

Ecosystem Essentials

Physical Geography Lecture - GEOG B1

Available on www.cherylnail.com

Biosphere

The biosphere, the sphere of life and organic activity, extends from the ocean floor to an altitude of about 8 km (5 mi). *

Ecosystem - a self-sustaining association of living plants and animals and their non-living physical environment

- *biotic* - living organisms
- *abiotic* - non-living things (sunlight, air, water, rocks/dirt, temperature)

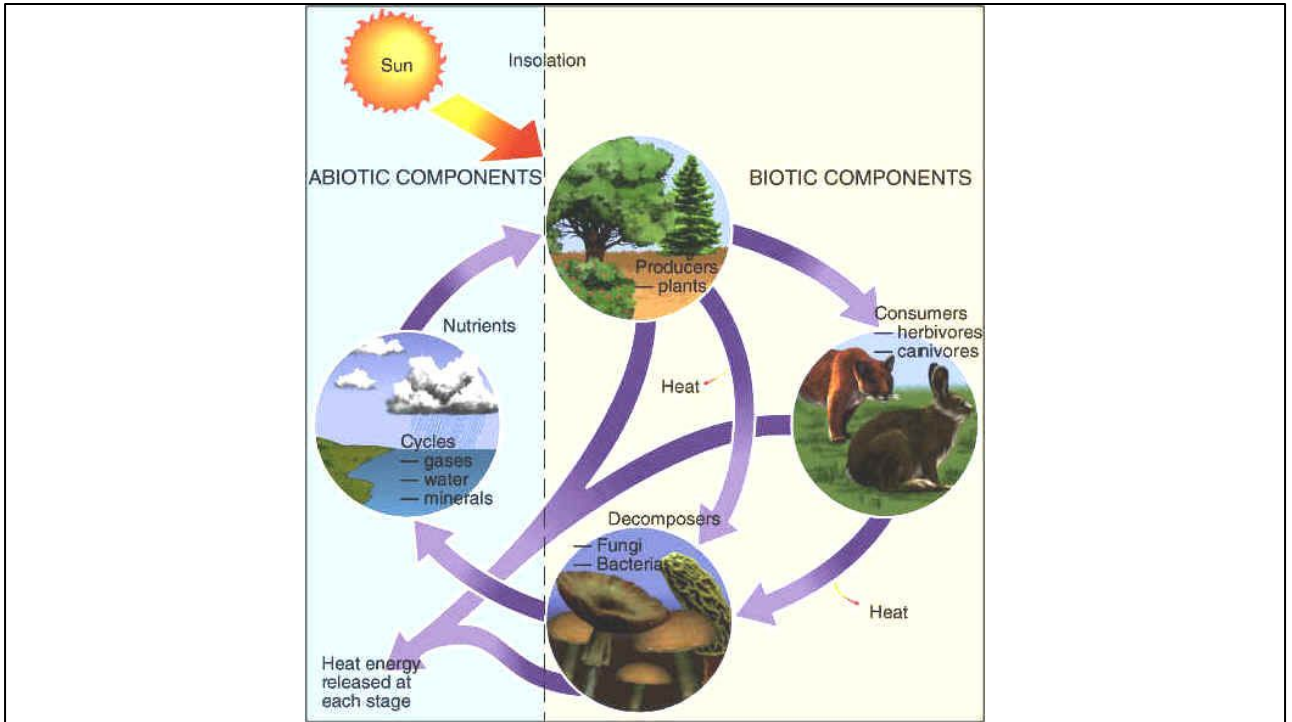
Natural ecosystems are open systems with regards to both solar energy and matter. **

*The biosphere contains a myriad of ecosystems from simple to complex, each operating within general spatial boundaries.

**All ecosystem boundaries function as transition zones rather than as sharp demarcations.

Ecosystems vary in size from small-scale (city park or pond), to mid-scale (mountain top or beach), to large-scale (forest or desert). Internally, every ecosystem is a complex of many interconnected variables, all functioning independently yet in concert, with complicated flows of energy and matter.

There are a few limited ecosystems that exist in dark caves, in wells, or on the ocean floor that depend on chemical reactions, not sunlight, for energy.



Ecology / Biogeography

Ecology - the study of the relationships between organisms and their environment and among the various ecosystems in the biosphere.

Biogeography - the study of the distribution of plants and animals, the diverse spatial patterns they create, and the physical and biological processes, past and present, that produce Earth's species diversity.

Earth's most influential biotic agents are humans because they affect every ecosystem on Earth.*

*From the time humans first developed agriculture, tended livestock, and used fire, the influence of humans over Earth's physical systems has been increasing.

Converting Energy to Biomass

The energy that powers the biosphere comes primarily from the sun.

Solar energy enters the ecosystem energy flow by way of photosynthesis, and heat energy is dissipated from the system as an output at many points.

Only about 1% of the energy that reaches the surface is actually bound into plant tissues by photosynthesis as carbohydrates.

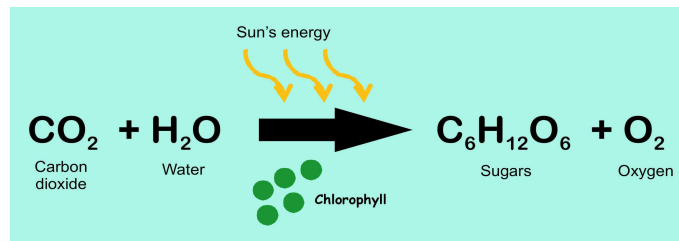
Plants are the critical biotic link between solar energy and the biosphere, and they become a source of energy for the rest of the ecosystem.

Producers and Photosynthesis

Producers - plants, algae, and cyanobacteria - organisms able to use sunlight (and CO₂) to produce their own food in a process called photosynthesis

The oxygen in our atmosphere was produced as a by-product of photosynthesis. *

Photosynthesis - unites CO₂ and water with certain wavelengths of visible light and produces starches and sugar as food for the plants, and releases oxygen **



*The first photosynthesizing bacteria to produce oxygen appeared in our oceans about 2.7 billion years ago - cyanobacteria (unicellular blue-green algae).

Integral in creating Earth's modern atmosphere, and in the origin of plants.

**Photosynthesis - the term is descriptive: *photo* - refers to sunlight, and *synthesis* describes the "manufacturing" of starches and sugars through reactions within the plant leaves.

Chlorophyll

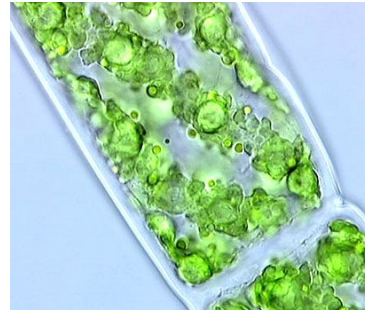
In leaf cells are organelles called chloroplasts - light responsive, photosynthetic structures.

Chloroplasts contain a green, light-sensitive pigment called **chlorophyll**.

Light stimulates the molecules of this pigment, producing a photochemical, or light-driven, reaction. *

Chlorophyll only absorbs about 1/4 of the light energy it receives (orange-red and violet-blue wavelengths) for photochemical operations.

It reflects the green wavelengths.



*Consequently, competition for light is a dominant factor in the formation of plant communities.

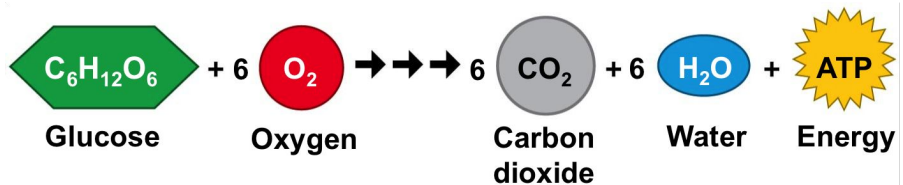
This competition is expressed in the height, orientation, distribution, and structure of plants.

Respiration

Photosynthesis removes carbon from the atmosphere - about 91 billion metric tons per year.

Plants use the sugar they create to build starches (complex carbohydrates), and store the starches for later use as food.

Plants consume this starch through **respiration**, which converts the carbohydrates to energy. Respiration is like a reverse of the photosynthesis process. *



*Plants oxidize carbohydrates (break them down through reaction with oxygen), releasing CO₂, water, and energy as heat.

The overall growth of a plant depends on on the amount of surplus carbohydrates it can hold on to beyond those lost to respiration.

A plant will literally shed its leaves - its production centers - if it doesn't get enough water or light. It can't afford to lose more carbs than it is producing.

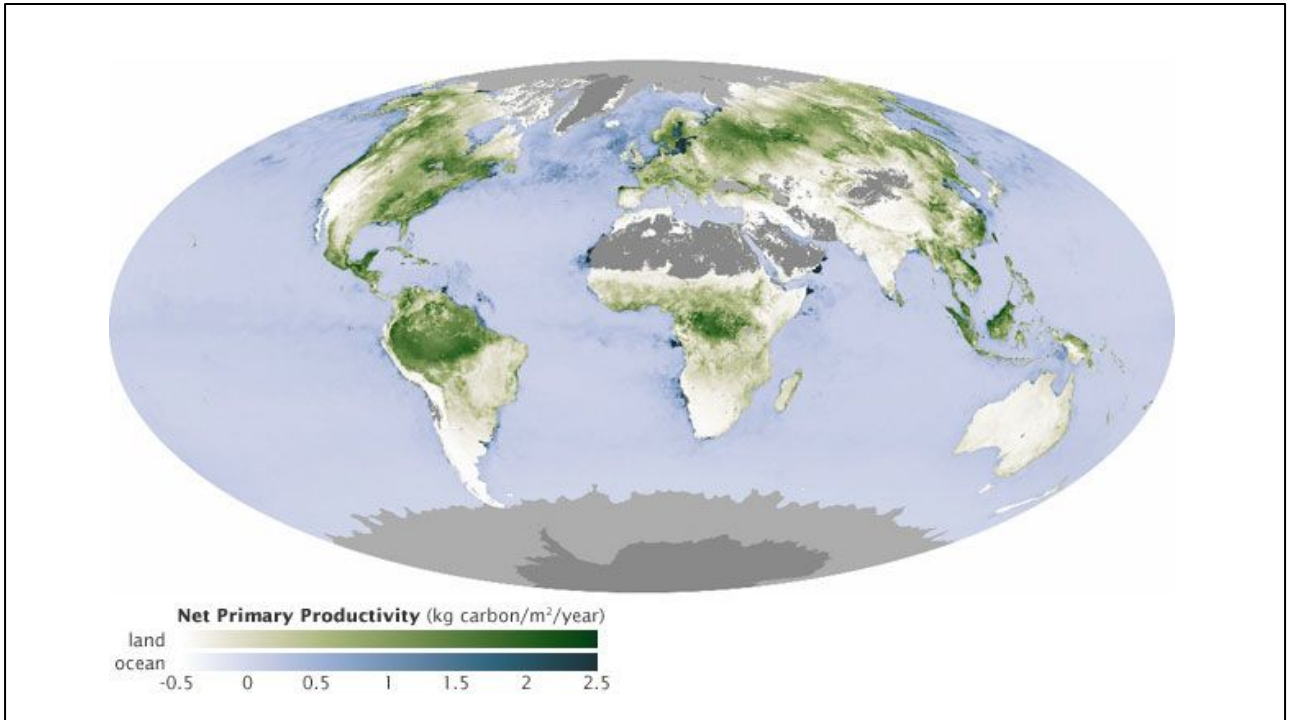
Net Primary Productivity

Net primary productivity - the amount of stored chemical energy that the producers in an ecosystem generate

Biomass - the total organic matter (living and recently living - both animal and plant) in an ecosystem, with its associated chemical energy

Net primary productivity is an important ecosystem aspect because it determines the biomass available for consumption by the **consumers** - organisms that feed on others.

Fig. 19.4 and **Table 19.1** on **p. 564**



Net primary productivity is measured as fixed carbon per square meter per year.

On land, net primary production tends to be highest between the Tropics of Cancer and Capricorn at sea level and decreases toward higher latitudes and elevations.

Productivity levels are tied to both sunlight and precipitation.

In the aquatic ecosystems, net primary production is highest in coral reefs and estuaries and areas where there are nutrient rich-upwelling currents off western coastlines.

Elemental Cycles

Numerous abiotic physical and chemical factors support the living organism of each ecosystem. *

Biogeochemical cycle - a continuous circuit of flowing elements and materials (like carbon, oxygen, nitrogen, water, etc.) that combine and renew Earth's biotic and abiotic systems in the biosphere

Fig. 19.5 - Oxygen and Carbon cycles - closely intertwined because they are closely related through photosynthesis and respiration **

Fig. 19.6 - Nitrogen cycle ***

*Some of these abiotic components such as light, temperature, and water, are critical for ecosystem operation.

The cycling of nutrients and flow of energy between organisms determine the structure of an ecosystem.

As energy moves through the system, it is constantly replenished by the sun.

But nutrients and minerals cannot be replenished from an external source, so they constantly cycle within an ecosystem and through the biosphere.

**We are adding carbon to the environment in an amount 400% greater than we were in 1950 - but we have cut down much forest, thereby removing part of our carbon sink (storage). Carbon is stored in the atmosphere - and it increases the greenhouse effect.

***Nitrogen is a major component of our atmosphere and is essential to living processes.

To improve agricultural yield, synthetic nitrogen fertilizers are applied (instead of organic manure or compost). However, this

synthetic fertilizer exceeds what the system can naturally process - the excess nutrients are washed out of the soil, into the waterways and eventually to the ocean.

Dead Zones

Excess nitrogen washed into the oceans or lakes begins a water pollution process:

1. feeds an excessive growth of algae and phytoplankton
2. increases biochemical oxygen demand
3. diminishes dissolved oxygen reserves
4. eventually disrupts the aquatic ecosystem

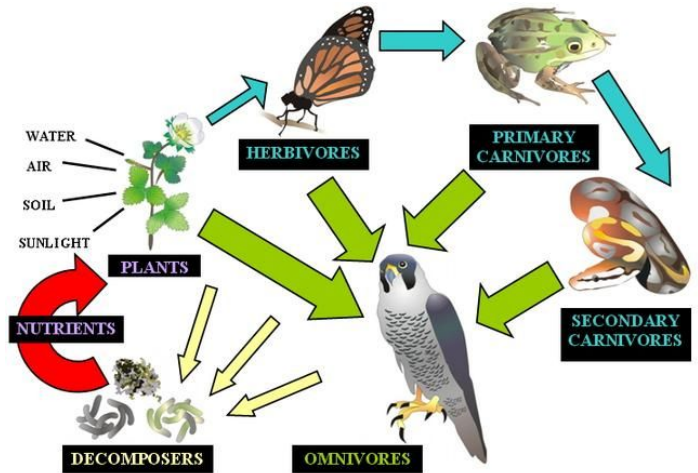
Dead zones - areas of limited marine life due to low-oxygen conditions

pp. 568-569, GIA - Coastal dead zones

Energy Pathways - I

Food chain - an idealized pathway that energy flows along in an ecosystem

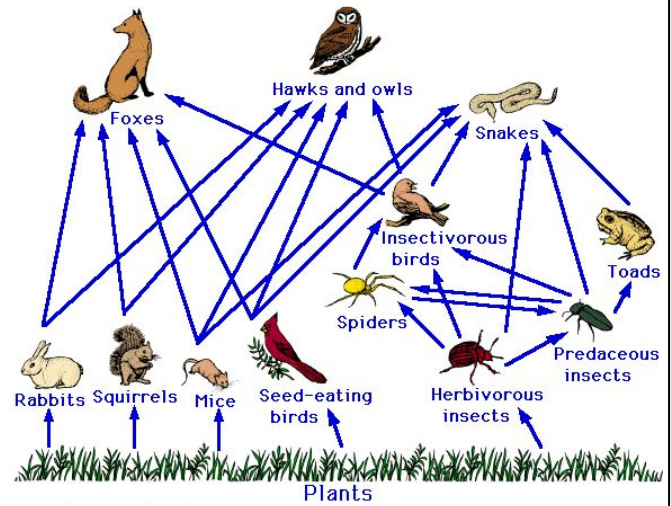
Solar energy enters the food chain through the producers, and then it flows to higher and higher levels of consumers.



Energy Pathways - II

Food web - more complex and realistic arrangement of interconnected food chains

Consumers participate in several food chains.



Energy Pathways - III

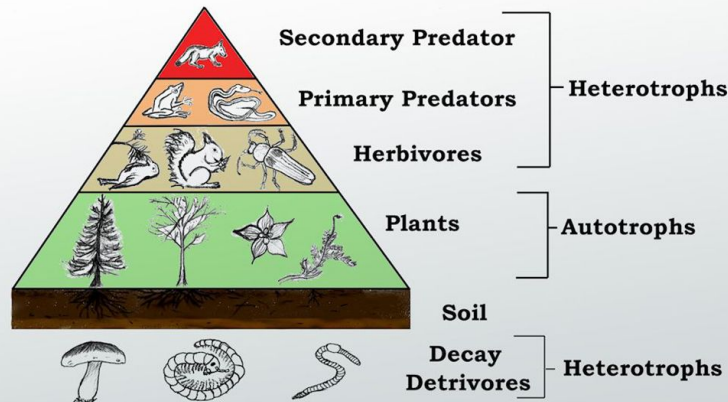
Detritivores (or scavengers) - aide in the continuous nutrient cycling by feeding on detritus - dead organic debris (dead bodies, fallen leaves, and waste products)
- break down organic materials and releasing simple inorganic compounds and nutrients

- *Examples:* worms, mites, termites, snails, crabs, catfish, vultures, etc.

Decomposers - bacteria and fungi that digest organic debris outside their bodies and absorb and release nutrients in the process

Herbivores / Carnivores / Omnivores

ENERGY TRANSFERS



©Study.com

In a food web, the organisms that feed on producers are primary consumers.

Because **producers** are always plants, the primary consumer is an **herbivore**, or plant eater.

A secondary consumer mainly eats primary consumers (herbivores) and that is a **carnivore**, or meat eater.

A tertiary consumer eats primary and secondary consumers, and is referred to as the “top carnivore” in the food chain.

A consumer that feeds on both producers (plants) and consumers (meat) is an **omnivore** - a category occupied by humans, among other animals.

Fig. 19.7 and **19.8**

Energy Pyramids

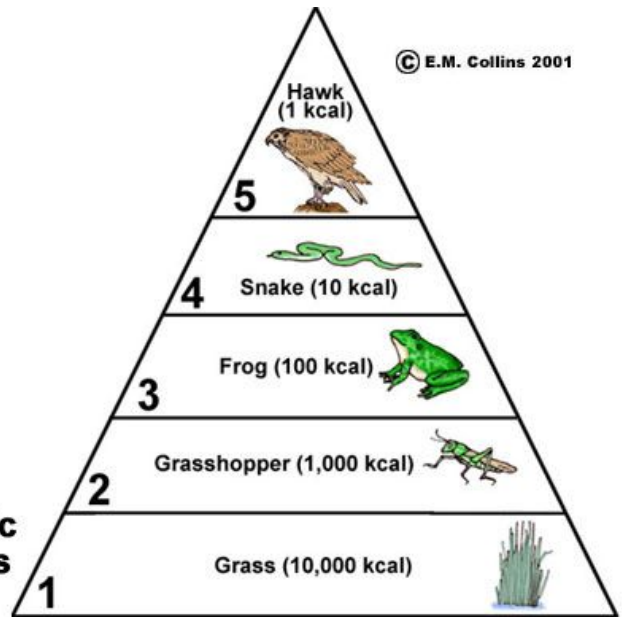
As energy moves through the levels of the food web, it decreases.*

Producers have the most energy available. As each level consumes the one below it uses energy to metabolize what it eats.

The number of consumers at each level is controlled by the amount of energy available.

Fig. 19.10

Trophic Levels



*Only 10% of the energy from one level is available to the next.

Biological Amplification

When chemical pesticides are applied to an ecosystem of producers and consumers, the food web concentrates some of these chemicals.

Some chemicals break down and become inert. However, others are long-lived, stable, and soluble in the fatty tissues of consumers, and they become increasingly concentrated at each higher level of the energy pyramid. This is called biological amplification, or *biomagnification*. *

Pollution in a food web can efficiently poison the organism at the top.

- polar bears, orca, humans

*1970s - DDT pesticide was biologically amplified in bird's fatty tissues and causing a thinning of eggshells that caused hatchling mortality.

This ban of DDT for agricultural use is now credited with saving the brown pelican and peregrine falcon from extinction.

Habitats

The biosphere can be grouped into ecosystems, each of which can be grouped into communities.

Community - made up of interacting populations of living plants and animals in a particular place

Communities live inside of habitats.

Habitat - the environment in which an organism resides or is biologically adapted to live *



*A habitat includes both biotic and abiotic elements of the environment, and habitat size and character vary with each species' needs.

For example, black-legged Kittiwakes are a type of gull that prefers small nesting habitats on the sheer cliff faces of offshore islands or sea stacks where their young are safe from predators. When breeding season is over, these gulls return to the open ocean for the rest of the year. **Fig. 19.11**

Niche Concept

Ecological niche - the function, or occupation, of a life form within a given community

A niche is determined by the physical, chemical, and biological needs of the organism - it is a unique role that a species performs within a habitat.*

No two species can occupy the same niche (using the same food or space) because one species will always outcompete the other. **

Therefore, closely related species are spatially separated either by distance or by species specific strategies.

*Whereas the habitat is an environment that can be shared by many species.

***For example:* the white-breasted nuthatch is a small bird that occurs throughout the U.S., and in parts of Canada and Mexico, especially in deciduous forest habitats. This species occupies a particular niche by foraging for insects up and down tree trunks, probing into the bark with their sharp bills and often turning upside down and sideways as they move. This behavior enables them to find and extract insects that are overlooked by other birds. They also jam nuts and acorns into the bark, and then bang on them with their bill to extract the seeds. Although nuthatches and woodpeckers occupy a similar habitat, the nuthatch's distinctive foraging behavior causes it to occupy a specific niche that is different from the woodpecker

Species Interactions

Symbiosis - some species have some type of overlapping relationships:

- *Mutualism* - each organism benefits and is sustained over an extended period of time (*Example: lichens*)
- *Parasitism* - one organism benefits and another is harmed by the association (*Example: ticks and the animals they feed off of*)
- *Commensalism* - one organism benefits and the other experiences neither harm nor benefit (*Example: remoras and sharks*)
- *Amensalism* - one species harms another but is not affected itself (*Example: black walnut trees*)

Abiotic Influences - I

Abiotic environmental factors which influence species distribution:

- Duration of light and dark over 24 hour period
- Air and soil temperatures
- Precipitation and water availability
- Water quality - mineral content, salinity, levels of pollution and toxicity

Abiotic Influences - II

Life zone - a zonation by altitude of plants and animals that form distinctive communities - each zone possesses its own temperature and precipitation regime and therefore, its own biotic communities

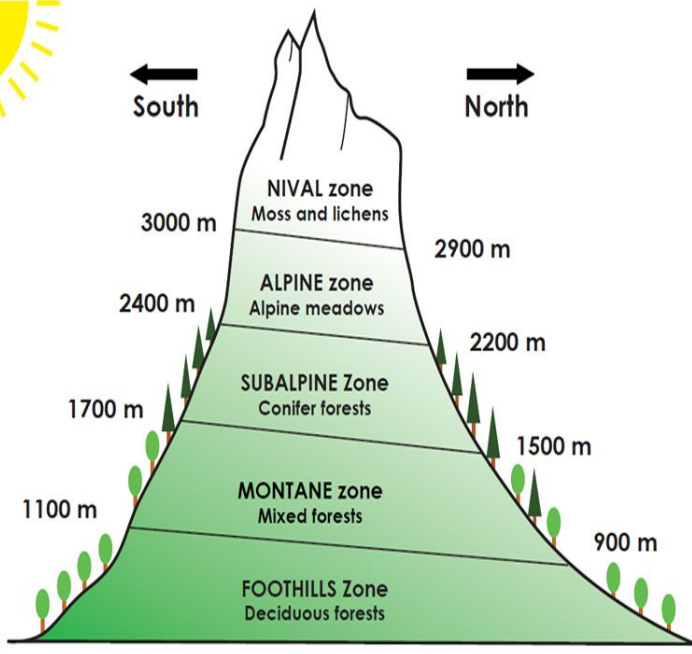
The life zone concept was expanded to include the changing zonation from the equator toward the higher latitudes.

Fig. 19.15



← South

→ North



3000 m
NIVAL zone
Moss and lichens

2900 m

2400 m
ALPINE zone
Alpine meadows

2200 m

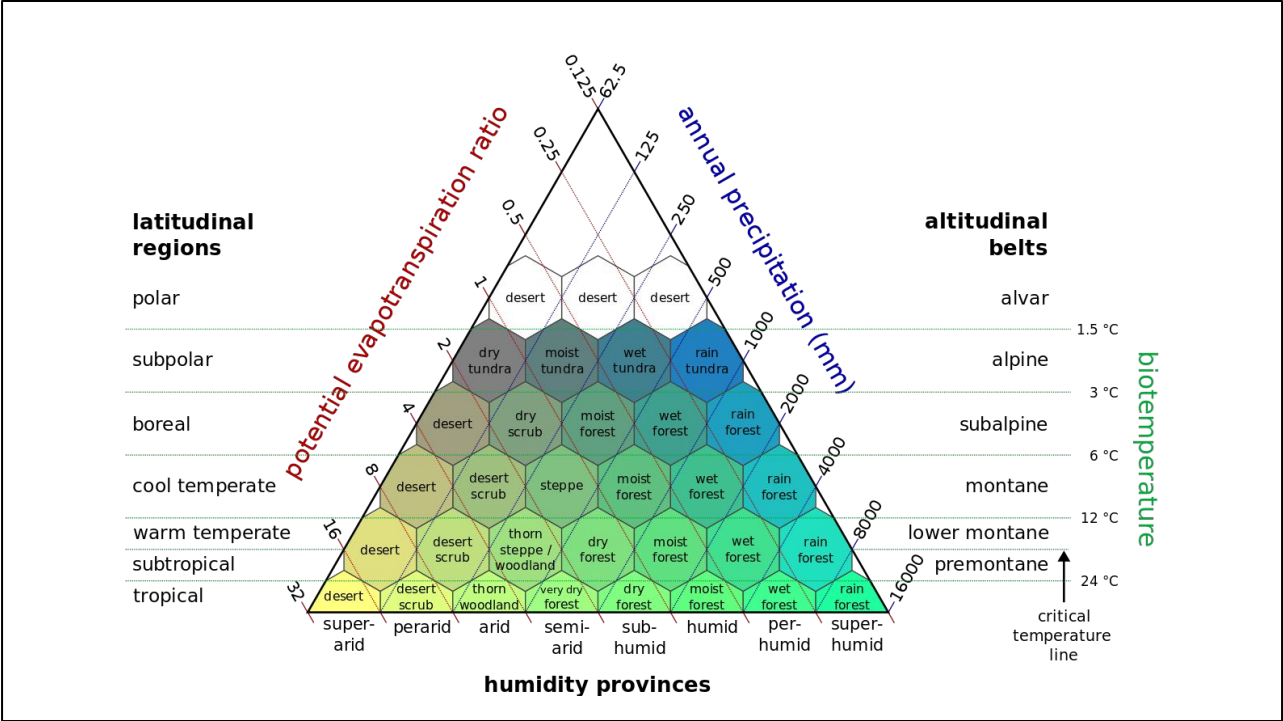
1700 m
SUBALPINE Zone
Conifer forests

1500 m

1100 m
MONTANE zone
Mixed forests

900 m

FOOTHILLS Zone
Deciduous forests



Limiting Factors

Limiting factors - physical, chemical, or biological characteristics of the environment that determine species distribution and population size

Natural factors that can limit a population in a habitat:

- Availability of food and water
- Space and light
- Soil nutrients
- Weather conditions / temperature
- Breeding site availability
- Prevalence of disease

Disturbance and Succession

Over time, communities undergo natural disturbance events such as windstorms, fires, flooding, volcanic eruptions, landslides, or an insect infestation.

Human activities also cause disturbances: clear-cut logging of a forest, overgrazing of a rangeland, etc.

These events damage or remove existing organisms, making way for new communities.



Fire Ecology

Wildfires are a natural component of many ecosystems.

Fire ecology - science that examines the role of fire in ecosystems, including adaptations of individual plants to the effects of fire and the human management of fire-adapted ecosystems

Focus Study 19.1, pp. 578-579



Ecological Succession

When a disturbance eliminates most or all of the species, a process known as ecological succession occurs.

Ecological succession - process in which the cleared area undergoes a series of changes in species composition as newer communities of plants and animals replace older ones.

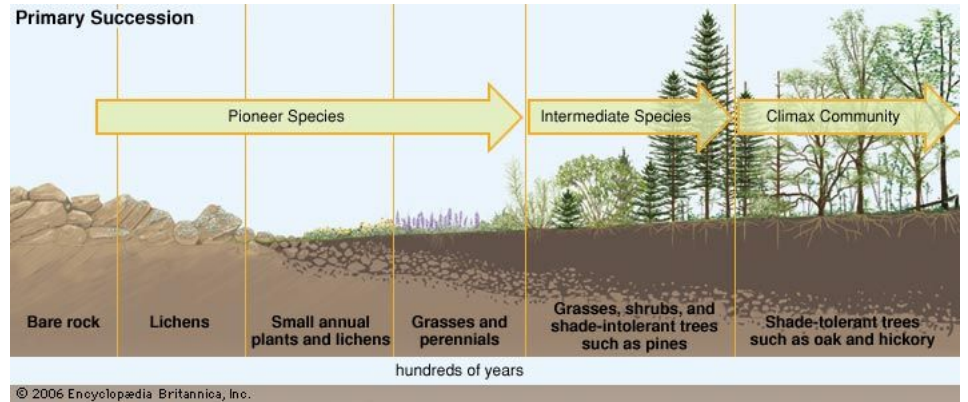
During the transition, species with adaptive advantages will outcompete other species for space light, water, and nutrients.

Advantage example: ability to produce seeds or disperse them over great distances

Primary succession

Primary succession - the beginning stage of an ecosystem, when there is only bare rock to start with - can take hundreds of years

Pioneer community - usually mosses, lichens, and ferns - well adapted to colonizing new substrates



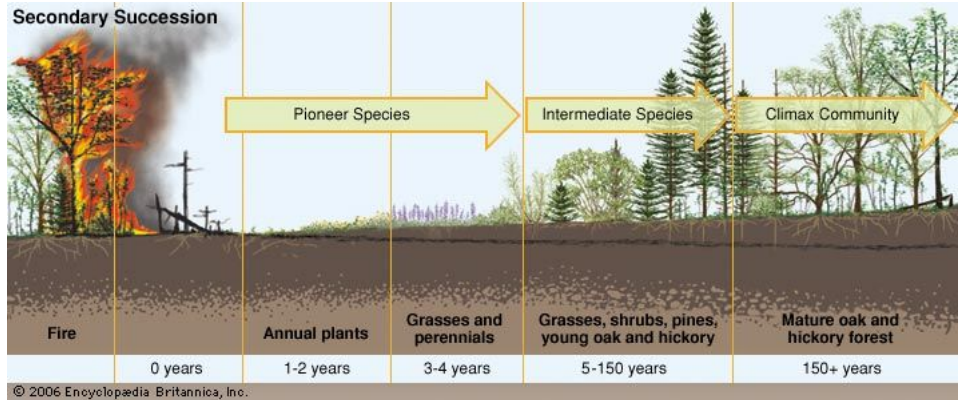


Secondary Succession

Secondary succession - more commonly encountered in nature - occurs when some aspect of a previously functioning community is still present - takes less time

Example: a disturbed area where the underlying soil remains intact

Fig. 19.19



Aquatic Succession

Ecological succession can also occur in aquatic ecosystems.

Lakes and ponds exhibit successional stages as they fill in with sediment and nutrients and as aquatic plants take root and grow.

Plant growth captures more sediment and adds organic debris to the system.

- **Eutrophication** - the gradual enrichment in water bodies as they fill with organic debris.

Fig. 19.20

As humans dump sewage, agricultural runoff, and pollution into waterways, the nutrient load is enhanced beyond the cleansing ability of natural biological processes. This human-caused eutrophication hastens succession in aquatic systems.

Biodiversity

A critical aspect of ecosystem stability and vitality is biodiversity.

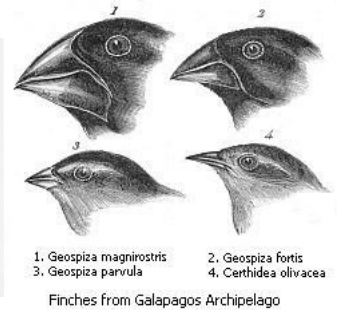
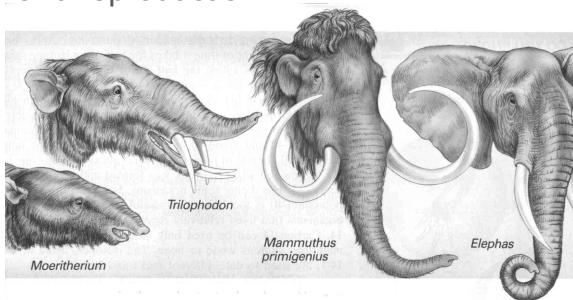
Biodiversity - a variation of life - encompasses the number and variety of different species, the number of genetic variations within these species, and the number and variety of ecosystems, habitats, and communities on a landscape.



Evolution Delivers Biodiversity

The Theory of **Evolution** states that single-cell organisms adapted, modified, and passed along inherited changes in multicellular organisms.

The genetic makeup of successive generations was shaped by environmental factors, physiological functions, and behaviors that led to greater rate of survival and reproduction.



Traits that help a species survive and reproduce are passed along more frequently than those that do not.

Traits that successfully exploit niches different from those of other species, or those that help a species adapt to environmental change are passed to successive generations.

Spatial variation in physical environments affects natural selection.

Migration to new environments where new traits are favored - mutations can increase survival chances.

Biodiversity = Stability

Greater biological diversity in an ecosystem leads to greater long-term stability and productivity.

“Stable” does not mean unchanging. Stable ecosystems are constantly changing.

A *stable* ecosystem is one that does not deviate greatly from its original state, despite changing environmental conditions.

Resilience is the ecosystem’s ability to recover from disturbance quickly and return to its original state. *

Some ecosystems are stable and resilient, others are stable yet not resilient. **

*Some disturbances are too extreme to recover from - then a new ecosystem develops and moves toward a new stable state.

***Example:*

- Tropical rainforests - diverse stable community that can withstand most natural disturbances, yet it has low-resilience in terms of severe events. A cleared track of rainforest will recover at a slower rate than many other communities because most of the nutrients are stored in the vegetation rather than in the soil.
- In contrast, a Midlatitude grassland, although less diverse than a rainforest, has high resilience because the system can cope with a range of disturbances and recover quickly - like a fire - rapid regrowth occurs from extensive root systems in the grassland species

Agricultural Ecosystems

When humans purposely eliminate biodiversity from an area, as they do in most agricultural practices, the area becomes more vulnerable to disturbance.

An artificial monoculture community is more susceptible to insect infestations and plant diseases.

In some regions, simply planting multiple crops brings more stability.

A modern agriculture ecosystem requires enormous amounts of energy, pesticides, herbicides, artificial fertilizers, and irrigation fertilizer.

The practice of harvesting and removing biomass from the land interrupts the cycling of materials into the soil and depletes soil nutrients over time, a loss that must be artificially replenished.

Biodiversity on the Decline

Human activities have a great impact on biodiversity. *

Five categories of human impact on biodiversity:

- Habitat loss and degradation due to agriculture and urban development
- Pollution of air, water, and soils
- Resource exploitation and harvesting of plants and animals at unsustainable levels
- Human-induced climate change
- Introduction of non-native plant and animal species

*The present loss of species is irreversible and is accelerating. Since life began on the planet, six major extinctions have occurred. The fifth was 65 million years ago. The sixth is currently happening, and it is the only one of biotic origin - caused mostly by human activity.

There is an estimated 13.6 million plant and animal species on Earth, and we have only classified 1.75 million of them.

The possibility exists that over half of Earth's present species could be extinct in the next 100 years if humans don't curb their destructive ways.

Species & Ecosystem Restoration

In the last 40 years, humans have:

- Worked to reintroduce animals back into their habitats
- Worked to restore habitats that had been degraded
- Worked to limit practices that cause species decline.

More needs to be done. We need to create a sustainable model of resource and land use that allows for stable biodiversity.