16 | COMMUNITY ECOLOGY

Figure 16.1 Invasive cheatgrass (*Bromus tectorum*) on Spruce Mountain, Nevada. Cheatgrass grows at lower temperatures than U.S. native grasses, so it grows and dies earlier. Tilling (mechanical control) and herbicide (chemical control) may be necessary to remove the plant, followed by reseeding with native grasses if there are not enough source grasses nearby (credit: "Famartin"/Wikipedia).

Chapter Outline

Introduction

Populations rarely, if ever, live in isolation from populations of other species. In most cases, numerous species share a habitat. The interactions between these populations play a major role in regulating population growth and abundance. All populations occupying the same habitat form a **community**: multiple populations inhabiting a specific area at the same time and interacting with each other.

Like the Asian carp in Chapter 15, cheatgrass (*Bromus tectorum*, Figure 16.1) was introduced by human activity: it was carried from Europe and Asia into the United States in packaging, contaminated seeds for crops, and at least once by a research experiment. Over the last 150 years, cheatgrass has spread across the U.S., dominating ecosystems where human activity such as fire, overgrazing, or railroad development has altered the ecosystem and eliminated native grasses and shrubs. Cheatgrass can begin growing at cooler temperatures than most other grasses, and grows rapidly. In the spring, cheatgrass is able to deplete the surrounding soil of moisture before native plants become active. These adaptations help cheatgrass outcompete native grasses as it grows before them and removes vital moisture.

Community ecologists look at the effects of cheatgrass and other invasive species on their native competitors, as well as the effects of this change on the herbivores and mutualists that depend on grasses, and on the overall diversity of the community. One way to compare communities is to quantify the organisms living in them. The number of species occupying the same habitat and their relative abundance is known as species diversity. Although tropical rainforests contain nearly unquantifiable diversity, areas with low diversity, such as the glaciers of Antarctica, still contain a wide variety of living things. A community ecologist might also look at how disturbances made the community vulnerable to invasion, how the community may change after invasive species become established, consider how to protect other systems, and what kind of control measures may be used to remove the invader.

16.1| Types of Interactions

By the end of this section, you will be able to do the following:

- Discuss the predator-prey cycle
- Give examples of defenses against predation and herbivory
- Describe the competitive exclusion principle and likely outcomes of competition
- Classify symbiotic relationships between species
- Hypothesize how species interactions may lead to coevolution

Ecology is studied at the community level to understand how species interact with each other and compete for the same resources. There are several categories (and subcategories) of interspecies interaction: predation (including herbivory), interspecific competition, and symbiosis (commensalism, mutualism, and parasitism). Each of these interactions has the potential to result in coevolution**.**

Predation (including Herbivory)

Consuming a living individual of another species for organic carbon, energy, or other nutrients is **predation.** If the organism consumed is a plant, that is further classified as **herbivory**.

Populations of predators and prey in a community are not constant over time: in most cases, they vary in cycles that appear to be related. The most often cited example of predator-prey dynamics is seen in the cycling of the lynx (predator) and the snowshoe hare (prey), using nearly 200 year-old trapping data from North American forests (**Figure 16.2**). As the hare numbers increase, there is more food available for the lynx, allowing the lynx population to increase as well. When the lynx population grows to a threshold level, however, they kill so many hares that hare population begins to decline, followed by a decline in the lynx population because of scarcity of food. When the lynx population is low, the hare population size begins to increase due, at least in part, to low predation pressure, starting the cycle anew. This cycle of predator and prey lasts approximately 10 years, with the predator population lagging 1–2 years behind that of the prey population.

Some researchers question the idea that predation models entirely explain the population cycling of the two species. More recent studies have pointed to undefined density-dependent factors as being important in the cycling, in addition to predation, or that more species are involved in the cycle, including the potential influence of food (plant populations) for the hare. One possibility is that the cycling is inherent in the hare population due to density-dependent effects such as lower fecundity (maternal stress) caused by crowding when the hare population gets too dense. The hare cycling would then induce the cycling of the lynx because it is the lynxes' major food source. The more we study communities, the more complexities we find, allowing ecologists to derive more accurate and sophisticated models of population dynamics.

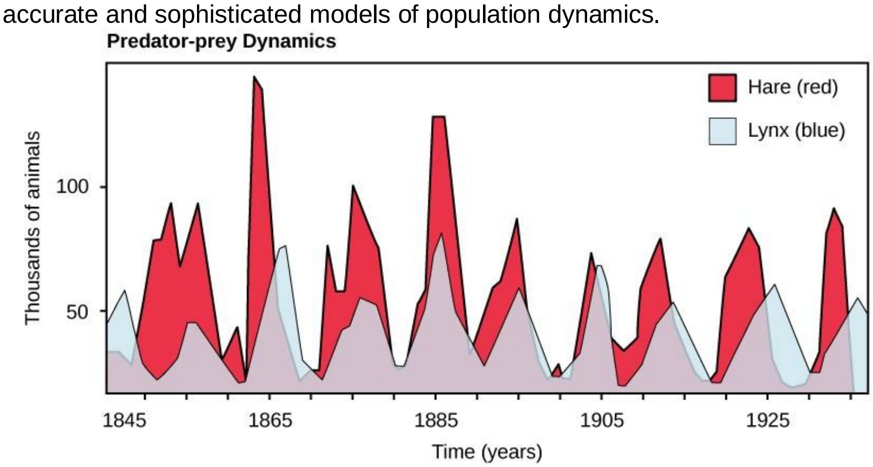


Figure 16.2 The cycling of lynx and snowshoe hare populations in Northern Ontario is an example of predator-prey dynamics.

Defense Mechanisms against Predation and Herbivory

The study of communities must consider evolutionary forces that act on the members of the various populations contained within it. Species are not static, but slowly changing and adapting to their environment by natural selection and other evolutionary forces. Species have evolved numerous mechanisms to escape predation and herbivory. These defenses may be mechanical, chemical, or behavioral.

Behavioral defenses include actions that prevent predation: prey species can distract, fool, or warn the predator to avoid consumption. Many species of birds will attack a larger predatory bird as a group to run it off (mobbing). Several different species, including opossums, will play dead, while other species will pretend to be injured to distract a predator away from their nest and young. Some species of skunks will do handstands as a warning before spraying. Flight, nocturnal behavior, and burrowing are also behavioral defenses. Plants may also close leaves or emit signals to each other in response to a predator.

Mechanical defenses are physical traits of the prey organisms, such as the presence of thorns on plants or the hard shell on turtles or the bright coloring of poisonous organisms (and their mimics), that discourage animal predation and herbivory by causing pain to the predator ,physically preventing the predator from being able to eat the prey, or warning the predator away. **Chemical defenses** are produced by many animals as well as plants, such as the foxglove, which is extremely toxic when eaten, or the odiferous spray of a skunk. **Figure 16.3** shows some organisms' defenses against predation and herbivory.

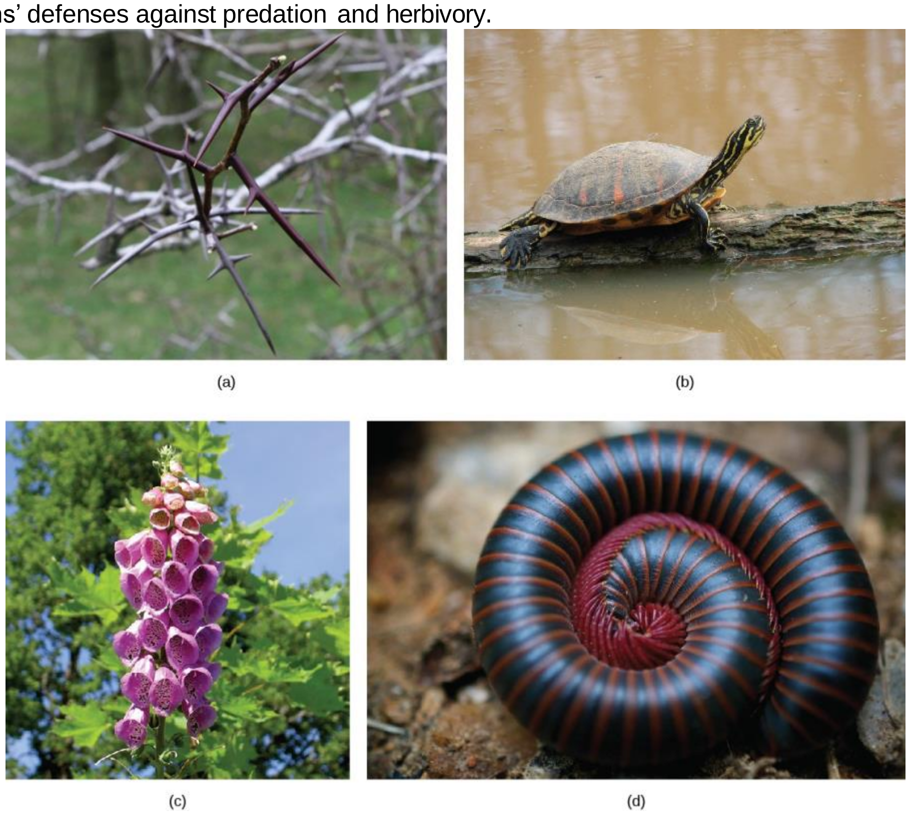


Figure 16.3 The (a) honey locust tree (*Gleditsia triacanthos*) uses thorns against herbivores, while the (b) Florida red-bellied turtle (*Pseudemys nelsoni)* uses its shell against predators; both are mechanical defenses. (c) Foxglove (*Digitalis* sp.) uses a chemical defense: toxins produced by the plant can cause nausea, vomiting, hallucinations, convulsions, or death when consumed. (d) The North American millipede (*Narceus americanus*) uses both mechanical and chemical defenses: when threatened, the millipede curls into a defensive ball and produces a noxious substance that irritates eyes and skin. (credit a: modification of work by Huw Williams; credit b: modification of work by "JamieS93"/Flickr; credit c: modification of work by Philip Jägenstedt; credit d: modification of work by Cory Zanker)

Many species use their body shape and coloration as mechanical defenses to avoid being detected by predators. The tropical walking stick is an insect with the coloration and body shape of a twig, which makes it very hard to see when stationary against a background of real twigs (**Figure 16.4a**). In another example, the chameleon can change its color to match its surroundings (**Figure 16.4b**). Both of these are examples of **camouflage**, or avoiding detection by blending in with the background.

(a) (b)

Figure 16.4 (a) The tropical walking stick and (b) the chameleon use body shape and/or coloration (mechanical defense) to prevent detection by predators. (credit a: modification of work by Linda Tanner; credit b: modification of work by Frank Vassen)

Some species **aposematic coloration**, or warning coloration (**Figure 16.5**) as a way of warning predators that they are not good to eat. For example, the cinnabar moth caterpillar, the fire-bellied toad, and many species of beetle have bright colors that warn of a foul taste, the presence of toxic chemicals, and/or the ability to sting or bite, respectively. Predators that ignore this coloration and eat the organisms will experience their unpleasant taste or presence of toxic chemicals and learn not to eat them in the future.

(a) (b)

Figure 16.5 (a) The strawberry poison dart frog (*Oophaga pumilio*) uses aposematic coloration (mechanical defense) to warn predators that it is toxic, while the (b) striped skunk (*Mephitis mephitis*) uses aposematic coloration to warn predators of the unpleasant odor it produces. (credit a: modification of work by Jay Iwasaki; credit b: modification of work by Dan Dzurisin)

In **Müllerian mimicry**, multiple species share the same warning coloration, but all of them actually have defenses. **Figure 16.6** shows a variety of foul-tasting butterflies with similar coloration.

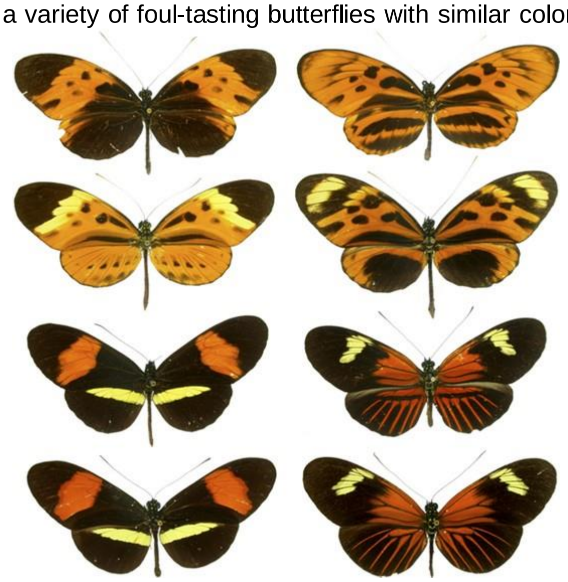
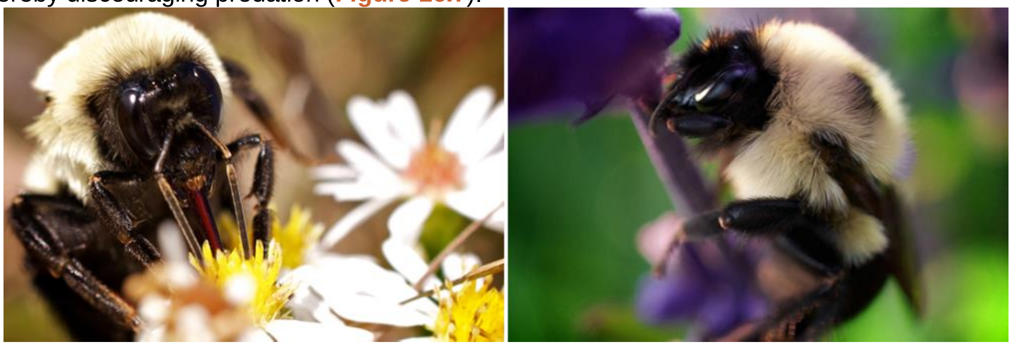


Figure 16.6 Several unpleasant-tasting *Heliconius* butterfly species share a similar color pattern with better-tasting varieties, an example of Müllerian mimicry. (credit: Joron M, Papa R, Beltrán M, Chamberlain N, Mavárez J, et al.)

While some predators learn to avoid eating certain potential prey because of their coloration, other species have evolved mechanisms to mimic this coloration to avoid being eaten, even though they themselves may not be unpleasant to eat or contain toxic chemicals. In **Batesian mimicry**, a harmless species imitates the warning coloration of a harmful one. Assuming they share the same predators, this coloration then protects the harmless ones, even though they do not have the same level of physical or chemical defenses against predation as the species they mimic. Many insect species mimic the coloration of wasps or bees, which are stinging, venomous insects, thereby discouraging predation (**Figure 16.7**).



(a) (b)

Figure 16.7 Batesian mimicry occurs when a harmless species mimics the coloration of a harmful species, as is seen with the (a) bumblebee and (b) bee-like robber fly. (credit a, b: modification of work by Cory Zanker)

LINK TO LEARNING

Go to this **website (http://openstaxcollege.org/l/find_the_mimic)** to view stunning examples of mimicry.

The examples in this section have focused on prey adaptations and defenses. But, for each of these, successful predators evolve a matching defense.

First, think about convergent evolution- what traits do many predators share, regardless of lineage?

Second, go through the section above and hypothesize – given the prey defenses listed, what adaptations would be present that allows their predators to succeed despite those defenses?

Competition

Resources (food, water, shelter, etc.) are often limited within a habitat and organisms may compete to obtain them. If individuals of the same species compete, it is **intraspecific competition** and the realm of population ecology. Community ecology is concerned with competition between species, or **interspecific competition**.

All species have an ecological **niche** in the ecosystem, which describes their role in the community: how they acquire the resources they need and how they interact with other species in the community. This is different from, but easily confused with, their **habitat**: the type of environment they are adapted to live in. Habitat focuses on what the organism needs, niche includes what it does for and to other organisms and the ecosystem, or its **ecological role**. The **fundamental niche** of a species is the set of all resources and interactions that determines the abundance and distribution of the species.

Species may compete with other species for some, but not all, the resources it needs to survive and reproduce which may impact how much of a niche the species can occupy. The **competitive exclusion principle** states that two species cannot occupy the same exact niche in a habitat. In other words, different species cannot coexist in a community if they are competing for all the same resources: one species is always going to be at least a little bit better at using a given resource than its competitors. An example of this principle is shown in **Figure 16.8**, with two protist species, *Paramecium aurelia* and *Paramecium caudatum*. When grown individually in the laboratory, they both thrive. But when they are placed together in the same test tube (habitat), *P. aurelia* outcompetes *P. caudatum* for food, leading to the latter's eventual extinction.

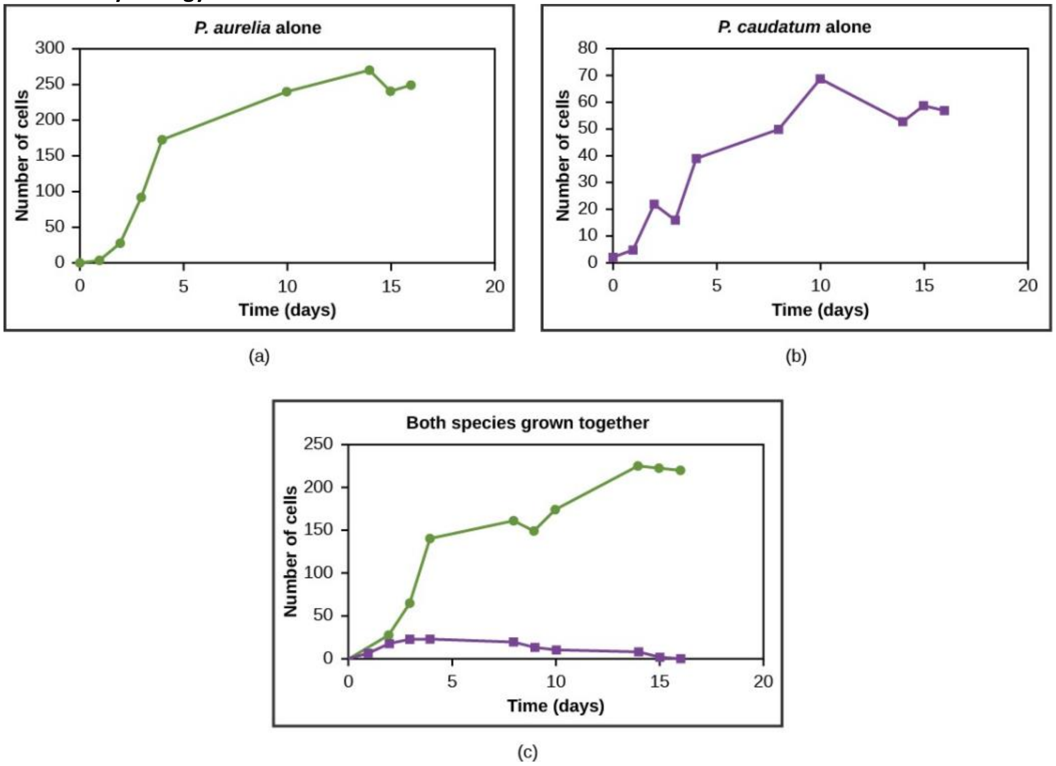


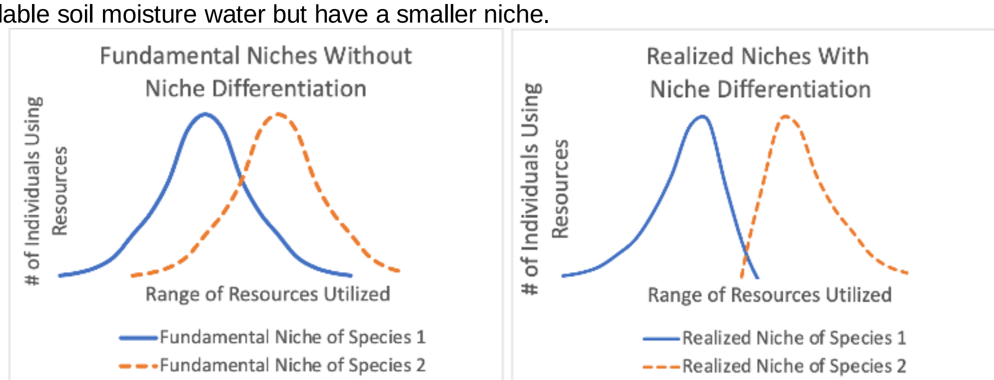
Figure 16.8 *Paramecium aurelia* and *Paramecium caudatum* grow well individually, but when they compete for the same resources, the *P. aurelia* outcompetes the *P. caudatum*.

There are generally two possible outcomes when two populations attempt to share a niche:

- one population may not survive (as in the example above),
- or each population may have to utilize a subset of the available resources.

In the second case, each populations have a smaller **realized niche** (the niche they actually occupy) that is smaller than the full fundamental niche that they would have if no other species negatively affected them. Competition is not the only factor that can keep a population from occupying their entire fundamental niche: other interactions, such as predation, may also result in a smaller realized niche.

If the two populations develop smaller realized niches by dividing the resources, this is **niche differentiation** (or niche partitioning) **Figure 16.9**. Recognize, however, that the two species are not "splitting" the niche – this is not a negotiation, but competition, and whichever species is more successful gets the resource. For example, the cheatgrass at the start of the chapter uses its early growth to remove water from the soil, effectively outcompeting other plants. Some other plants will not be able to obtain enough moisture to survive, and others may tolerate lower available soil moisture water but have a smaller niche.



(a) (b)

Figure 16.9 Fundamental versus realized niches in competition. When two species' niches overlap and they compete for resources, one potential outcome is for the niche of each species to shrink. Although this theoretical modeling implies that the species would split the resources evenly, in actuality one species will generally outcompete the other for a given resource, and either of the two species may keep more of its fundamental niche (credit: Laura Baumgartner)

If niche differentiation results in evolutionary adaptations that allow one or both organisms to use different resources (often via selection), this is **character displacement.** The many phenotypically different beak shapes of the Galapagos finches is one example of niche differentiation leading to character displacement: finches whose food requirements did not overlap were more fit, favoring different beak shapes in the population and eventual speciation.

Which category of selection is likely in character displacement, and why?

Symbiosis

Symbiotic relationships, or **symbioses**, are generally defined as close interactions between individuals of different species over an extended period of time which impact the abundance and distribution of the associating populations. Because these interactions are closer and often more specific than the other discussed above, they have a high potential for coevolution.

Commensalism

A **commensal** relationship occurs when one species benefits from the close, prolonged interaction, while the other neither benefits nor is harmed. Birds nesting in trees provide an example of a commensal relationship (**Figure 16.10**). The tree is not harmed by the presence of the nest among its branches. The nests are light and produce little strain on the structural integrity of the branch, and most of the leaves, which the tree uses to get energy by photosynthesis, are above the nest so they are unaffected. The bird, on the other hand, benefits greatly. If the bird had to nest in the open, its eggs and young would be vulnerable to predators.

Figure 16.10 The southern masked-weaver bird is starting to make a nest in a tree in Zambezi Valley, Zambia. This is an example of a commensal relationship, in which one species (the bird) benefits, while the other (the tree) neither benefits nor is harmed. (credit: "Hanay"/Wikimedia Commons)

Many relationships that are commonly described as commensal are, in fact, not when they are studied more thoroughly. The bacteria of the healthy human body are referred to as "commensal bacteria" when we now know they provide benefits for their host as well. A common example of commensalism is birds sitting on larger animals, such as the oxpeckers of Africa and Cape buffalos (bison). The oxpecker eats insects on the bison, and gets protection from predators, but what about the bison? In reality, the bison gets potential parasite removal, and the oxpeckers also hiss when they sense potential danger, which may protect the bison as well. However, red-billed oxpeckers appear to wait until ticks have fed, enjoying not just the tick but also the blood of their host.

As you continue to read, consider: if the relationships in the paragraph above are not commensalism, how could you classify them instead?

Mutualism

A second type of symbiotic relationship is called **mutualism**, where two species benefit from their interaction. For example, termites have a mutualistic relationship with protists that live in the insect's gut (**Figure 16.11a**). The termite benefits from the ability of bacterial symbionts within the protists to digest cellulose. The termite itself cannot do this, and without the protists, it would not be able to obtain energy from its food (cellulose from the wood it chews and eats). The protists and the bacterial symbionts benefit by having a protective environment and a constant supply of food from the wood chewing actions of the termite. Some evolutionary studies hypothesize that the ancestral protists were pathogens to an ancestor of the termites, but loss of a second life stage and increasing dependence by the host resulted in coevolution toward mutualism.

Lichens have a mutualistic relationship between fungus and photosynthetic algae or bacteria (**Figure 16.11b**). As these symbionts grow together, the glucose produced by the algae provides nourishment for both organisms, whereas the physical structure of the lichen protects the algae from the elements and makes certain nutrients in the atmosphere more available to the algae. Recent research on lichens has uncovered a third party to this symbiosis, a yeast, whose role is not yet understood but appears to be key to lichen development.

(a) (b)

Figure 16.11 (a) Termites form a mutualistic relationship with symbiotic protists in their guts, which allow both organisms to obtain energy from the cellulose the termite consumes. (b) Lichen is a fungus that has symbiotic photosynthetic algae living inside its cells. (credit a: modification of work by Scott Bauer, USDA; credit b: modification of work by Cory Zanker)

Parasitism

A **parasite** is an organism that lives in or on another living organism and derives nutrients from it. In this relationship, the parasite benefits, but the **host** is harmed. The host is usually weakened by the parasite as it siphons resources the host would normally use to maintain itself. The parasite, however, is unlikely to kill the host, especially not quickly, because this would allow no time for the organism to complete its life cycle by spreading to another host.

The life cycles of parasites are often very complex, sometimes requiring more than one host species. A tapeworm is a parasite that causes disease in humans when contaminated, undercooked meat is consumed (**Figure 16.12**). The tapeworm can live inside the intestine of the host for several years, benefiting from the food the host is eating, and may grow to be over 50 ft long by adding segments. The parasite moves from species to species in a cycle, making two hosts necessary to complete its life cycle.

Another common parasite is *Plasmodium falciparum*, the protist cause of malaria, a significant disease in many parts of the world. Living in human liver and red blood cells, the organism reproduces asexually in the gut of blood-feeding mosquitoes to complete its life cycle. Thus, malaria is spread from human to human by mosquitoes, one of many arthropod-borne infectious diseases.

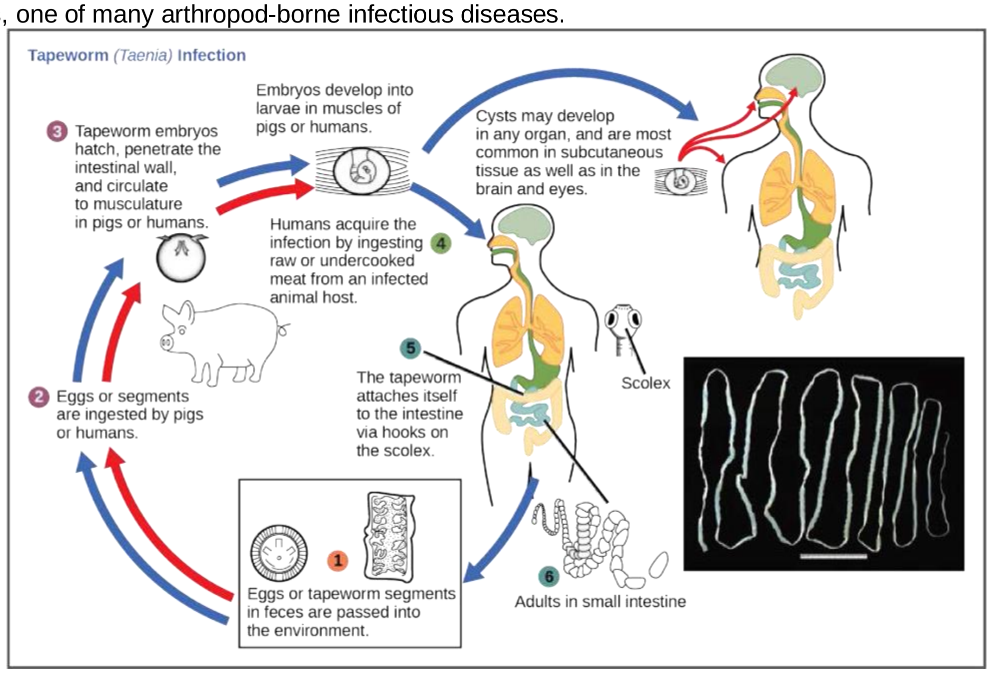


Figure 16.12 This diagram shows the life cycle of a pork tapeworm (*Taenia solium*), a human worm parasite. (credit: modification of work by CDC)

everyday CONNECTION

Invasive Species

Invasive species are nonnative organisms that, when introduced to an area out of their native range, threaten the ecosystem balance of that habitat. Many such species exist in the United States, as shown in Figure 16.13. Whether enjoying a forest hike, taking a summer boat trip, or simply walking down an urban street, you have likely encountered an invasive species.

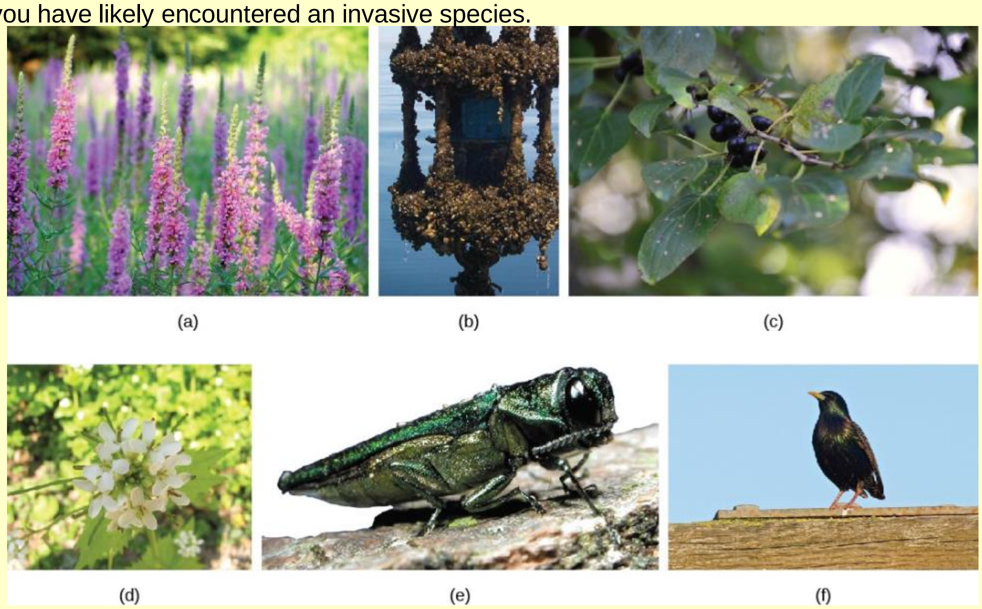


Figure 16.13 In the United States, invasive species like (a) purple loosestrife (*Lythrum salicaria*) and the (b) zebra mussel (*Dreissena polymorpha*) threaten certain aquatic ecosystems. Some forests are threatened by the spread of (c) common buckthorn (*Rhamnus cathartica*), (d) garlic mustard (*Alliaria petiolata*), and (e) the emerald ash borer (*Agrilus planipennis*). The (f) European starling (*Sturnus vulgaris*) may compete with native bird species for nest holes. (credit a: modification of work by Liz West; credit b: modification of work by M. McCormick, NOAA; credit c: modification of work by E. Dronkert; credit d: modification of work by Dan Davison; credit e: modification of work by USDA; credit f: modification of work by Don DeBold)

One of the many recent proliferations of an invasive species concerns the growth of Asian carp populations, also discussed in Ch 15. Asian carp were introduced to the United States in the 1970s by fisheries and sewage treatment facilities that used the fish's excellent filter feeding capabilities to clean their ponds of excess plankton. Some of the fish escaped, however, and by the 1980s they had colonized many waterways of the Mississippi River basin, including the Illinois and Missouri Rivers.

Voracious eaters and rapid reproducers, Asian carp outcompete native species for food, potentially leading to their extinction. For example, black carp are voracious eaters of native mussels and snails, limiting this food source for native fish species. Silver carp eat plankton that native mussels and snails feed on, reducing this food source by a different alteration of the food web. In some areas of the Mississippi River, Asian carp species have become the most predominant, effectively outcompeting native fishes for habitat. In some parts of the Illinois River, Asian carp constitute 95 percent of the community's biomass. Although edible, the fish is bony and not a desired food in the United States.

The Great Lakes and their prized salmon and lake trout fisheries are also being threatened by these invasive fish. Asian carp have already colonized rivers and canals that lead into Lake Michigan. Electric barriers have been successfully used to prevent the Asian carp from leaving the Chicago Sanitary and Ship Channel linking the Great Lakes to the Mississippi River. However, the threat is significant enough that several states and Canada have sued to have the Chicago channel permanently cut off from Lake Michigan. Other areas have poisoned or electroshocked the carp to remove them. No one knows whether the Asian carp will ultimately be considered a nuisance, like other invasive species such as the water hyacinth and zebra mussel, or whether it will be the destroyer of the largest freshwater fishery of the world.

Invasive species control measures can be biological (releasing a predator to remove the organisms), mechanical (physical removing the organisms or changing the habitat), or chemical (toxins) mechanisms. Identify examples of each type of mechanism above.

How is each level of ecology involved in studying the problem of the Asian carp?

16.2| Characteristics of Communities

By the end of this section, you will be able to do the following:

- Differentiate measures of diversity
- Describe some patterns of diversity
- Describe community structure and succession

Communities are complex entities that can be characterized by their structure (the types and numbers of species present) and dynamics (how communities change over time). Understanding community structure and dynamics enables community ecologists to manage ecosystems more effectively.

Biodiversity, Species Richness, and Relative Species Abundance

Biodiversity describes a community's biological complexity: it is measured by the number of different species (species richness) in a particular area and their relative abundance (species evenness). The area in question could be a habitat, a biome, or the entire biosphere. There are several ways to measure biodiversity, but the two most common measures are richness and relative abundance (Figure 16.14):

- **Species richness** is the number of species living in a habitat or biome.
- **Relative species abundance (species evenness)** is the number of individuals in a species relative to the total number of individuals in all species within a habitat, ecosystem, or biome.

Both measures of diversity are important: an area with four species, all with equal abundance, will be functionally different from one in which there are five members of one species and only one or two members of each of the other three species.

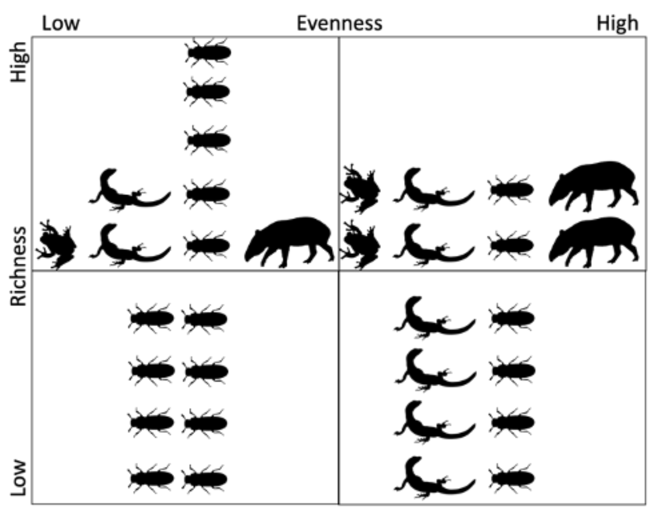


Figure 16.14 Species richness reflects how many species are represented. Species evenness (relative abundance) reflects how well each species is represented. Note that this graphic is a simplification, any functional community would be more complex. (credit: Laura Baumgartner)

Species richness varies across the globe (Figure 16.15). One factor in determining species richness is latitude, with the greatest species richness occurring in ecosystems near the equator, which often have higher productivity due to warmer temperatures, large amounts of rainfall, and low seasonality. These tropical ecosystems have also been relatively stable for long periods of geologic time. The lowest species richness occurs near the poles, which are much colder, drier, and thus less conducive to life in geologic time (time since glaciations). The predictability of climate or productivity is also an important factor.

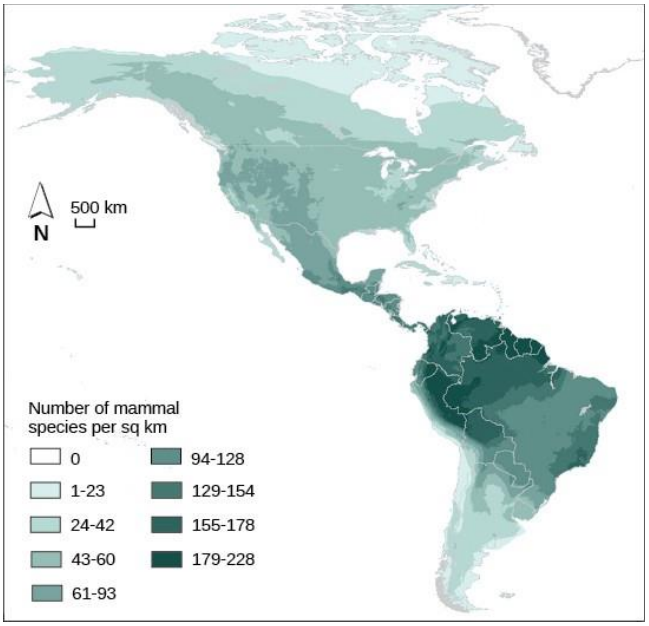


Figure 16.15 The greatest species richness for mammals in North and South America is associated with the equatorial latitudes. (credit: modification of work by NASA, CIESIN, Columbia University)

Other factors influence species richness as well. For example, the study of **island biogeography** attempts to explain the relatively high species richness found in certain isolated island chains, including the Galápagos Islands that inspired the young Darwin. Island biogeography argues that diversity is a function of the size of an island and its distance to the mainland, as well as a balance between colonization and extinction rates. Higher species richness is predicted on:

- larger islands, which have more land, and thus are likely to have more variation, and thus more niches.
- and islands closer to the mainland, which would have more immigration.

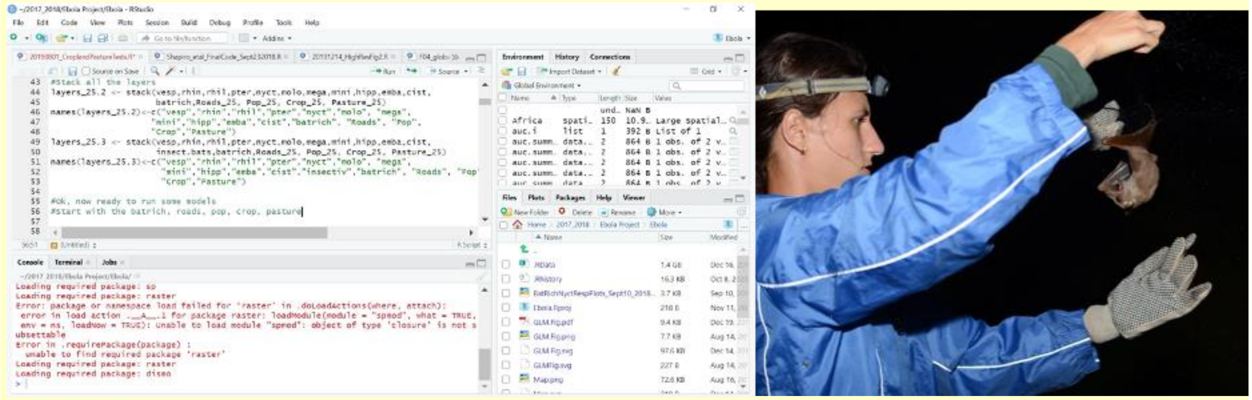
Smaller islands may not have sufficient resources to support populations, so extinction rates may be higher compared to larger islands even if colonization rates are similar.

The concepts of island biogeography can also be applied to fragmented landscapes. Human activity can lead to small, isolated patches of suitable habitat which can act as small islands in terms of species diversity. Large habitat patches are likely to have more available niches and therefore may support greater diversity. Connecting smaller patches with land bridges and corridors can increase colonization, maintain gene flow and effectively enlarge the habitat to support greater diversity. Conservation ecologists use principles of island biogeography to develop land management plans to protect as many species and possible and support sustainable communities.

career CONNECTION

Modeling

In their simplest forms, models are representations of how a system might work; they can be conceptual (like a flow diagram) or mathematical. Mathematical models are used in every branch of science, as well as in economics and social sciences. Modeling is the science of using data to make predictions or look for statistical correlations. Modelers often use data from other researchers, although they may also collect their own. Beyond their scientific background, modelers need skills in computer programming (**Figure 16.16**), and sometimes mathematical skills as well.



(a) (b)

Figure 16.16: Code in R Studio for the research discussed below (Shapiro et al. 2020). (b) Dr. Shapiro taking a Wahlberg's epauletted fruit bat (*Epomophorus wahlbergi*) out of a mist net in Eswatini. (credit a: Julie Teresa Shapiro; credit b: Brian Smith, ecosmith.org)

Dr. Julie Teresa Shapiro (**Figure 16.16**) is an ecological modeler who is interested in disease, wildlife, and human impacts on ecosystems. She has examined how human-caused changes affect disease and wildlife, using a combination of field studies, molecular analysis, and modeling. She has published research describing new species, assessing the conservation status of various animals, examining the effects of human activities on animals, and modeling antibiotic resistance in hospitals. She has studied the, effects of grazing animals on populations of small mammals, distances of travel for bat calls, habitat requirements of small mammals, and effects of seasons and land cover on bat activity and biodiversity.

Her ecological modeling includes a study that looked at whether the diversity of bats, which may be hosts for Ebola viruses, and increasing human activity affects the likelihood of humans contracting Ebola virus (https://doi.org/10.1007/s10344-019-1346-7). Dr. Shapiro and her colleagues used information from other studies to gather data on 22 human Ebola outbreaks in sub-Saharan Africa, along with data on bat species richness (all bats, and subgroups) and human population density and disturbance (roads, crop land, pastures). With these data, they then compared sites where Ebola virus outbreaks have occurred to 10,000 other random sites using two types of models. They found that Ebola outbreaks were best predicted by the species richness of nycterid bats, with outbreaks occurring where more nycterid species may be present. Nycterids have not been heavily researched as potential hosts of Ebola viruses. In addition, they found the Ebola outbreaks actually occurred in areas with low levels of human population density or activity, which is not what most scientists would predict.

Beyond her research, Dr. Shapiro is also passionate about science communication and presents to groups of all ages about bats, wildlife, and research. She also loves cats, caving, and is involved in political activism through Democrats Abroad. For a long time, she wasn't sure if science was right for her (especially because math was her weakness!) and actually majored in Latin American Studies with a minor in Biology as an undergraduate. Learning foreign languages and better understanding culture, history, and politics helped her become a better scientist. You can learn more about Dr. Shapiro at https://www.jtshapiro.com/.

What are the levels of ecology? Dr. Shapiro has conducted research at every level – identify examples of each level in the research above.

The researchers had data on species richness, but not species abundance, First, why might this be? Second, how might relative abundance or evenness information change our understanding of these data?

Community Dynamics

Community dynamics are the changes in community structure and composition over time. Sometimes these changes are induced by **environmental disturbances,** (generally) short-term changes in conditions that can cause long-term changes to the ecosystem, such as volcanoes, earthquakes, storms, fires, and climate change. Communities with a stable structure are said to be at equilibrium. Following a disturbance, the community may or may not return to the equilibrium state. Many communities have a **disturbance regime**, a normal cycle of disturbance, such as fire in the grasslands biome.

What other types of disturbances are common, and in what biomes?

Succession describes the sequential appearance and disappearance of species in a community over time, particularly after a disturbance.

- In **primary succession**, newly exposed or newly formed land (ex: lava flows or glacially-scraped rock) is colonized by living things- there is no useful organic matter available in the soil to support life and the only species that can survive can fix their own carbon, nitrogen, and make anything other nutrients they need.
- In **secondary succession**, part of an ecosystem is disturbed and remnants of the previous community remain, particularly in the form of viable soil nutrients.

In both cases, the first species to appear are generally **pioneer species** (**Figure 16.17**), fast-growing, highly reproductive organisms that can survive in the poor conditions. These pioneer species where other, less hardy species will grow and eventually replace the pioneer species. In addition, as these early species grow and die, they add to an ever-growing layer of decomposing organic material and contribute to soil formation (particularly important in primary succession). Other organisms will outcompete and replace these pioneers as the conditions improve.

Figure 16.17 During primary succession in lava on Maui, Hawaii, succulent plants are the pioneer species. (credit: Forest and Kim Starr)

Connect: what life history strategies would pioneer species have and why? Given that, are they likely to be equilibrium or opportunistic species?
Connect: Why are nitrogen fixing cyanobacteria often the first pioneer species in primary succession?

Equilibrium is the steady state of an ecosystem where all organisms are in balance with their environment and with each other. In ecology, two parameters are used to measure changes in ecosystems: resistance and resilience.

- **Resistance** is the ability of an ecosystem to remain at equilibrium in spite of disturbances.
- **Resilience** is the speed at which an ecosystem recovers equilibrium after being disturbed.

Some communities resist change and remain stable for long periods of time. For instance, plants in tropical rainforests have adaptations to compete in a community of mature plants in an environment that does not vary widely, such as seeds that germinate and grow well in the shaded understory. A fire would be devastating to this forest community and it may or may not recover from the disturbance.

However, plants in tropical grasslands have adaptations to survive frequent fires, such as extensive underground root systems or seeds that germinate rapidly in full sun. Fires in this resilient community are not devastating since the community can return to its equilibrium state relatively quickly following the disturbance.

Ecosystem resistance and resilience are especially important when considering human impact. The nature of an ecosystem may change to such a degree that it can lose its resilience entirely. This process can lead to the complete destruction or irreversible altering of the ecosystem.

KEY TERMS

aggressive display visual display by a species member to discourage other members of the same species or different species

aposematic coloration warning coloration used as a defensive mechanism against predation

Batesian mimicry type of mimicry where a non-harmful species takes on the warning colorations of a harmful one

behavior change in an organism's activities in response to a stimulus

camouflage avoid detection by blending in with the background

climax community final stage of succession, where a stable community is formed by a characteristic assortment of plant and animal species

commensalism relationship between species wherein one species benefits from the close, prolonged interaction, while the other species neither benefits nor is harmed

competitive exclusion principle no two species within a habitat can coexist when they compete for the same resources at the same place and time

distraction display visual display used to distract predators away from a nesting site

Emsleyan/Mertensian mimicry type of mimicry where a harmful species resembles a less harmful one

environmental disturbance change in the environment caused by natural disasters or human activities

host organism a parasite lives on

interspecific competition competition between species for resources in a shared habitat or environment

intraspecific competition competition between members of the same species

island biogeography study of life on island chains and how their geography interacts with the diversity of species found there

keystone species species whose presence is key to maintaining biodiversity in an ecosystem and to upholding an ecological community's structure

migration long-range seasonal movement of animal species

mutualism symbiotic relationship between two species where both species benefit

Müllerian mimicry type of mimicry where species share warning coloration and all are harmful to predators

parasite organism that uses resources from another species, the host

pioneer species first species to appear in primary and secondary succession

primary succession succession on land that previously has had no life

relative species abundance absolute population size of a particular species relative to the population sizes of other species within the community

secondary succession succession in response to environmental disturbances that move a community away from its equilibrium

species richness number of different species in a community

symbiosis close interaction between individuals of different species over an extended period of time that impacts the abundance and distribution of the associating populations

CHAPTER SUMMARY

16.1 Types of Interactions

Communities are groups of interacting populations living in the same area- these interactions include predation (including herbivory), interspecific competition, and symbiosis (commensalism, mutualism, and parasitism). Many organisms have developed defenses against predation and herbivory, including mechanical defenses, warning coloration, and mimicry, as a result of evolution and the interaction with other members of the community. Two species cannot exist in the same habitat competing directly for the same resource. Species may form symbiotic relationships such as parasitism or mutualism.

16.2 Characteristics of Communities

The variety of species in a community is called species richness, while the representation of each species can be quantified as relative species abundance. Island biogeography hypothesizes that larger islands closer to mainland have higher diversity. Disturbances cause changes in ecosystem, and may result in succession. The ability of an ecosystem to maintain equilibrium is resistance, and to recover from disturbance is resilience.

REVIEW QUESTIONS

1. The first species to live on new land, such as that formed from volcanic lava, are called ______.
  a. climax community
  b. keystone species
  c. foundation species
  d. pioneer species

2. Which type of mimicry involves multiple species with similar warning coloration that are all toxic to predators?
  a. Batesian mimicry
  b. Müllerian mimicry
  c. Emsleyan/Mertensian mimicry
  d. Mertensian mimicry

3. A symbiotic relationship where both of the coexisting species benefit from the interaction is called
  a. commensalism
  b. parasitism
  c. mutualism
  d. communism

4. Which of the following is **not** a mutualistic relationship?
  a. a shark using an aquatic cleaning station
  b. a helminth feeding from its host
  c. a bumblebee collecting pollen from a flower
  d. bacteria living in the gut of humans

CRITICAL THINKING QUESTIONS

5. Describe the competitive exclusion principle and its effects on competing species.