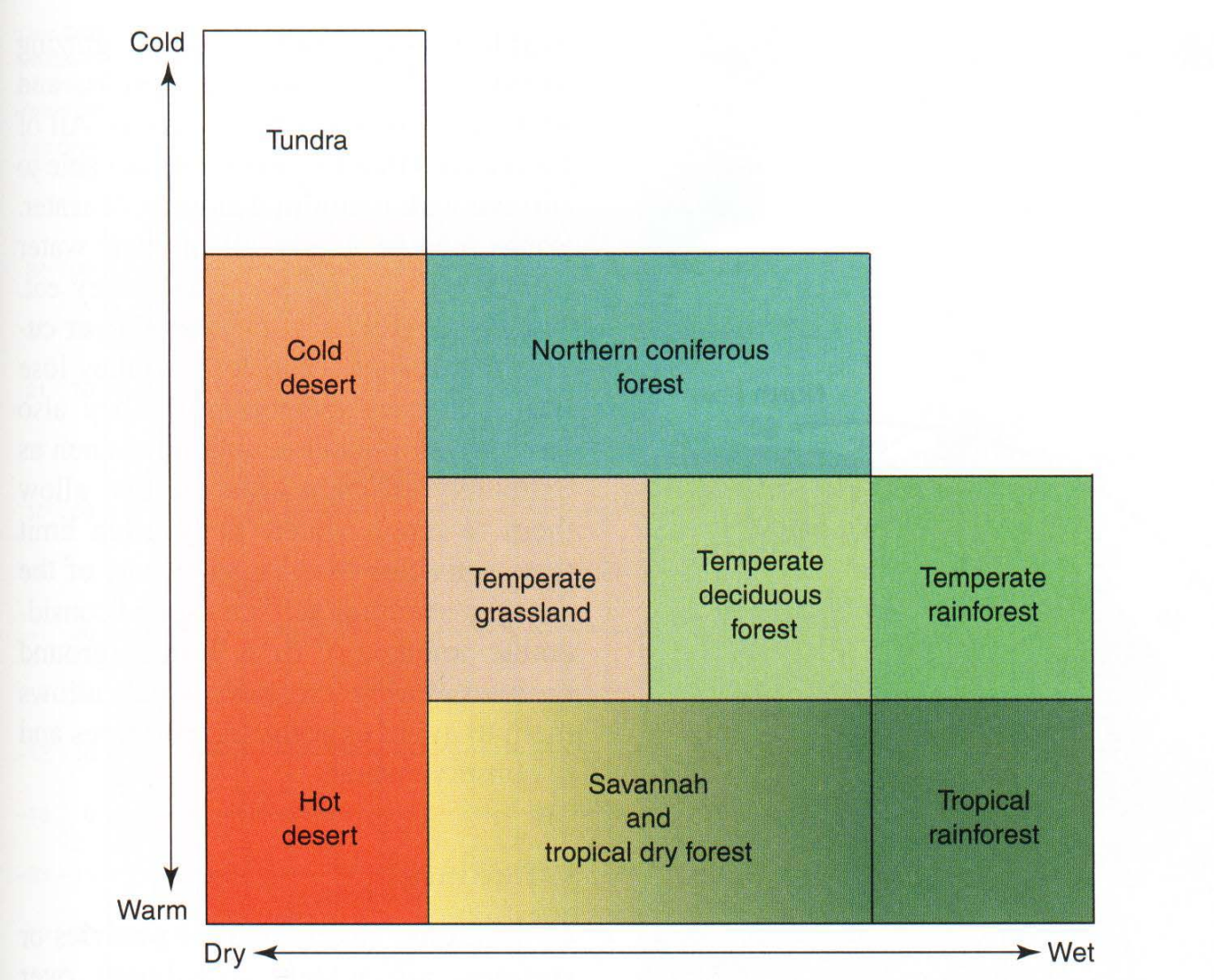
- As settlers changed “original” ecosystems to agriculture, climax communities were destroyed.
  - Many farms were abandoned, and land began to experience succession.
- Ecologists began to recognize there was not a fixed, pre-determined community.
  - Only thing differentiating climax community from successional community is time scale.

Climax Communities - Biomes

- Biome - Major type of terrestrial climax communities with wide geographic distributions. Usually defined by undisturbed natural plant communities.
- Two main non-biological factors determining biomes:
  - Temperature
  - Precipitation



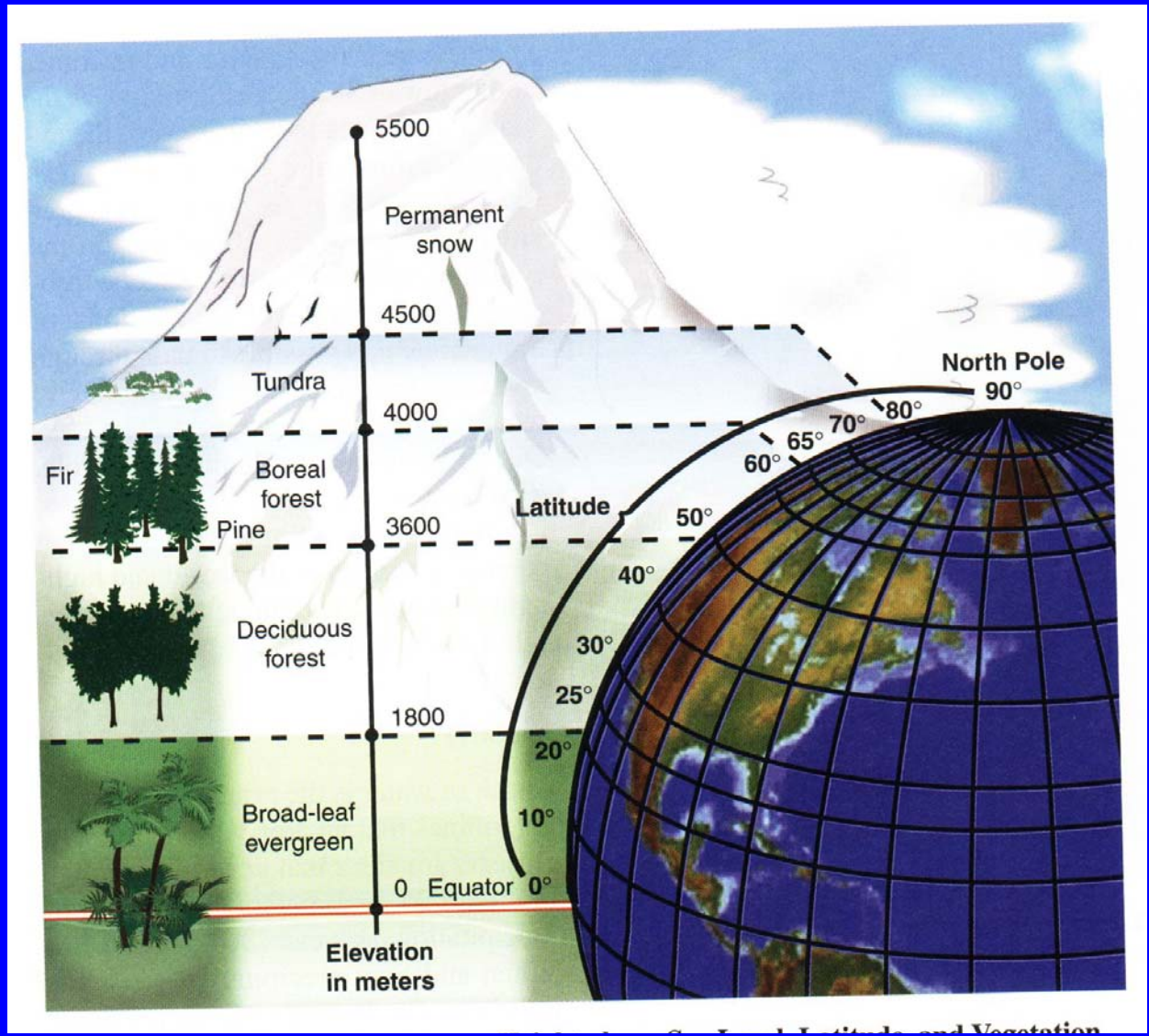
Biomes of the World: Although most biomes are named for a major type of vegetation, each includes a specialized group of animals adapted to the plants and the biome's climatic conditions.



Influence of Precipitation and Temperature on Vegetation: Temperature and moisture are two major factors that influence the kind of vegetation in an area.

The Effect of Elevation on Climate and Vegetation

- As altitude increases, average temperature decreases.
- As you move from sea level to mountain tops, it is possible to pass through a series of biomes similar to what you would encounter moving from the equator to the north pole.



Relationship Between Height above Sea Level, Latitude, and Vegetation: As one travels up a mountain, the climate changes. The higher the elevation, the cooler the climate.

Major Aquatic Ecosystems

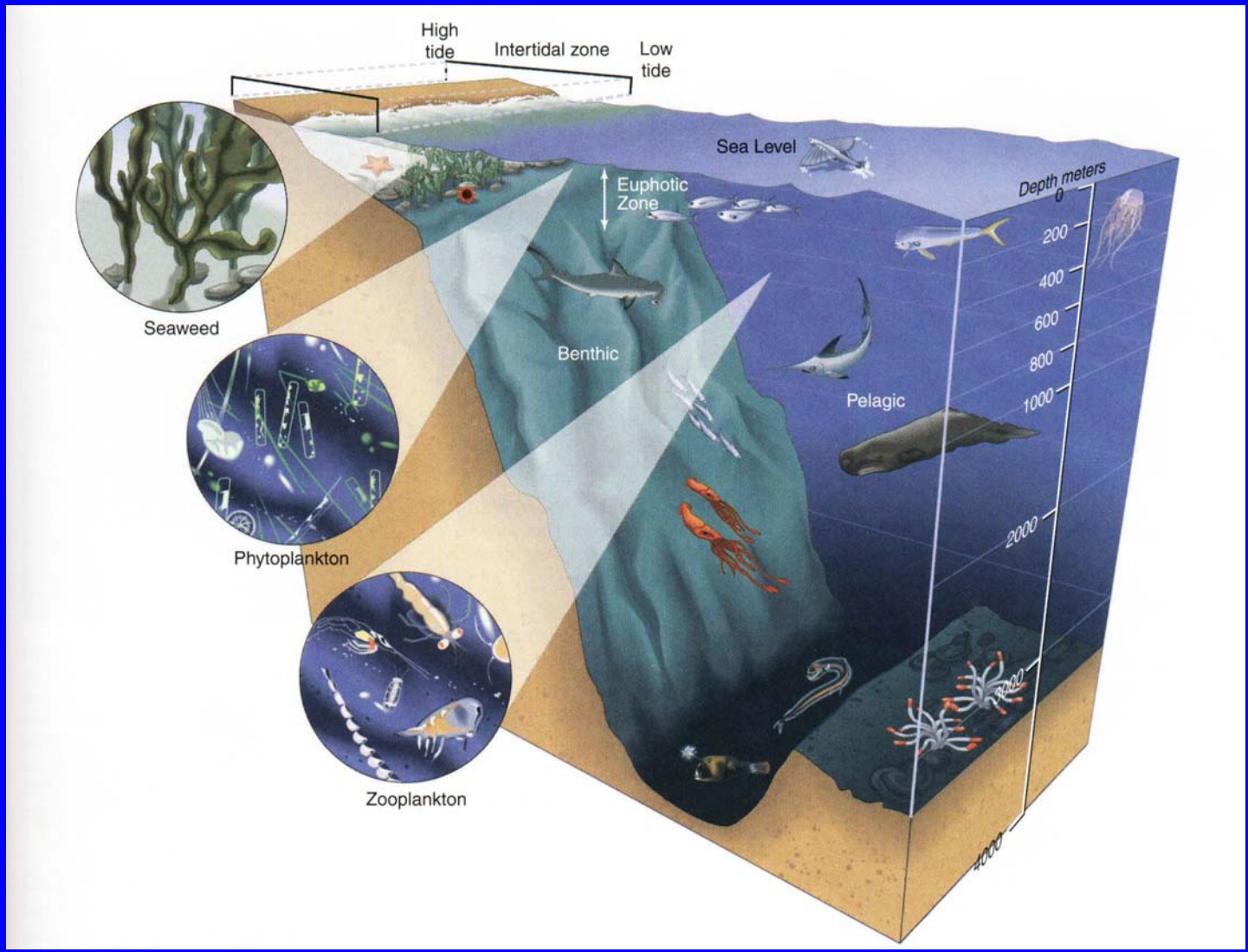
- Four factors influencing aquatic ecosystems:
  - Penetration of sun's rays.
  - Nature of bottom substrate.
  - Water temperature.
  - Amount of dissolved materials.

Marine Ecosystems

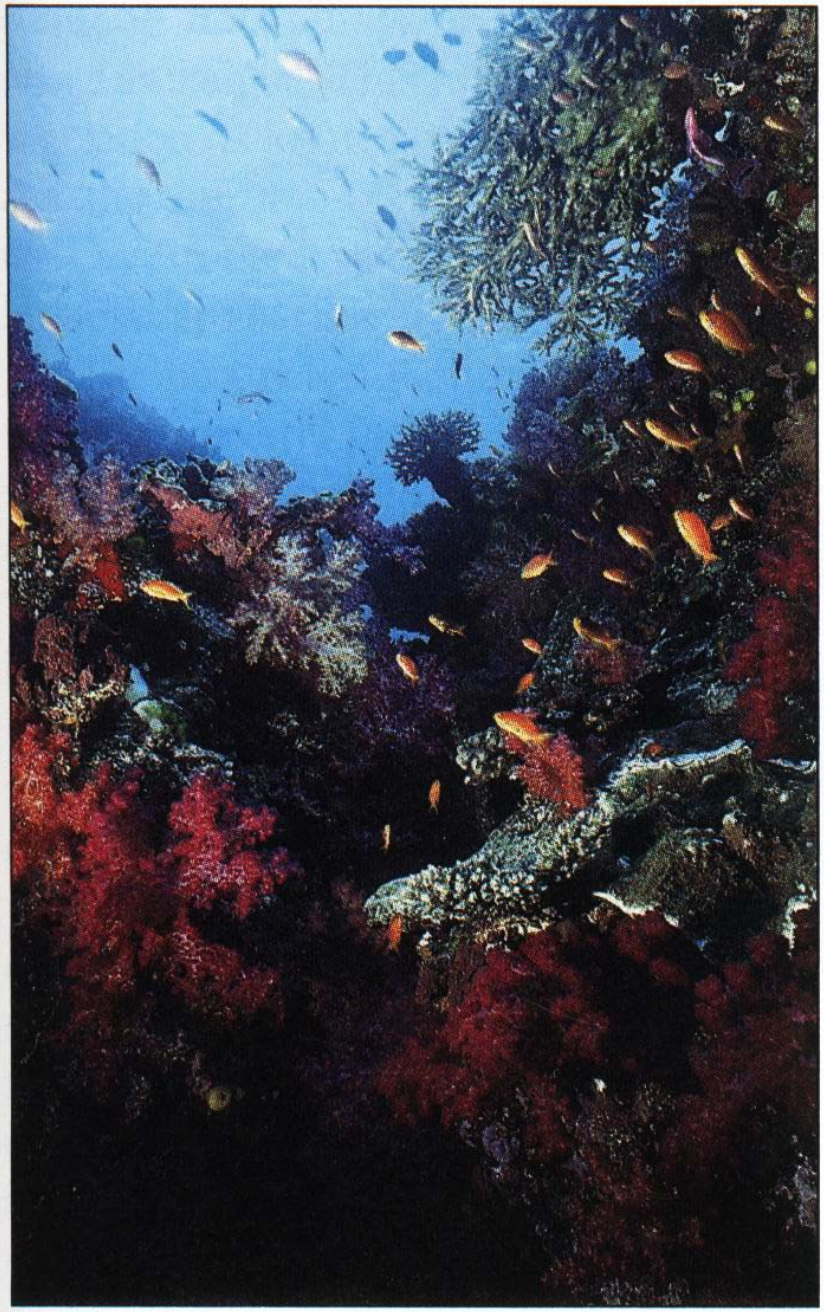
- Pelagic Region - Open sea
  - Euphotic Zone: Upper layer of ocean where sun's rays penetrate.
- Phytoplankton - Microscopic plants floating in the ocean. (perform photosynthesis)
- Zooplankton - Microscopic animals of many kinds - feed on phytoplankton.
  - Productive aquatic ecosystems are those in which essential nutrients are common.

Marine Ecosystems

- Benthic Marine Ecosystems
  - Bottom of sea.
- Coral Reef Ecosystems - large number of animals that build cup-shaped external skeletons around themselves.
  - Contain single-celled algae and carry on photosynthesis.



Marine Ecosystems: All of the photosynthetic activity of the ocean occurs in the shallow water either by attached algae near the shore or by minute phytoplankton in the upper levels of the ocean. Consumers are either free-swimming pelagic organisms or benthic organisms that live on the bottom.



Coral Reef: Corals are small sea animals with secrete external skeletons. They have a mutualistic relationship with certain algae, which allows both kinds of organisms to be very successful. The skeletal materials serves as a substrate upon which many other kinds of organisms live.

Marine Ecosystems

- Mangrove Swamp Ecosystems
  - Occupy region near shore.
  - Trees tolerate high salt content.
    - Excrete salt from leaves.
  - Extensively developed roots.
    - Can extend above water.
  - Trap sediment in shallow areas.
    - Develop terrestrial ecosystems.

Mangrove Swamp: Mangroves are tropical trees that are able to live in very wet, salty muds found along the ocean shore. Since they are able to trap additional sediments, they tend to extend farther seaward as they reproduce.

Marine Ecosystems

- Estuaries
  - Shallow, partially enclosed areas where freshwater enters the ocean.
  - Extensive production because areas are shallow, warm, and nutrient-rich.

Freshwater Ecosystems

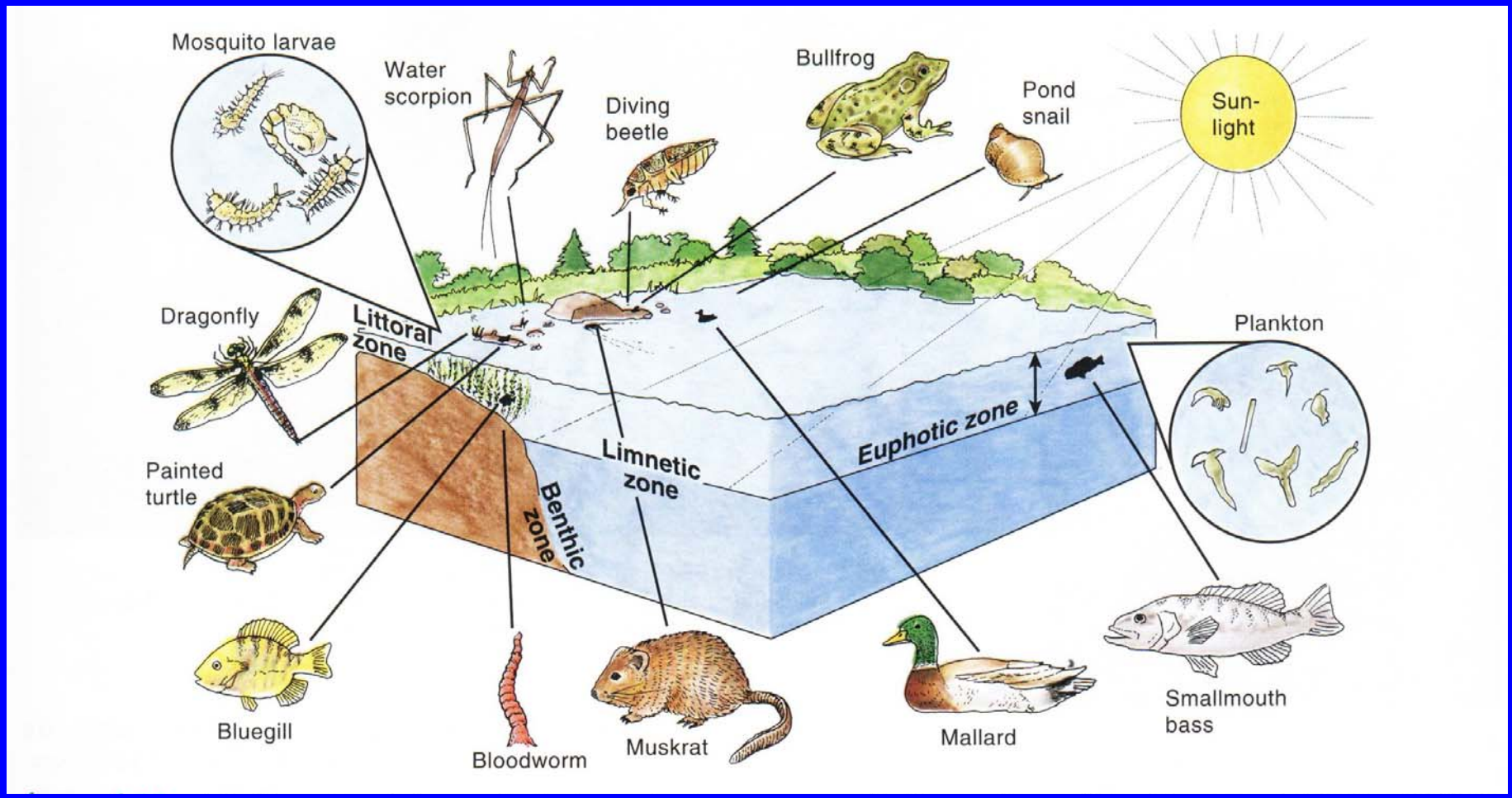
- Two broad Categories:
  - Stationary Water
  - Running Water (Downhill)

Lakes and Ponds

- Littoral and Limnetic Zones - presence or absence of rooted vegetation.
- Productivity of a lake determined by many factors.
  - Cold temps. reduce rate of photosynthesis.
  - Shallow = more photosynthesis.
  - Erosion from land = high nutrients.
  - Dissolved Oxygen - wave action and photosynthesis from aquatic plants.

Lakes and Ponds

- Oligotrophic - Deep, cold, nutrient-poor.
- Eutrophic - Shallow, warm, nutrient - rich.
- Biochemical Oxygen Demand (BOD)
  - Amount of oxygen used by decomposers to break down specific amount of organic matter.



Lake Ecosystem: Lakes are similar in structure to ocean except that the species are different because most marine organisms cannot live in freshwater. Insects are common organisms in freshwater lakes, as are many kinds of fish, zooplankton, and phytoplankton.

Streams and Rivers

- Even though most streams are shallow, it is difficult for most photosynthetic organisms to accumulate nutrients necessary for growth.
  - Most clear streams are not very productive.
  - Most debris is input from terrestrial sources.
- Periphyton - collection of algae, animals and fungi attached to rocks and other objects on the bottom.

Streams and Rivers

- Swamps - Wetlands containing trees able to live in environments that are permanently flooded or flooded most of the year.
- Marshes - Wetlands dominated by grasses and reeds.

Summary

- The environment of an organism can be divided into ***biotic*** and ***abiotic*** components.
- The space an organism occupies is its ***habitat***, and the role it plays in its environment is its ***niche***.
- Organisms interact with one another in a variety of ways: ***predation***, ***competition***, ***symbiotic relationships*** etc.
- A ***community*** is the biotic portion of an ecosystem that is a set of interacting populations of organisms. Those organisms and their abiotic environment constitute an ***ecosystem***.
- In an ecosystem, ***energy*** is trapped by producers and flows from producers through various ***trophic levels*** of consumers.

Summary

- The ***flow of nutrients*** through an ecosystem involves all the organisms in the community, and these nutrients are cycled in ecosystems.
- Ecocystems change as one kind of organism replaces another in a process called ***succession***.
- Major regional terrestrial climax communities are called ***biomes*** (such as desert, grassland, savanna and so on) each of which has a particular set of organisms that is adapted to the climate conditions typically for the area.
- ***Aquatic ecosystems*** are divided into marine ecosystems which include pelagic and benthic zones, and freshwater ecosystems which include lakes and ponds, and streams and rivers.

Key Terms

- **Biomass**

  the weight of living material in a trophic level

- **Carbon cycle**

  the process and pathways involved in capturing inorganic carbon-containing molecules, converting them into organic molecules that are used by organisms, and the ultimate release of inorganic carbon molecules back to abiotic environment

Key Terms

- Carnivore

  animals that eat other animals
- Herbivore

  animals that eat producers (plants or phytoplankton)
- Omnivore:

  animals that include both plants and animals in their diet

Key Terms

- **Commensalism**

  the relationship between organisms in which one organism benefits while the other is not affected

- **Competition**

  the type of interaction between species in which two organisms strive to obtain the same limited resource

- **Predation**

  the interaction in which one organisms kills and eats another

Key Terms

- Endoparasite

  organisms that live inside the bodies of their hosts and derive nourishment from the hosts

- Food chain

  the passage of energy from one trophic level to the next as a result of one organism consuming another

- Food web

  the relationship made up by overlaps and intersections of several food chains

Key Terms

- **Genes**

  distinct pieces of DNA that determine the characteristics an individual displays

- **Keystone species**

  species that have a critical role to play in the maintenance of specific ecosystems

- **Natural selection**

  the process that determines which individuals within a species will reproduce and pass their genes to the next generation

Key Terms

- **Niche**

  the functional role an organism has in its surroundings (its profession)

- **Nitrogen cycle**

  the cycling of nitrogen atoms between the abiotic and biotic components and among the organisms in an ecosystem

- **Ecology**

  the study of the ways organisms interact with each other and with their nonliving surroundings

Key Terms

- **Speciation**

  the production of new species from previously existing species
- **Trophic level**

  each step in the flow of energy through an ecosystem
- **Benthic**

  organisms that live on the ocean bottom
- **Biome**

  terrestrial climax communities with wide geographic distribution

Key Terms:

- Estuary

  a special category of aquatic ecosystem that consists of shallow, partially enclosed areas where freshwater enters the ocean

- Succession

  the concept that communities proceed through a series of recognizable, predictable changes in structure over time

- Climax community

  the relative stable, long-lasting community that the result of succession

Key Terms

- Pioneer community

  the collection of organisms that can become established and survive in inhospitable places such as bare rock or sand

- Plankton

  aquatic organisms that are so small and weakly swimming that they are simply carried by currents

- Phytoplankton

  the planktonic organisms that carry on photosynthesis

- Zooplankton

  small, weakly swimming animals

Review Questions

- Describe, in detail, the niche of a human.
- How is natural selection related to the concept of niche?
- List five predators and their prey organisms.
- Give examples of organisms that are herbivores, canivores, and onmivores.
- What are some different trophic levels in an ecosystem?
- Describe the carbon cycle, nitrogen cycle and phosphorus cycle.

Review Questions

- Describe the process of succession. How does primary succession differ from secondary succession?
- How does a climax community differ from a successional community?
- How does height above sea level affect the kind of biome present?
- What is the role of each of the following organisms in a marine ecosystem: phytoplankton, zooplankton, algae, coral animals, and fish?