Chapter 9: Ecology
Lesson 9.3: Relationships and Interactions in an Ecosystem

Why are pyramids important in ecology? The classic example of a pyramid is shown here. But the pyramid structure can also represent the decrease in a measured substance from the lowest level on up. In ecology, pyramids model the use of energy from the producers through the ecosystem.

What is the source of energy for almost all ecosystems? The Sun supports most of Earth's ecosystems. Plants create chemical energy from abiotic factors that include solar energy. Chemosynthesizing bacteria create usable chemical energy from unusable chemical energy. The food energy created by producers is passed to consumers, scavengers, and decomposers, thus it passes through the food chain.

What does it mean to be interdependent? Organisms are not independent, they are interdependent. Species cannot live alone. All life needs other life to survive, many live in communities with other organisms. All species rely on other species in some way for their survival. They may rely on other species for food, shelter or to help them reproduce. Species are not independent, they are interdependent.

Lesson Objectives

- Describe how energy flows through ecosystems.
- Explain how food chains and webs model feeding relationships.
- Identify trophic levels in a food chain or web.
- Define community as the term is used in ecology.
- Describe interdependent relationship like predation and competition and their effects on population size.
- Explain why interspecific competition leads to extinction or greater specialization.
- Compare and contrast mutualism, commensalism, and parasitism.

Vocabulary

- biological interactions
- carnivore
- chemoautotroph
- commensalism
- consumer (heterotroph)
- decomposer
- detritivore
- detritus
- food chain
- food web
- herbivore
- interdependent
- interspecific competition
- intraspecific competition
- keystone species
- mutualism
- omnivore
- parasitism
- photoautotroph
- predation
- producer (autotroph)
- saprotroph
- scavenger
- specialization
- trophic level

Introduction

When it comes to energy, ecosystems are not closed. They need constant inputs of energy. Most ecosystems get energy from sunlight. A small minority get energy from chemical compounds. Unlike energy, matter is not constantly added to ecosystems. Instead, it is recycled. Water and elements such as carbon, oxygen, phosphorus, nitrogen and hydrogen are constantly recycled.

All biomes have populations of interacting species. Species interact in the same basic ways in all biomes. For example, all biomes have some species that prey on others for food. Species also compete with one another for living spaces, mates, habitats, and food resources. The focus of study of species interactions is the community.

Symbiosis is a close relationship between two species in which at least one species benefits. For the other species, the relationship may be positive, negative, or neutral. There are three basic types of symbiosis: mutualism, commensalism, and parasitism.

Community Relationships: How Energy Flows Through Ecosystems

Energy enters ecosystems in the form of sunlight or chemical compounds. Some organisms, like producers (autotrophs) use this energy to make food (usable energy). Other organisms (consumers, heterotrophs) get energy by eating the producers. They pass some of the energy on to other consumers when they are eaten. In this way, energy flows from one living thing to another.

All living things need energy. They need it to power the processes of life. For example, it takes energy to grow. It also takes energy to produce offspring. In fact, it takes energy just to stay alive. Remember that energy cannot be created or destroyed (first law of thermodynamics). It can only change form. Energy changes form as it moves through ecosystems.

Producers (Autotrophs)

Producers are organisms that produce food for themselves and other organisms. They use energy and simple inorganic molecules to make organic compounds. The stability of producers is vital to ecosystems because all organisms need organic molecules. Producers are also called autotrophs. There are two basic types of autotrophs: photoautotrophs and chemoautotrophs.

1. Photoautotrophs use energy from sunlight to make food by photosynthesis. They include plants, algae, and certain bacteria (see **Figure 9.15**, on next page).
2. Chemoautotrophs use energy from chemical compounds to make food by chemosynthesis. They include some bacteria and also Archaea. Archaea are microorganisms that resemble bacteria.

The energy of the sun is first captured by producers, organisms that can make their own food. Many producers make their own food through the process of photosynthesis. The "food" the producers make is the sugar, glucose. Producers make food for the rest of the ecosystem. As energy is not recycled, energy must consistently be captured by producers. This energy is then passed on to the organisms that eat the producers, and then to the organisms that eat those organisms, and so on.

Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic ingredients, photosynthetic organisms produce the carbohydrate glucose ($C_6H_{12}O_6$), and other complex organic compounds. Essentially, these producers are changing the energy from the sunlight into a usable form of energy. They are also making the oxygen that we breathe. Oxygen is a waste product of photosynthesis.

The survival of every ecosystem is dependent on the producers. Without producers capturing the energy from the sun and turning it into glucose, an ecosystem could not exist. On land, plants are the dominant producers. Phytoplanktons, tiny photosynthetic organisms, are the most common producers in the oceans and lakes. Algae, which is the green layer you might see floating on a pond, are an example of phytoplankton.

There are also bacteria that use chemical processes to produce food. They get their energy from sources other than the sun, but they are still called producers. This process is known as chemosynthesis, and is common in ecosystems without sunlight, such as certain marine ecosystems.

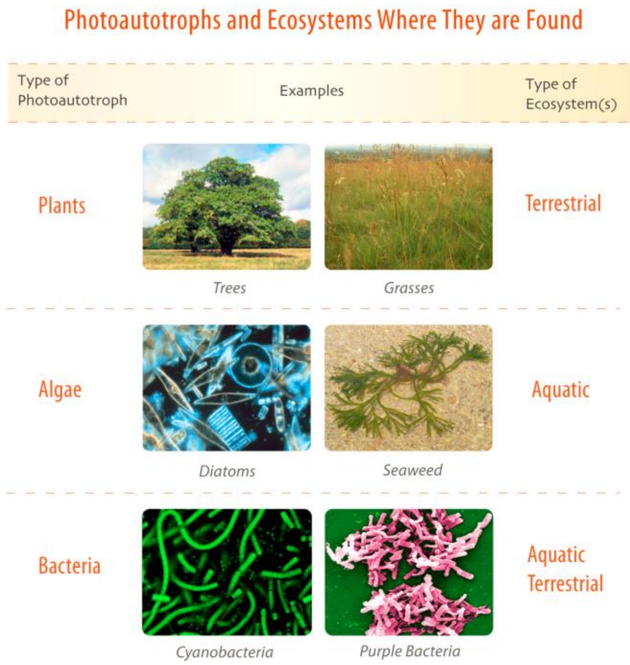

Figure 9.15: Different types of photoautotrophs are important in different ecosystems.

Consumers (Heterotrophs)

Consumers are organisms that depend on other organisms for food. They take in organic molecules by essentially ‘‘eating” other living things. They include all animals and fungi. (Fungi don’t really ‘‘eat”; they absorb nutrients from other organisms.) They also include many bacteria and even a few plants, such as the pitcher plant in **Figure 9.16**. Consumers are also called heterotrophs. Heterotrophs are classified by what they eat:

- Herbivores consume producers such as plants or algae. They are a necessary link between producers and other consumers. Examples include deer, rabbits, and mice.
- Carnivores consume animals. Examples include lions, polar bears, hawks, frogs, salmon, and spiders. Carnivores that are unable to digest plants and must eat only animals are called obligate carnivores. Other carnivores can digest plants but do not commonly eat them.
- Omnivores consume both plants and animals. They include humans, pigs, brown bears, gulls, crows, and some species of fish.

Figure 9.16: Pitcher Plant. Virtually all plants are producers. This pitcher plant is an exception. It consumes insects. It traps them in a sticky substance in its flower.

Decomposers

The organisms that obtain their energy from other organisms are called consumers. All animals are consumers, and they eat other organisms. Fungi and many protists and bacteria are also consumers. But, whereas animals eat other organisms, fungi, protists, and bacteria "consume" organisms through different methods, they are known as decomposers.

When organisms die, they leave behind energy and matter in their remains. Decomposers break down the remains and other wastes and release simple inorganic molecules back to the environment. Producers can then use the molecules to make new organic compounds. The stability of decomposers is essential to every ecosystem. Decomposers are classified by the type of organic matter they break down:

- Scavengers consume the soft tissues of dead animals. Examples of scavengers include vultures, raccoons, and blowflies.
- Detritivores consume detritus—the dead leaves, animal feces, and other organic debris that collects on the soil or at the bottom of a body of water. On land, detritivores include earthworms, millipedes, and dung beetles (see **Figure 9.17**). In water, detritivores include ‘‘bottom feeders” such as sea cucumbers and catfish.
- Saprotrophs are the final step in decomposition. They feed on any remaining organic matter that is left after other decomposers do their work. Saprotrophs include fungi and single-celled protozoa. Fungi are the only organisms that can decompose wood.

Figure 9.17: Dung Beetle. This dung beetle is rolling a ball of feces to its nest to feed its young.

Decomposers and Stability

Decomposers (**Figure 9.18**) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen, back into the environment. These nutrients are recycled back into the ecosystem so that the producers can use them. They are passed to other organisms when they are eaten or consumed. Many of these nutrients are recycled back into the soil, so they can be taken up by the roots of plants.

The stability of an ecosystem depends on the actions of the decomposers. Examples of decomposers include mushrooms on a decaying log. Bacteria in the soil are also decomposers. Imagine what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would not be released back into the ecosystem. Producers would not have enough nutrients. The carbon and nitrogen necessary to build organic compounds, and then cells, allowing an organism to grow, would be insufficient. Other nutrients necessary for an organism to function properly would also not be sufficient. Essentially, many organisms could not exist.

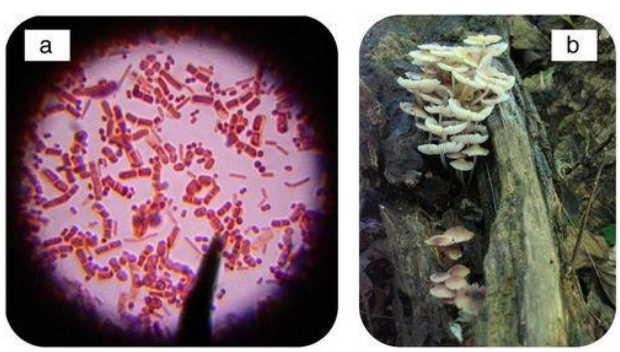

Figure 9.18 Examples of decomposers are (a) bacteria and (b) fungi.

Food Chains and Food Webs

Food chains and food webs are diagrams that represent the feeding relationships from producers to consumers to decomposers. They show who eats whom. In this way, they model how energy and matter move through ecosystems.

Food Chains

A food chain represents a single pathway through which energy and matter flow through an ecosystem. An example is shown in **Figure 9.19.** Food chains are generally simpler than what really happens in nature. Most organisms consume—and are consumed by—more than one species.

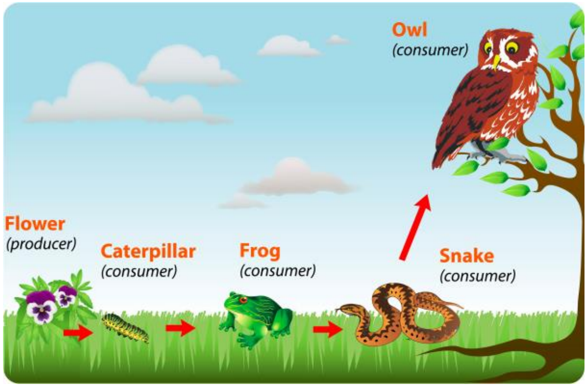

Figure 9.19: This food chain includes producers and consumers. How could you add decomposers to the food chain?

A musical summary of food chains can be heard at http://www.youtube.com/watch?v=TE6wqG4nb3M (2:46).

A food chain is a simple diagram that shows one way energy flows through an ecosystem. Producers form the base of all food chains. The consumers that eat producers are called primary consumers. The consumers that eat primary consumers are secondary consumers. This chain can continue to multiple levels, see **Figure 9.20**.

At each level of a food chain, a lot of energy is lost. Only about ten percent of the energy passes to the next level, see **Figure 9.21** on the next page. Where does that energy go? Some energy is given off as heat. Some energy goes into animal wastes. Energy also goes into growing things that another consumer cannot eat, like fur. It's because so much energy is lost that most food chains have just a few levels. There's not enough energy left for higher levels.

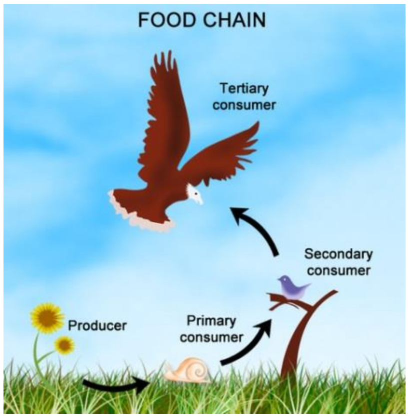

Figure 9.20 What do the arrows stand for in a food chain?

Figure 9.21 How many ospreys are there relative to the number of shrimp?

What does this mean for the range of the osprey (or lion, or other top predator)? A top predator must have a very large range in which to hunt so that it can get enough energy to live.

Why do most food chains have only four or five trophic levels? There is not enough energy to support organisms in a sixth trophic level. Food chains of ocean animals are longer than those of land-based animals because ocean conditions are more stable.

Why do organisms at higher trophic levels tend to be larger than those at lower levels? The reason for this is simple: a large fish must be able to eat a small fish, but the small fish does not have to be able to eat the large fish.

Food Webs

A food web represents multiple pathways through which energy and matter flow through an ecosystem. It includes many intersecting food chains. It demonstrates that most organisms eat, and are eaten, by more than one species. An example is shown in **Figure 9.22.**

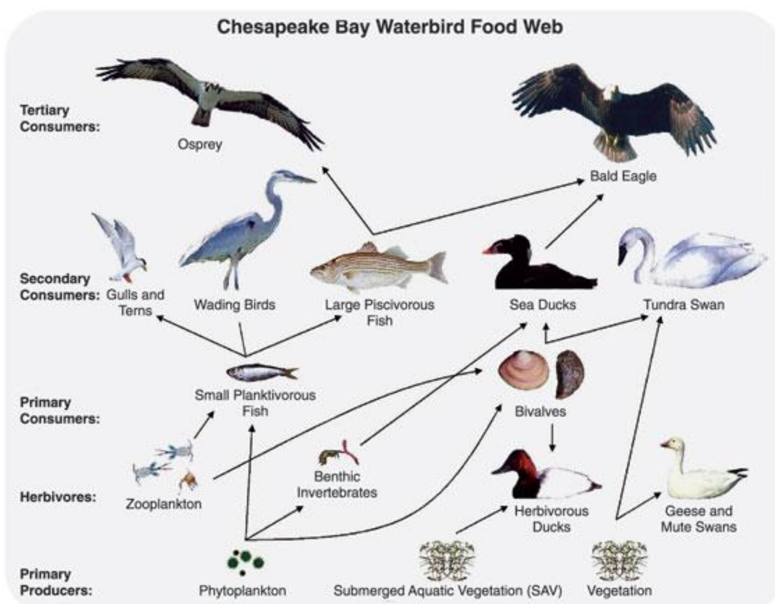

Figure 9.22: Food Web. This food web consists of several different food chains. Which organisms are producers in all of the food chains included in the food web?

Even food webs are interconnected. All organisms depend on two global food webs. The base of aquatic food webs is phytoplankton and the base of terrestrial food webs is land plants. How are these two webs interconnected? Birds or bears that live on land may eat fish, which connects the two food webs. Humans are an important part of both of these food webs; we are at the top of a food web, since nothing eats us. That means that we are top predators.

Trophic Levels and Energy

The feeding positions in a food chain or web are called trophic levels. The different trophic levels are defined in **Table 9.4**. Examples are also given in the table. All food chains and webs have at least two or three trophic levels. Generally, there are a maximum of four trophic levels.

Table 9.4: Trophic Levels

Trophic Level	Where It Gets Food	Example
1st Trophic Level: Producer	Makes its own food	Plants make food
2nd Trophic Level: Primary Consumer	Consumes producers	Mice eat plant seeds
3rd Trophic Level: Secondary Consumer	Consumes primary consumers	Snakes eat mice
4th Trophic Level: Tertiary Consumer	Consumes secondary consumers	Hawks eat snakes

Many consumers feed at more than one trophic level. Humans, for example, are primary consumers when they eat plants such as vegetables. They are secondary consumers when they eat cows. They are tertiary consumers when they eat salmon.

Energy flows through an ecosystem in only one direction. Energy is passed from organisms at one trophic level or energy level to organisms in the next trophic level. Which organisms do you think are at the first trophic level (**Figure 9.23**)?

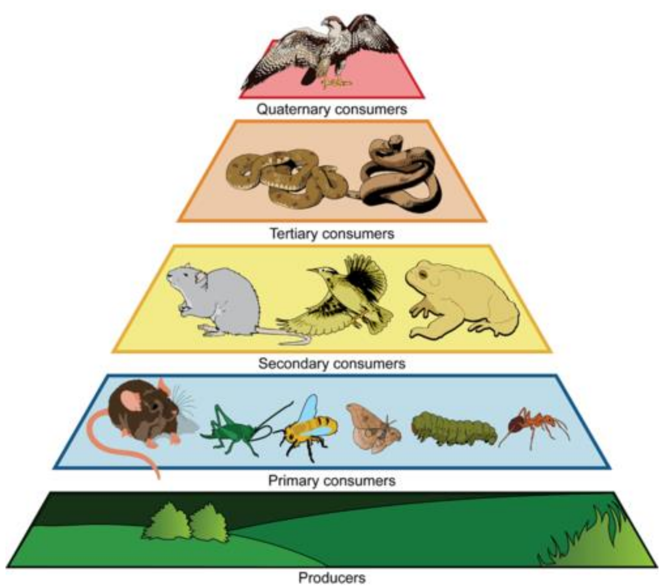

Figure 9.23 Producers are always the first trophic level, herbivores the second, the carnivores that eat herbivores the third, and so on.

Energy is passed up a food chain or web from lower to higher trophic levels. Most of the energy at a trophic level – about 90% – is used at that trophic level. Organisms need it for locomotion, heating themselves, and reproduction. So animals at the second trophic level have only about 10% as much energy available to them as do organisms at the first trophic level. Animals at the third level have only 10% as much available to them as those at the second level.

Energy pyramids are discussed at
http://www.youtube.com/watch?v=8T2nEMzk6_E&feature=related.

Trophic Levels and Biomass

With less energy at higher trophic levels, there are usually fewer organisms as well. Organisms tend to be larger in size at higher trophic levels, but their smaller numbers result in less biomass. Biomass is the total mass of organisms at a trophic level. The decrease in biomass from lower to higher levels is also represented by **Figure 9.23.**

Community Interactions: What Is a Community?

A community is the biotic part of an ecosystem. It consists of all the populations of all the species in the same area. It also includes their biological interactions, the interactions between different organisms in an environment. Species interactions in communities are important factors in natural selection. They help shape the evolution of the interacting species.

All living things depend on their environment to supply them with what they need, including food, water, and shelter. Their environment consists of physical factors—such as soil, air, and temperature—and also of other organisms. An organism is an individual living thing. Many living things interact with other organisms in their environment. In fact, they may need other organisms in order to survive. This is known as interdependence. For example, living things that cannot make their own food must eat other organisms for food. Other interactions between living things include predation, competition, and symbiosis.

Predation

Predation is a relationship in which members of one species (the predator) consume members of another species (the **prey**). The lions and buffalo in **Figure 9.24** are classic examples of predators and prey. In addition to the lions, there is another predator in this figure. Can you spot it? The other predator is the buffalo. Like the lion, it consumes prey species, in this case species of grass. However, unlike the lions, the buffalo does not kill its prey. Predator-prey relationships such as these account for most energy transfers in food chains and food webs.

Figure 9.24: Predators and Their Prey. Two lions feed on the carcass of a South African cape buffalo.

Predation and Population

A predator-prey relationship tends to keep the populations of both species in balance. This is shown by the graph in **Figure 9.25** on the next page**.** As the prey population increases, there is more food for predators. So, after a slight lag, the predator population increases as well. As the number of predators increases, more prey are captured. As a result, the prey population starts to decrease. What happens to the predator population then?

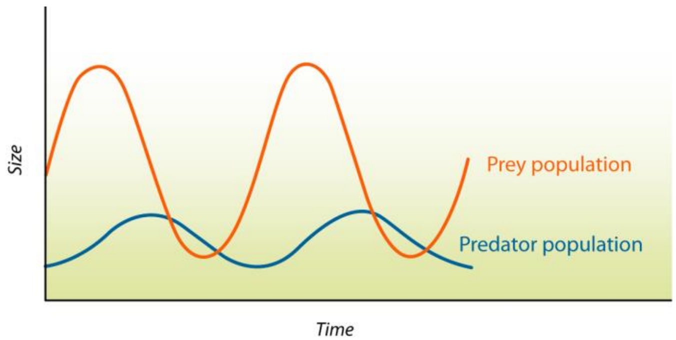

Figure 9.25: Predator-Prey population Dynamics. As the prey population increases, why does the predator population also increase?

Keystone Species

Some predator species are known as keystone species. A keystone species is one that plays an especially important role in its community. Major changes in the numbers of a keystone species affect the populations of many other species in the community. For example, some sea star species are keystone species in coral reef communities. The sea stars prey on mussels and sea urchins, which have no other natural predators. If sea stars were removed from a coral reef community, mussel and sea urchin populations would have explosive growth. This, in turn, would drive out most other species. In the end, the coral reef community would be destroyed.

Adaptations to Predation

Both predators and prey have adaptations to predation that evolve through natural selection. Predator adaptations help them capture prey. Prey adaptations help them avoid predators. A common adaptation in both predator and prey is camouflage. Camouflage in prey helps them hide from predators. Several examples are shown in **Figure 9.26**. Camouflage in predators helps them sneak up on prey.

Figure 9.26: Camouflage in Predator and Prey species. Can you see the crab in the photo on the left? It is camouflaged with algae. The praying mantis in the middle looks just like the dead leaves in the background. Can you tell where one zebra ends and the other begins? This may confuse a predator and give the zebras a chance to run away.

Competition

Competition is a relationship between organisms that strive for the same resources in the same place. The resources might be food, water, or space. Competition occurs whenever they both try to get the same resources in the same place and at the same time. The two organisms are likely to come into conflict, and the organism with better adaptations may win out over the other organism.

There are two different types of competition:

1. Intraspecific competition occurs between members of the same species. For example, two male birds of the same species might compete for mates in the same area. This type of competition is a basic factor in natural selection. It leads to the evolution of better adaptations within a species.
2. Interspecific competition occurs between members of different species. For example, predators of different species might compete for the same prey.

Interspecific Competition and Extinction

Interspecific competition, in ecology, is a form of competition in which individuals of different species compete for the same resource in an ecosystem (e.g. food or living space). If a tree species in a dense forest grows taller than surrounding tree species, it is able to absorb more of the incoming sunlight. However, less sunlight is then available for the trees that are shaded by the taller tree, thus interspecific competition. Cheetahs and lions can also be in interspecific competition, since both species feed on the same prey, and can be negatively impacted by the presence of the other because they will have less food.

Competition is only one of many interacting biotic and abiotic factors that affect community structure. Moreover, competition is not always a straightforward, direct, interaction. Interspecific competition may occur when individuals of two separate species share a limiting resource in the same area. If the resource cannot support both populations, then lowered fecundity, growth, or survival may result in at least one species. Interspecific competition has the potential to alter populations, communities and the evolution of interacting species. On an individual organism level, competition can occur as interference or exploitative competition.

Direct competition has been observed between individuals, populations and species, but there is little evidence that competition has been the driving force in the evolution of large groups. Many studies have shown major impacts on both individuals and populations from interspecific competition. Documentation of these impacts has been found in species from every major branch of organism. The effects of interspecific competition can also reach communities and can even influence the evolution of species as they adapt to avoid competition. This evolution may result in the exclusion of a species in the habitat, niche separation, and local extinction. The changes of these species over time can also change communities as other species must adapt.

Intraspecific Competition and Specialization

Intraspecific competition is an interaction in population ecology, whereby members of the same species compete for limited resources. This leads to a reduction in fitness for both individuals. By contrast, interspecific competition occurs when members of different species compete for a shared resource. Members of the same species have very similar resources requirements whereas different species have a smaller contested resource overlap, resulting in intraspecific competition generally being a stronger force than interspecific competition.

Individuals can compete for food, water, space, light, mates or any other resource which is required for survival. The resource must be limited for competition to occur; if every member of the species can obtain a sufficient amount of every resource then individuals do not compete and the population grows exponentially. Exponential growth is very rare in nature because resources are finite and so not every individual in a population can survive, leading to intraspecific competition for the scarce resources.

Sometimes competition between individuals of the same species can lead to specialization. Specialization allows competing individuals to continue to survive. **Figure 9.27** on the next page explains how anole lizards specialized in order to survive.

Intraspecific competition does not just involve direct interactions between members of the same species (such as male deer locking horns when competing for mates) but can also include indirect interactions where an individual depletes a shared resource (such as a grizzly bear catching a salmon that can then no longer be eaten by bears at different points along a river).

The way in which resources are partitioned by organisms also varies and can be split into scramble and contest competition. Scramble competition involves a relatively even distribution of resources among a population as all individuals exploit a common resource pool. In contrast, contest competition is the uneven distribution of resources and occurs when hierarchies in a population influence the amount of resource each individual receives. Organisms in the most prized territories or at the top of the hierarchies obtain a sufficient quantity of the resources, whereas individuals without a territory do not obtain any of the resource.

<table>
<tr><td colspan="2">Specialization in Anole Lizards
Many species of Anole Lizards prey on insects in tropical rainforests. Competition among them has led to evolution of specializations. Some Anoles prey on insects on the forest floor. Others prey on insects in trees. This allows the different species of Anoles to live in the same area without competing.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Ground Anole Lizard</td><td>Tree Anole Lizard</td></tr>
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Figure 9.27: Specialization in Anole Lizards. Specialization lets different species of anole lizards live in the same area without competing.

Symbiosis

The term symbiosis comes from a Greek word that means "living together". Symbiosis can be used to describe various types of close relationships between organisms of different species, such as mutualism and commensalism, which are relationships in which neither organism is harmed. Symbiosis can also be used to describe relationships where one organism lives on or in another, called parasitism.

Mutualism

Mutualism is a symbiotic relationship in which both species benefit. An example of mutualism involves goby fish and shrimp (see **Figure 9.28**). The nearly blind shrimp and the fish spend most of their time together. The shrimp maintains a burrow in the sand in which both the fish and shrimp live. When a predator comes near, the fish touches the shrimp with its tail as a warning. Then, both fish and shrimp retreat to the burrow until the predator is gone. From their relationship, the shrimp gets a warning of approaching danger. The fish gets a safe retreat and a place to lay its eggs.

Figure 9.28: The multicolored shrimps in the back and the goby fish in front have a mutualistic relationship.

Commensalism

Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. One species typically uses the other for a purpose other than food. For example, mites attach themselves to larger flying insects to get a ‘‘free ride.” Hermit crabs use the shells of dead snails for homes. Clown fish live with sea anemones for protection from predators and the sea anemone is neither helped nor harmed (**Figure 9.29).** If you saw the movie *Finding Nemo,* then you probably recognize this fish. It’s known as a clownfish, and it’s swimming near the tentacles of an animal called a sea anemone. The sea anemone kills prey by injecting poison with its tentacles. For some reason, the anemone doesn’t harm the clownfish, perhaps because the fish has a coating of mucus that helps disguise it. But why does the clownfish ‘‘hang out” with the sea anemone? One reason is for the food. The clownfish eats the remains of the anemone’s prey after it finishes feeding. Another reason is safety. The clownfish is safe from predators when it’s near the anemone. Predators are scared away by the anemone’s poison tentacles. In return, the clownfish helps the anemone catch food by attracting prey with its bright colors. Its feces also provide nutrients to the anemone. The clownfish and anemone are just one example of the diverse ways that living things may help each other in nature.

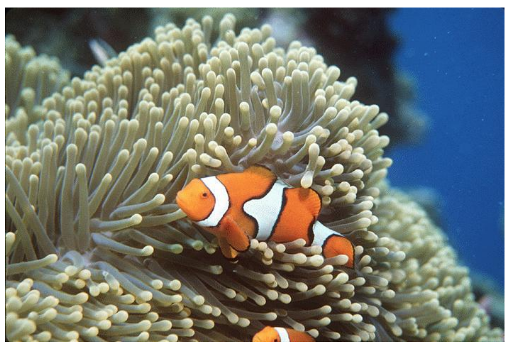

Figure 9.29: The clown fish is protected from predators by the sea anemone.

Parasitism

Parasitism is a symbiotic relationship in which one species (the parasite) benefits while the other species (the **host**) is harmed. Many species of animals are parasites, at least during some stage of their life. Most species are also hosts to one or more parasites. Some parasites live on the surface of their host. Others live inside their host. They may enter the host through a break in the skin or in food or water. For example, roundworms are parasites of mammals, including humans, cats, and dogs (see **Figure 9.30**). The worms produce huge numbers of eggs, which are passed in the host’s feces to the environment. Other individuals may be infected by swallowing the eggs in contaminated food or water.

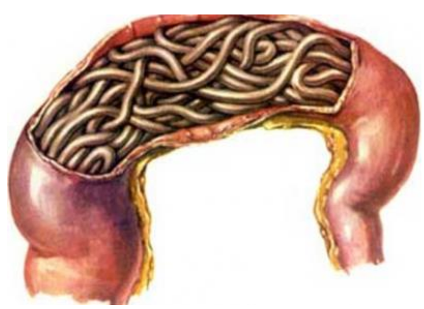

Figure 9.30: Canine Roundworm. The roundworm above, found in a puppy’s intestine, might eventually fill a dog.

Some parasites kill their host, but most do not. It’s easy to see why. If a parasite kills its host, the parasite is also likely to die. Instead, parasites usually cause relatively minor damage to their host.

Lesson Summary

- Ecology is the study of how living things interact with each other and with their environment. The environment includes abiotic (nonliving) and biotic (living) factors.
- Ecosystems require constant inputs of energy from sunlight or chemicals. Producers use energy and Inorganic molecules to make food. Consumers take in food by eating producers or other living things. Decomposers break down dead organisms and other organic wastes and release inorganic molecules back to the environment.
- Food chains and food webs are diagrams that represent feeding relationships. They model how energy and matter move through ecosystems.
- The different feeding positions in a food chain or web are called trophic levels. Generally, there are no more than four trophic levels because energy and biomass decrease from lower to higher levels.
- Predation is a relationship in which members of one species (the predator) consume members of another species (the prey). A predator-prey relationship keeps the populations of both species in balance.
- Competition is a relationship between organisms that strive for the same resources in the same place. Intraspecific competition occurs between members of the same species. It improves the species' adaptations. Interspecific competition occurs between members of different species. It may lead to one species going extinct or both becoming more specialized.
- Symbiosis is a close relationship between two species in which at least one species benefits. Mutualism is a symbiotic relationship in which both species benefit. Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. Parasitism is a symbiotic relationship in which one species (the parasite) benefits while the other species (the host) is harmed.

References/ Multimedia Resources