Chapter 5 and 6 -- Biological Communities and Species Interaction

After studying this chapter, you should be able to:

- describe how environmental factors determine which species live in a given ecosystem and where or how they live.
- understand how random genetic variation and natural selection lead to evolution, adaptation, niche specialization, and partitioning of resources in biological communities.
- compare and contrast interspecific predation, competition, symbiosis, commensalism, mutualism, and coevolution.
- discuss productivity, diversity, complexity, and structure of biological communities and how these characteristics might be connected to resilience and stability.
- explain how ecological succession results in ecosystem development and allows one species to replace another. You should also understand the difference between primary and secondary succession.
- give some examples of exotic species introduced into biological communities and describe the effects such introductions can have on indigenous species

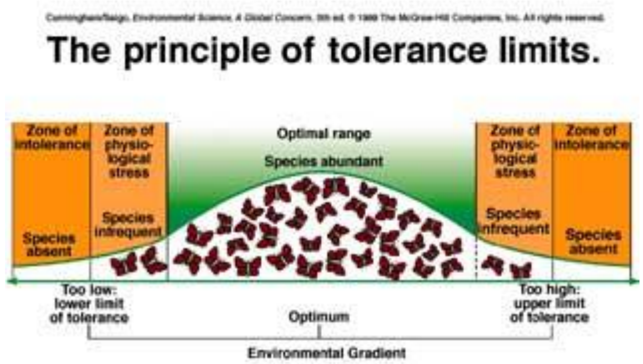
Who Lives Where, and Why?

- Why does a particular species live where it does?
- How is it able to live where it does?
- How does it deal with the physical resources of its environment?
- How does it interact with the other species present?
- What gives one species an edge over another species in a particular habitat?

Critical Factors and Tolerance Limits

- Every living organism has limits to the environmental conditions it can endure.
- Environmental factors must be within appropriate levels for life to persist.
    - Temperature
    - Moisture levels
    - Nutrient supply
    - Soil and water chemistry
    - Living space

In 1840, Justus von Liebig proposed that the single factor in shortest supply relative to demand is the critical determinant in the distribution of that species.



Victor Shelford later expanded Liebig's principal by stating that each environmental factor has both minimum and maximum levels called tolerance limits beyond which a particular species cannot survive.

The above concepts used to be considered laws; however, the interaction of several factors together determines biogeographical distribution.

A specific critical factor that, more than any other, may determine the abundance and distribution of a species in a given area.

- Cold intolerance in the Giant saguaro cactus
- Salt and temperature tolerance in egg and juvenile desert pupfish

Sometimes the requirements and tolerances of species are useful indicators of specific environmental characteristics

The presence or absence of these environmental indicators can tell us something about the community and ecosystem as a whole.

Natural Selection, Adaptation, and Evolution

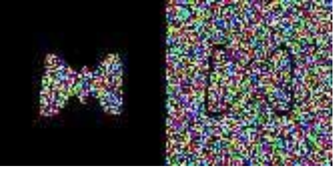
Species acquire traits that allow them to be adapted to their environment.

The term adapt can be used in two ways:

1. **Acclimation:** limited range of physiological modifications available to individual organisms
    - Individuals can adapt to a certain degree, but change is not permanent.
    - Changes cannot be passed to offspring.
2. **Evolution:** Operates at the population level, brought about by inheritance of specific genetic traits that allow species to live in a particular environment.

Species change gradually through two mechanisms:

1. Competition for scarce resources.



2. **<u>Natural selection:</u>** members of a population that are best suited for a particular environment will survive and produce offspring more successfully than their ill-suited competitors
    - Acts on preexisting genetic diversity created by a series of small, random mutations that occur spontaneously in every population.
    - Where resources are limited or environmental conditions place some selective pressure on a population, individuals with those advantageous traits become more abundant in the population, and the species gradually evolves or becomes better suited to that environment.
    - Examples of natural selection.
        - Changing coloration of European peppered moths
        - The variety of finches observed by Charles Darwin on the Galapagos Islands

What environmental factors cause selective pressure and influence fertility or survivorship in nature?

- Physiological stress due to inappropriate levels of some critical environmental factor
- Predation, including parasitism and disease
- Competition
- Luck

Given enough geographical isolation or selective pressure, members of a population can become so different from their ancestors that they can be considered a new species that has replaced the original one.

Alternatively, isolation of population subsets by geographical or behavior factors that prevent exchange of genetic material can result in branching off of new species that coexist with their parental line

<u>Convergent evolution:</u> unrelated organisms coming to look and act very much alike due to natural selection and adaptation.

The Ecological Niche

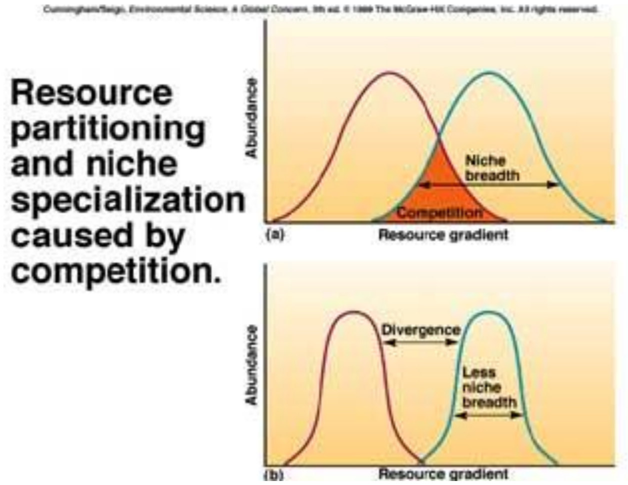
<u>Habitat:</u> place or set of environmental conditions in which a particular organism lives.

<u>Ecological niche:</u> description of either the role played by a species in a biological community or the total set of environmental factors that determine species distribution.

- American limnologist G.E. Hutchinson pointed out that every species has a range of physical and chemical conditions as well as biological interactions within which it can exist.
- Niches can evolve, just as physical characteristics do.

Law of competitive exclusion: no two species will occupy the same niche and compete for exactly the same resources in the same habitat for very long.

- Eventually, one group will gain a larger share of resources while the other will migrate to a new area, become extinct, or change its behavior in a way to minimize competition.
- This process of niche evolution is called resource partitioning.
- Niche specialization can create behavior separation that allows subpopulations of a single species to diverge into separate species.



Species Interactions and Community Dynamics

Predation and competition for scarce resources are major factors in evolution and adaptation.

Organisms can also cooperate with, or at least tolerate, members of their own species as well as individuals of other species in order to survive and reproduce.

Predation

Predator: an organisms that feeds directly upon another living organism, whether or not it kills the prey to do so.

All forms of organisms which feed on living things can be considered predators:

- Carnivores
- Herbivores
- Omnivores
- Parasites
- Pathogens

Exceptions include scavengers, detritivores, and decomposers (which feed on dead things)

Predation is a potent and complex influence on the population balance of communities involving:

- All stages of the life cycles of predator and prey species
- Many specialized food-obtaining mechanisms
- Specific pre-predator adaptations that either resist or encourage predation

Predators play a role in evolution by

- Preying most successfully on the slowest, weakest, least fit members of their target population
- Reducing competition
- Preventing excess population growth
- Allowing successful traits to become dominant in the prey population

Coevolution: process in which species exert selective pressure on each other

Prey species evolve many protective or defensive adaptations to avoid predation.

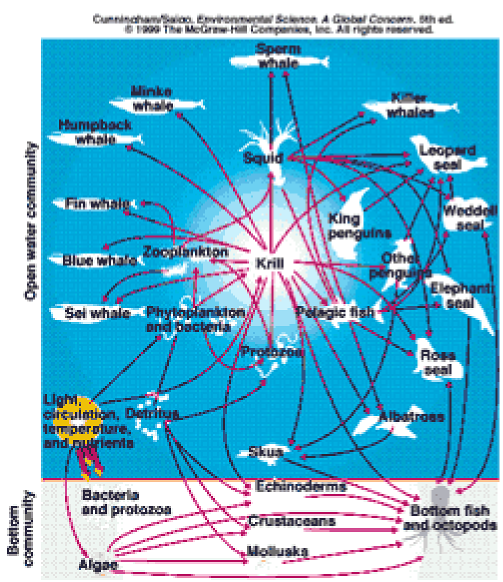
Predators evolve mechanisms to overcome the defenses of their prey.

Keystone Species

Keystone species: species or set of species whose impact on its community or ecosystem is much larger and more influential than would be expected from mere abundance.

Both top predators (e.g. wolves) as well as less conspicuous species (e.g. tropical figs and some microorganisms) play essential community roles.

Often a number of species are intricately interconnected in biological communities so that it is difficult to tell which is the essential key.



The filter-feeding Krill is a keystone species in the complex food web of the Antarctic.

Competition

For what do organisms compete?

- Energy and matter in usable forms.
- Space
- Specific sites for life activities

Intraspecific competition: competition among members of the same species

Interspecific competition: competition among members of different species

- Competition among animals may not be in the form of fighting. In fact, many animals tend to avoid fighting if possible as it is not worth getting injured.
- Intraspecific competition can be especially intense because members of the same species have the same space and nutritional requirements.
- Plants have developed mechanisms to cope with intraspecific competition.
    - Seedlings unable to germinate in the shady conditions created by parent plants.
    - Plants disperse seeds to other sites by water, air, or animals.
    - Plants secrete substances that inhibit the growth of seedlings near them.
- Animals have developed mechanisms to cope with intraspecific competition.
    - Varied life cycles (e.g. different habitats and feeding in juvenile and adult invertebrates)
    - Occupy different ecological niches.
    - Territoriality: intense form of intraspecific competition in which organisms define an area surrounding their home site or nesting site and defend it.
- These mechanisms (plant and animal):
    - Help allocate resources of an area by spacing out the members of a population
    - Promote dispersal into adjacent areas.

Symbiosis

Symbiosis: the intimate living together of members of two or more species.

- In contrast to predation and competition, symbiotic interactions between organisms can be non antagonistic.

Commensalism: type of symbiosis in which one member clearly benefits and the other is neither benefited nor harmed.

- Cattle and cattle egrets
- Many mosses, bromeliads, and other plants growing on trees.

Mutualism: association in which both members of the partnership benefit.

- Lichens (combination of fungi and a photosynthetic partner)

Parasitism: type of symbiosis in which one member benefits and the other is harmed.

Symbiotic relationships often entail some degree of coadaptation or coevolution of the partners, shaping, or at least in part, their structural or behavior characteristics (mutualistic coadaptation).

- Swollen thorn acacias and their symbiotic ants.

Defensive Mechanisms

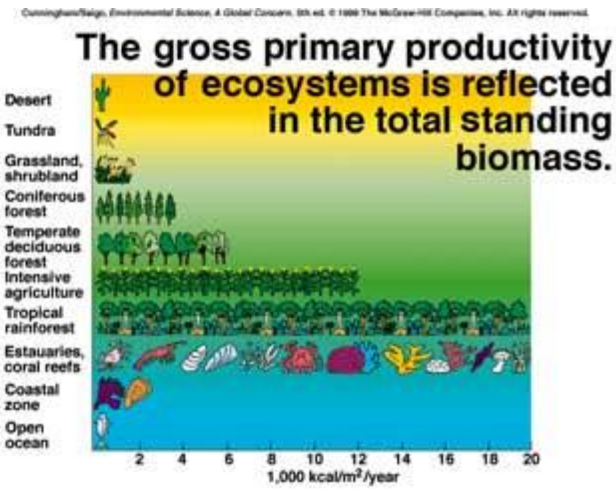
Many plants and animals have toxic chemicals, body armor, and other defensive adaptations to protect themselves from competitors or predators.

- Arthropods, amphibians, snakes, and some mammals produce noxious odors or poisonous secretions
- Plants also produce a variety of chemical compounds that make them unpalatable or dangerous to disturb
  - Poison ivy
  - Stinging nettles

Batesian mimicry: harmless species will evolve colors, patterns, or body shapes that mimic species that are unpalatable or poisonous.

- Wasps and longhorn beetle

Muellerian mimicry: two species, both of which are unpalatable or dangerous have evolved to look alike so that when predators learn to avoid either species, both benefit.



Species also evolve amazing abilities to avoid being discovered.

- Insects that look exactly like dead leaves or twigs

Predators use camouflage to hide as they lay in wait for their prey.

- Scorpion fish

Community Properties

This section focuses on how fundamental properties of biological communities and ecosystems are affected by factors such as tolerance limits, species interactions, resource partitioning, evolution, and adaptation.

Productivity

Primary productivity: rate of biomass production is an indication of the rate of solar energy conversion to chemical energy.

- The energy left after respiration is the net primary production.
- Photosynthetic rates are regulated by many factors.
  - Light levels
  - Temperature
  - Moisture
  - Nutrient availability

Tropical forests, coral reefs, and estuaries have high levels of productivity because they have abundant supplies of all of the above resources.

Other systems do not have sufficient levels of the necessary resources.

- Lack of water in deserts limits photosynthesis.
- Cold temperatures in Arctic tundra or high mountains inhibit plant growth.
- Lack of nutrients in the open ocean reduces the ability of algae to make use of plentiful sunshine and water.

Even in the most photosynthetically active ecosystems, only a small percentage of the available sunlight is captured and used to make energy-rich compounds.

- Much of the light reaching plants is reflected by leaf surfaces
- Most of the light that is absorbed by leaves is converted to heat is either radiated away or dissipated by evaporation and water.

Abundance and Diversity

Abundance: expression of the total number of organisms in a biological community

Diversity: measure of the number of different species, ecological niches, or genetic variation present.

- Abundance of a particular species often is inversely related to total diversity of the community.
- Communities with a very large number of species often have only a few members of any given species in a given area.
- Climate and history are important factors that dictate the abundance and diversity in a biological community.
- Productivity is related to abundance and diversity, both of which are dependent a several factors.
  - Total resource availability in an ecosystem
  - Reliability of resources
  - The adaptations of the member species
  - Interactions between species.

Complexity and Connectedness

Complexity: number of species at each trophic level and the number of trophic levels in a community.

- Diverse community may not be very complex if all species are clustered in only a few trophic levels.
- Diverse community may be complex if it has many interconnected trophic levels that can be compartmentalized into subdivisions.

Resilience and Stability

Three types of stability or resiliency in ecosystems

- Constancy: lack of fluctuations in composition or functions
- Inertia: resistance to perturbations
- Renewal: ability to repair damage after disturbance

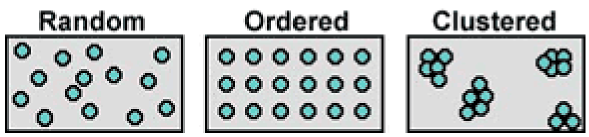
In 1955, Robert McArthur proposed that the more complex and interconnected a community is, the more stable and resilient it will be in the face of disturbance

Minnesota ecologist David Tilman has found that plots of native prairie and recovering farm fields with high diversity were better able to withstand and recover from drought than those with only a few species.

In highly specialized ecosystems, removal of a few keystone species can eliminate many other associated species.

Community Structure

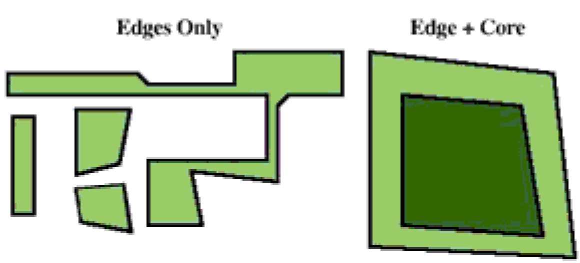
<u>Structure:</u> patterns of spatial distribution of individuals and population within the community and the relation of a particular community to its surroundings.



- Individuals within a population can be distributed randomly, clumped together, or in highly regular patterns.
- Larger communities often contain a mosaic of smaller units or subsets of the whole assemblage.
- Subunits develop because each species has a preference for specific, localized conditions.
- Patchiness: patterns of smaller units or subsets of the whole assemblage.
- Distribution in a community can be vertical as well as horizontal.

Edges and Boundaries

<u>Edge effects:</u> relationship of the boundary between one habitat and its neighbors.



- Edge of a patch of habitat can be relatively sharp and distinct (e.g. woodland patch into grassland)

Ecotones: boundaries between adjacent communities.

Closed community: community that is sharply divided from its neighbors.

Open community: community with gradual or indistinct boundaries over which many species cross.

Many game animals such as white-tailed deer are often most plentiful in boundary zones between different types of habitat.

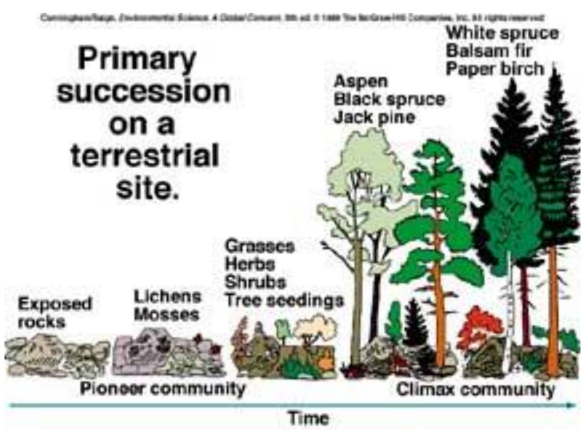
Game managers were once urged to develop as much edge as possible to promote large game populations.

Today, however, most ecologists recognize that edge effects associated with habitat fragmentation are detrimental to biodiversity.

Communities in Transition

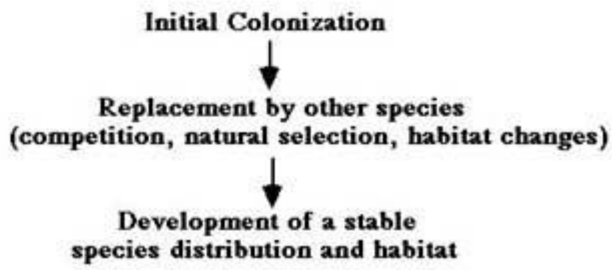
Ecological Succession

Ecological succession: process by which organisms occupy a site and gradually change environmental conditions by creating soil, shelter, and increasing humidity. .



- **Primary succession:** community begins to develop on a site previously unoccupied by living organisms.
- **Secondary succession:** existing community is disrupted and a new one develops.

Both types of succession usually follow an orderly sequence of stages.



Communities of organisms often become more diverse and increasingly competitive as development continues

Climax community: either a primary or secondary community that seemingly resists further change.

- Climax communities may still be changing because rate of succession is slow.

Equilibrium communities: landscapes that never reach a stable climax because they are characterized by and adapted to periodic disruption.

- Fire-climax: communities that are shaped and maintained by periodic fires.

Introduced Species and Community Change

- Succession requires the continual introduction of new community members and the disappearance of existing species.
- Human introductions of Eurasian plants and animals to non-Eurasian communities often have been disastrous to native species.
- Introducing new species in an attempt to solve problems created by previous introductions often make situations worse.

Summary

- Principle of limiting factors states that for every physical factor in the environment, there are both maximum and minimum tolerable limits beyond which a given species cannot survive.
- Best suited organisms will survive and reproduce more successfully than ill suited ones.

  - Eventually genes for successful characteristics predominate in the population and the species becomes adapted to its environment and to a particular role.
  - Result in evolution of species either by gradual replacement of original parental type or splitting of a population into two species.
- Habitat describes the place in which an organism lives
- Niche describes either the role an organism plays or the total set of conditions that control its distribution.
- Organisms interact within communities in many ways including predation, competition, mutualism, and commensalism.
- Some fundamental properties of biological communities are productivity, diversity, complexity, resilience, stability, and structure.
- Ecological succession and development are processes by which organisms alter the environment in ways that allow some species to replace others.
- Introduction of new species by natural processes or through human intervention can upset the natural relationships in a community and cause catastrophic changes of indigenous species.

Questions for Review

1. Explain how tolerance limits to environmental factors determine distribution of a highly specialized species such as the desert pupfish. Compare this to the distribution of a generalist species such as cowbirds or starlings.
2. Productivity, diversity, complexity, resilience, and structure are exhibited to some extent by all communities and ecosystems. Describe how these characteristics apply to the ecosystem in which you live.
3. Describe the general niche occupied by a bird of prey, such as a hawk or an owl. How can hawks and owls exist in the same ecosystem and not adversely affect each other?
4. Define keystone species and explain their importance in community structure and function.
5. All organisms within a biological community interact with each other. The most intense interactions often occur between individuals of the same species. What concept discussed in this chapter can be used to explain this phenomenon?
6. Relationships between predators and prey play an important role in the energy transfers that occur in ecosystems. They also influence the process of natural selection. Explain how predators affect the adaptations of their prey. This relationship also works in reverse. How do prey species affect the adaptations of their predators?
7. Competition for a limited quantity of resources occurs in all ecosystems. This competition can be interspecific or intraspecific. Explain some of the ways an organism might deal with these different types of competition.
8. Each year fires burn large tracts of forestland. Describe the process of succession that occurs after a forest fire destroys an existing biological community. Is the composition of the final successional community likely to be the same as that

which existed before the fire? What factors might alter the final outcome of the successional process? Why may periodic fire be beneficial to a community?

Questions for Critical Thinking

1. Ecologists debate whether biological communities have self-sustaining, self-regulating characteristics or are highly variable, accidental assemblages of individually acting species. What outlook or worldview might lead scientists to favor one or the other of these theories?
2. The concepts of natural selection and evolution are central to how most biologists understand and interpret the world, and yet the theory of evolution is contrary to the beliefs of many religious groups. Why do you think this theory is so important to science and so strongly opposed by others? What evidence would be required to convince opponents of evolution?
3. What is the difference between saying that a duck has webbed feet because it needs them to swim and saying that a duck is able to swim because it has webbed feet?
4. The concept of keystone species is controversial among ecologists because most organisms are highly interdependent. If each of the trophic levels is dependent on all the others, how can we say one is most important? Choose an ecosystem with which you are familiar and decide whether it has a keystone species or keystone set.
5. Some scientists look at the boundary between two biological communities and see a sharp dividing line. Others looking at the same boundary see a gradual transition with much intermixing of species and many interactions between communities. Why such different interpretations of the same landscape?
6. The absence of certain lichens is used as an indicator of air pollution in remote areas such as national parks. How can we be sure that air pollution is really responsible? What evidence would be convincing?
7. We tend to regard generalists or "weedy" species as less interesting and less valuable than rare and highly specialized endemic species. What values or assumptions underlie this attitude?
8. What part of this chapter do you think is most likely to be challenged or modified in the future by new evidence or new interpretations?