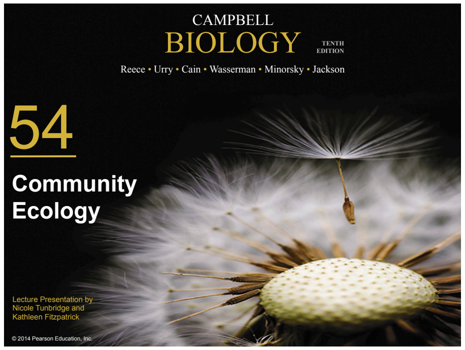


Communities in Motion

- A biological **community** is an assemblage of populations of various species living close enough for potential interaction
  - For example, the carrier crab carries a sea urchin on its back for protection against predators

Figure 54.1

Figure 54.1a

Concept 54.1: Community interactions are classified by whether they help, harm, or have no effect on the species involved

- Ecologists call relationships between species in a community **interspecific interactions**
- Examples are competition, predation, herbivory, symbiosis (parasitism, mutualism, and commensalism), and facilitation
- Interspecific interactions can affect the survival and reproduction of each species, and the effects can be summarized as positive (+), negative (-), or no effect (0)

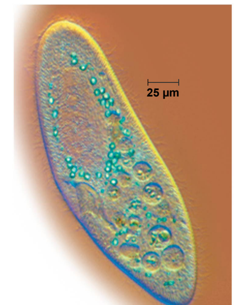
Competition

- **Interspecific competition** (-/- interaction) occurs when species compete for a resource in short supply

Competitive Exclusion

- Strong competition can lead to **competitive exclusion**, local elimination of a competing species
- The competitive exclusion principle states that two species competing for the same limiting resources cannot coexist in the same place

Figure 54.UN01



Paramecium caudatum

Ecological Niches and Natural Selection

- The sum of a species' use of biotic and abiotic resources is called the species' **ecological niche**
- An ecological niche can also be thought of as an organism's ecological role
- Ecologically similar species can coexist in a community if there are one or more significant differences in their niches

- **Resource partitioning** is differentiation of ecological niches, enabling similar species to coexist in a community

Figure 54.2

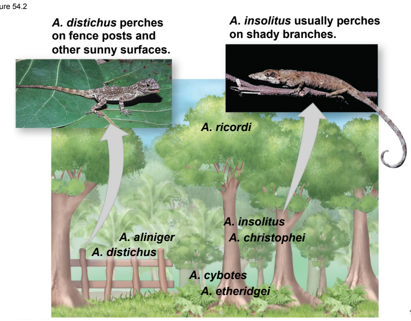


Figure 54.2a

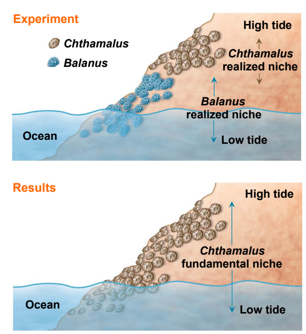
A. distichus

Figure 54.2b

A. insolitus

- A species' fundamental niche is the niche potentially occupied by that species
- A species' realized niche is the niche actually occupied by that species
- As a result of competition, a species' fundamental niche may differ from its realized niche
  - For example, the presence of one barnacle species limits the realized niche of another species

Figure 54.3



- The common spiny mouse and the golden spiny mouse show temporal partitioning of their niches
- Both species are normally nocturnal (active during the night)
- Where they coexist, the golden spiny mouse becomes diurnal (active during the day)

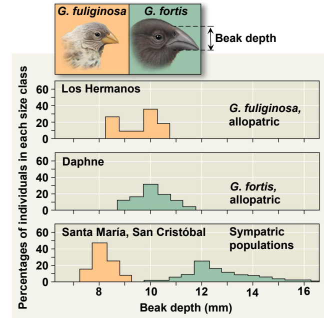
Figure 54.UN02

The golden spiny mouse (*Acomys russatus*)

Character Displacement

- **Character displacement** is a tendency for characteristics to be more divergent in sympatric populations of two species than in allopatric populations of the same two species
- An example is variation in beak size between populations of two species of Galápagos finches

Figure 54.4



Predation

- **Predation** (+/- interaction) refers to an interaction in which one species, the predator, kills and eats the other, the prey
- Some feeding adaptations of predators are claws, fangs, and poison

- Prey display various defensive adaptations
- Behavioral defenses include hiding, fleeing, forming herds or schools, self-defense, and alarm calls
- Animals also have morphological and physiological defense adaptations
- Mechanical and chemical defenses protect species such as porcupines and skunks

Figure 54.5

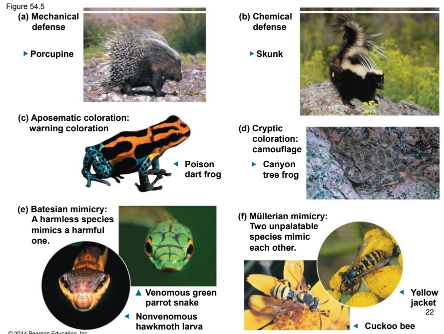


Figure 54.5a

(a) Mechanical defense, porcupine

Figure 54.5b

(b) Chemical defense, skunk

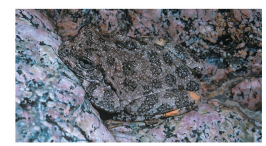
- Animals with effective chemical defense often exhibit bright warning coloration, called **aposematic coloration**
- Predators are particularly cautious in dealing with prey that display such coloration

Figure 54.5c

(c) Aposematic coloration, poison dart frog

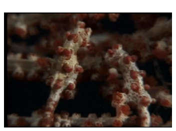
- **Cryptic coloration**, or camouflage, makes prey difficult to spot

Figure 54.5d



d) Cryptic coloration, canyon tree frog

Video: Seahorse Camouflage



- In some cases, a prey species may gain significant protection by mimicking the appearance of another species
- In **Batesian mimicry**, a palatable or harmless species mimics an unpalatable or harmful model

Figure 54.5e

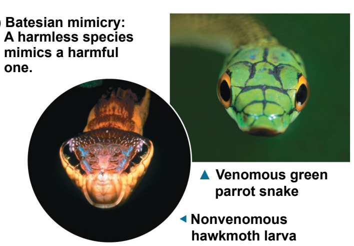


Figure 54.5ea

Batesian mimicry, nonvenomous hawkmoth larva

Figure 54.5eb

Batesian mimicry, venomous green parrot snake

- In **Müllerian mimicry**, two or more unpalatable species resemble each other

Figure 54.5f

(f) Müllerian mimicry: Two unpalatable species mimic each other.

Figure 54.5fa

Müllerian mimicry, cuckoo bee

Figure 54.5fb

Müllerian mimicry, yellow jacket

- Mimicry can also be used by predators to approach prey
  - For example, the mimic octopus can take on the appearance and movement of more than a dozen marine animals

Figure 54.6

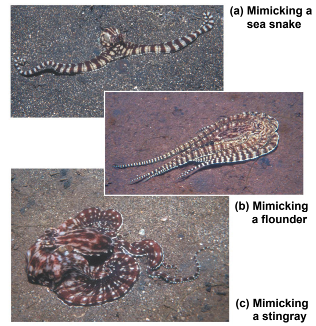
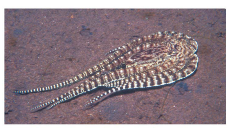


Figure 54.6a

(a) Mimicking a sea snake

Figure 54.6b



(b) Mimicking a flounder

Figure 54.6c

(c) Mimicking a stingray

Herbivory

- **Herbivory** (+/- interaction) refers to an interaction in which an herbivore eats parts of a plant or alga
- It has led to evolution of plant mechanical and chemical defenses and adaptations by herbivores

Figure 54.7

Symbiosis

- **Symbiosis** is a relationship where two or more species live in direct and intimate contact with one another

Parasitism

- In **parasitism** (+/- interaction), one organism, the **parasite**, derives nourishment from another organism, its **host**, which is harmed in the process
- Parasites that live within the body of their host are called **endoparasites**
- Parasites that live on the external surface of a host are **ectoparasites**

- Many parasites have a complex life cycle involving a number of hosts
- Some parasites change the behavior of the host in a way that increases the likelihood that the parasite will be transmitted to the next host
- Parasites can significantly affect the survival, reproduction, and density of their host population

Mutualism

- Mutualistic symbiosis, or **mutualism** (+/+ interaction), is an interspecific interaction that benefits both species
- A mutualism can be
  - Obligate, where one species cannot survive without the other
  - Facultative, where both species can survive alone

Figure 54.8

(a) Hollow thorns that house stinging ants of the genus *Pseudomyrmex*

(b) Area cleared by ants around an acacia tree

Figure 54.8a

(a) Hollow thorns that house stinging ants of the genus *Pseudomyrmex*

Figure 54.8b

(b) Area cleared by ants around an acacia tree

Video: Clownfish and Anemone

Commensalism

- In **commensalism** (+/0 interaction), one species benefits and the other is neither harmed nor helped
- Commensal interactions are hard to document in nature because any close association likely affects both species

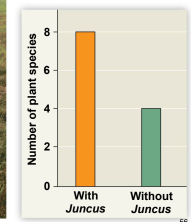
Figure 54.9

Facilitation

- **Facilitation** (+/+ or 0/+) is an interaction in which one species has positive effects on another species without direct and intimate contact
  - For example, the black rush makes the soil more hospitable for other plant species

Figure 54.10

(a) Salt marsh with *Juncus* (foreground)



(b)

Figure 54.10a

(a) Salt marsh with *Juncus* (foreground)

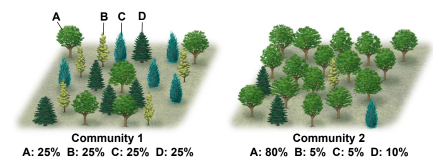
Concept 54.2: Diversity and trophic structure characterize biological communities

- In general, a few species in a community exert strong control on that community's structure
- Two fundamental features of community structure are species diversity and feeding relationships

Species Diversity

- **Species diversity** of a community is the variety of organisms that make up the community
- It has two components: species richness and relative abundance
  - **Species richness** is the number of different species in the community
  - **Relative abundance** is the proportion each species represents of all individuals in the community

Figure 54.11



- Two communities can have the same species richness but a different relative abundance
- Diversity can be compared using a diversity index
  - **Shannon diversity index** (H)

$$H = -(p_A \ln p_A + p_B \ln p_B + p_C \ln p_C + \ldots)$$

where A, B, C . . . are the species, p is the relative abundance of each species, and ln is the natural logarithm

- Determining the number and abundance of species in a community is difficult, especially for small organisms
- Molecular tools can be used to help determine microbial diversity

Figure 54.12

Technique

Results

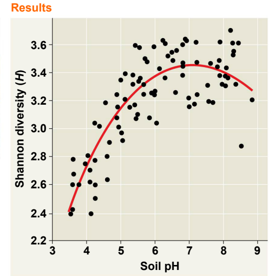


Figure 54.12a

Technique

Diversity and Community Stability

- Ecologists manipulate diversity in experimental communities to study the potential benefits of diversity
  - For example, plant diversity has been manipulated at Cedar Creek Ecosystem Science Reserve in Minnesota for two decades

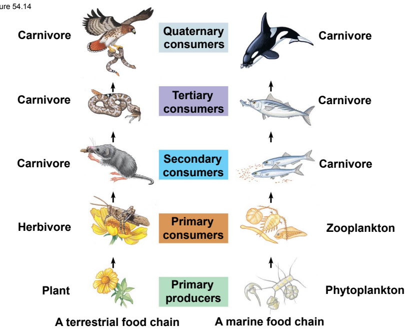
Figure 54.13

- Communities with higher diversity are
  - More productive; they produce more **biomass** (the total mass of all organisms)
  - More stable in their productivity
  - Better able to withstand and recover from environmental stresses
  - More resistant to **invasive species**, organisms that become established outside their native range

Trophic Structure

- **Trophic structure** is the feeding relationships between organisms in a community
- It is a key factor in community dynamics
- **Food chains** link trophic levels from producers to top carnivores

Figure 54.14

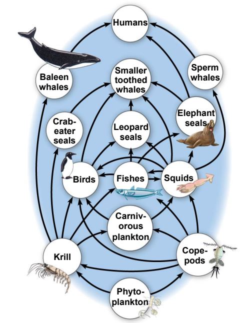


Video: Shark Eating a Seal

Food Webs

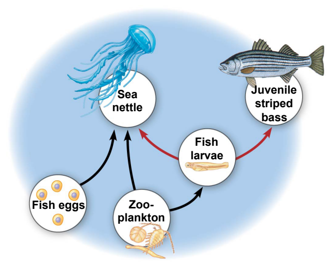
- A **food web** is a branching food chain with complex trophic interactions

Figure 54.15



- Species may play a role at more than one trophic level
- Food webs can be simplified by
  - Grouping species with similar trophic relationships into broad functional groups
  - Isolating a portion of a community that interacts very little with the rest of the community

Figure 54.16



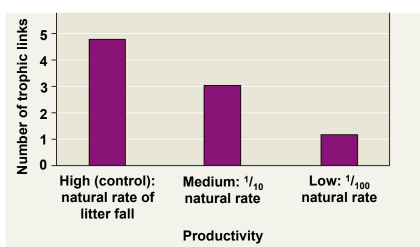
Limits on Food Chain Length

- Each food chain in a food web is usually only a few links long

- The **energetic hypothesis** suggests that length is limited by inefficient energy transfer
- Only about 10% of the energy stored in organic matter at each trophic level is converted to organic matter at the next trophic level
  - For example, a producer level consisting of 100 kg of plant material can support about 10 kg of herbivore biomass and 1 kg of carnivore biomass

- The energetic hypothesis can be tested by manipulating productivity
  - For example, researchers varied the amount of leaf litter available to consumers in tree-hole communities and measured the number of links in the food chain

Figure 54.17



Species with a Large Impact

- Certain species have a very large impact on community structure
- Such species are highly abundant or play a pivotal role in community dynamics

- **Dominant species** are those that are most abundant or have the highest biomass
- One hypothesis suggests that dominant species are most competitive in exploiting resources
- Another hypothesis is that they are most successful at avoiding predators
- Invasive species, typically introduced to a new environment by humans, may become dominant because they lack predators or disease

- One way to discover the impact of a dominant species is to remove it from the community
  - For example, introduction of chestnut blight to eastern North America killed most of the dominant American chestnut trees
  - Removal of the dominant species had a small impact on some species and severe effects on others

- **Keystone species** exert strong control on a community by their ecological roles, or niches
- In contrast to dominant species, they are not necessarily abundant in a community
- Field studies of sea stars illustrate their role as a keystone species in intertidal communities

Figure 54.18

Experiment

Results

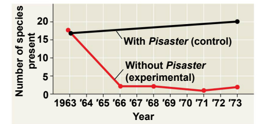
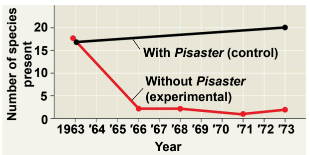


Figure 54.18a

Experiment

Figure 54.18b

Results



- **Ecosystem engineers** (or "foundation species") cause physical changes in the environment that affect community structure
  - For example, beaver dams can transform landscapes on a very large scale

Figure 54.19

Bottom-Up and Top-Down Controls

- The **bottom-up model** of community organization proposes a unidirectional influence from lower to higher trophic levels
- In this case, the presence or absence of mineral nutrients *(N)* controls plant *(V)* numbers, which control herbivore *(H)* numbers, which control predator *(P)* numbers

$$N \rightarrow V \rightarrow H \rightarrow P$$

- The **top-down model**, also called the trophic cascade model, proposes that control comes from the trophic level above
- In this case, predators limit herbivores, herbivores limit plants, and plants limit nutrient levels

$$N \leftarrow V \leftarrow H \leftarrow P$$

- **Biomanipulation** can help restore polluted communities
- In a Finnish lake, blooms of cyanobacteria (primary producers) occurred when zooplankton (primary consumers) were eaten by large populations of roach fish (secondary consumers)
- The addition of pike perch (tertiary consumers) controlled roach populations, allowing zooplankton populations to increase and ending cyanobacterial blooms

Figure 54.UN05

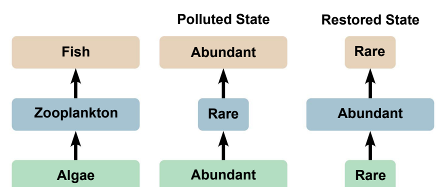


Figure 54.UN06

Lake Vesijärvi, Finland

Concept 54.3: Disturbance influences species diversity and composition

- Decades ago, most ecologists favored the view that communities are in a state of equilibrium
- This view was supported by F. E. Clements, who suggested that biotic interactions caused species in a climax community to function as a superorganism

- Other ecologists, including A. G. Tansley and H. A. Gleason, challenged whether communities were at equilibrium
- They viewed communities as chance assemblages of species with similar abiotic requirements

- A **disturbance** is an event that changes a community, removes organisms from it, and alters resource availability
- The recent emphasis on the role of change has produced a **nonequilibrium model**, which describes communities as constantly changing after being buffeted by disturbances

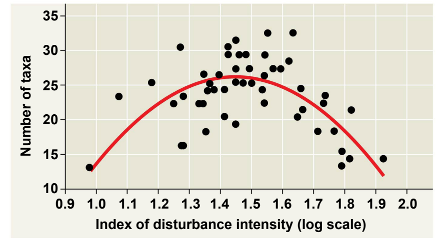
Characterizing Disturbance

- The types of disturbances and their frequency and severity vary among communities.
- Storms and fire are significant sources of disturbance in many ecosystems
- A high level of disturbance is the result of a high intensity and high frequency of disturbance
- Low levels of disturbance can result from low frequency or low intensity of disturbance

- The **intermediate disturbance hypothesis** states that moderate levels of disturbance can foster greater diversity than either high or low levels of disturbance
- High levels of disturbance exclude many slow-growing species
- Low levels of disturbance allow dominant species to exclude less competitive species

- In a New Zealand study, the richness of invertebrate taxa was highest in streams with an intermediate intensity of flooding

Figure 54.20



- The large-scale fire in Yellowstone National Park in 1988 demonstrated that communities can often respond very rapidly to a massive disturbance
- The Yellowstone forest is an example of a nonequilibrium community

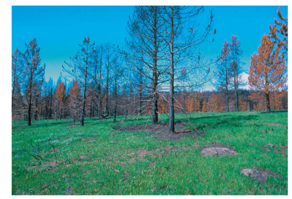
Figure 54.21

(a) Soon after fire (b) One year after fire

Figure 54.21a

(a) Soon after fire

Figure 54.21b



(b) One year after fire

Ecological Succession

- **Ecological succession** is the sequence of community changes after a disturbance
- **Primary succession** occurs where no soil exists when succession begins

- Early-arriving species and later-arriving species may be linked in one of three processes
  - Early arrivals may facilitate the appearance of later species by making the environment favorable
  - They may inhibit the establishment of later species
  - They may tolerate later species but have no impact on their establishment

- Retreating glaciers provide a valuable field-research opportunity for observing primary succession
- Succession on the moraines in Glacier Bay, Alaska, follows a predictable pattern of change in vegetation and soil characteristics
  1. The exposed moraine is colonized by pioneering plants, including liverworts, mosses, fireweed, *Dryas*, and willows

Figure 54.22-1

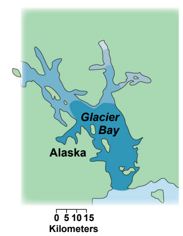


Figure 54.22-2

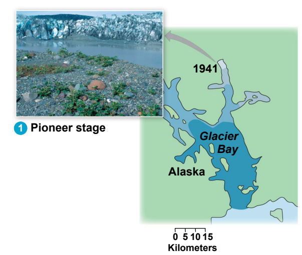


Figure 54.22-3

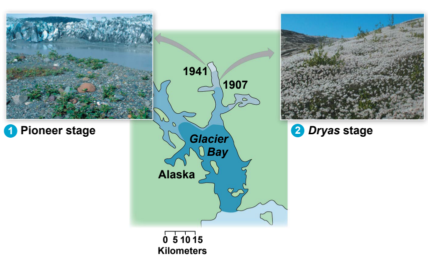


Figure 54.22-4

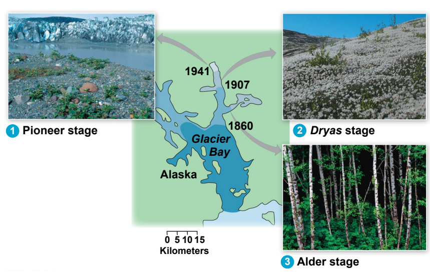


Figure 54.22-5

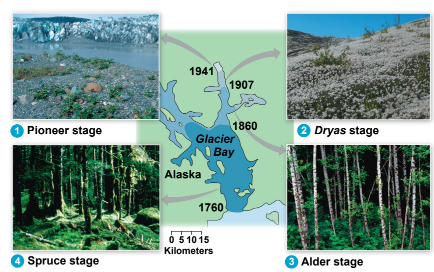


Figure 54.22a

1 Pioneer stage

2. *Dryas* dominates the plant community

Figure 54.22b

2 *Dryas* stage

3. Alder invades and forms dense thickets

Figure 54.22c

3 Alder stage

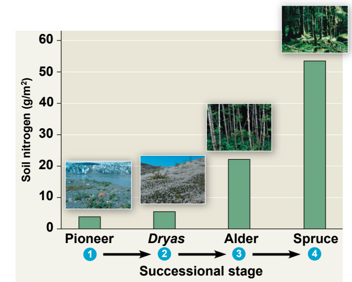
4. Alder are overgrown by Sitka spruce, western hemlock, and mountain hemlock

Figure 54.22d

4 Spruce stage

- Succession is the result of changes induced by the vegetation itself
- On the glacial moraines, pioneer plant species facilitate later arrivals by increasing soil nitrogen content

Figure 54.23



- **Secondary succession** begins in an area where soil remains after a disturbance
  - For example, abandoned agricultural land may return to its original state through secondary succession

Human Disturbance

- Humans have the greatest impact on biological communities worldwide
- Both terrestrial and marine ecosystems are subject to human disturbance
- Human disturbance to communities usually reduces species diversity

Figure 54.24

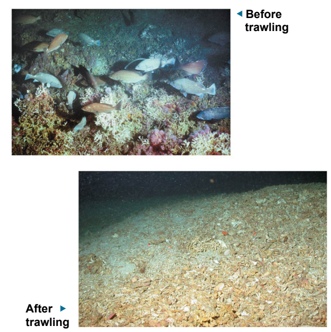
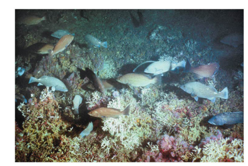
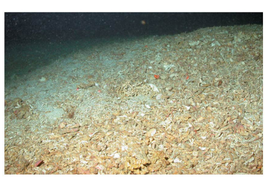


Figure 54.24a



Before trawling

Figure 54.24b



After trawling

Concept 54.4: Biogeographic factors affect community diversity

- Latitude and area are two key factors that affect a community's species diversity

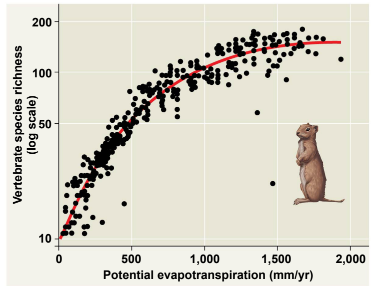
Latitudinal Gradients

- Species richness is especially great in the tropics and generally declines along an equatorial-polar gradient
- Two key factors in equatorial-polar gradients of species richness are probably evolutionary history and climate

- Temperate and polar communities have started over repeatedly following glaciations
- The greater age of tropical environments may account for their greater species richness
- In the tropics, the growing season is longer, so biological time runs faster

- Climate is likely the primary cause of the latitudinal gradient in biodiversity
- Two main climatic factors correlated with biodiversity are sunlight and precipitation
- They can be considered together by measuring a community's rate of evapotranspiration
- **Evapotranspiration** is evaporation of water from soil plus transpiration of water from plants

Figure 54.25



Area Effects

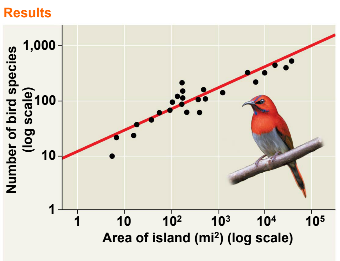
- The **species-area curve** quantifies the idea that, all other factors being equal, a larger geographic area has more species
- The species-area relationship can be described mathematically

$$S = cA^z$$

where S is the number of species, c is a constant, A is the area, and z represents how many more species should be found as habitat area increases

- In a log-log plot of S versus A, z is the slope of the line through the data points
  - For example, in the Sunda Islands of Malaysia, the number of bird species increased with island size, with a value of $z = 0.4$

Figure 54.26



Island Equilibrium Model

- Species richness on islands depends on island size, distance from the mainland, immigration, and extinction
- The equilibrium model of island biogeography maintains that species richness on an ecological island levels off at a dynamic equilibrium point

- Tests of the island equilibrium model in the Florida Keys support the prediction that species richness increases with island size and proximity to the mainland

Figure 54.27

Concept 54.5: Pathogens alter community structure locally and globally

- Ecological communities are universally affected by **pathogens**, which include disease-causing microorganisms, viruses, viroids, and prions
- Pathogens can be particularly virulent in a new habitat

Pathogens and Community Structure

- Pathogens can have dramatic effects on communities
  - For example, coral reef communities are being decimated by white-band disease

- Human activities are transporting pathogens around the world at unprecedented rates
- Community ecology is needed to help study and combat pathogens

Community Ecology and Zoonotic Diseases

- **Zoonotic pathogens** have been transferred from other animals to humans
- The transfer of pathogens can be direct or through an intermediate species called a **vector**
- Many of today's emerging human diseases are zoonotic

- Identifying the community of hosts and vectors for a pathogen can help prevent disease
  - For example, recent studies identified two species of shrew as the primary hosts of the pathogen for Lyme disease

Figure 54.28

- Avian flu is a highly contagious virus of birds
- Ecologists are studying the potential spread of the virus from Asia to North America through migrating birds

Figure 54.29

Figure 54.UN03a

Type of Prey Offered	% of Snakes That Ate Prey Offered in Each Area	
	Cane Toads Present in Area for 40–60 Years	No Cane Toads in Area
Native frog	100	100
Cane toad	0	50

Figure 54.UN03b

Time Since First Exposure to Cane Toads (years)	5	10	10	20	50	60	60	60	60	60
% Reduction in Swimming Speed	52	19	30	30	5	5	9	11	12	22

Figure 54.UN03c

Figure 54.UN04

Figure 54.UN07

Interspecific Interaction	Description
Interspecific competition (−/−)	Two or more species compete for a resource that is in short supply.
Predation (+/−)	One species, the predator, kills and eats the other, the prey. Predation has led to diverse adaptations, including mimicry.
Herbivory (+/−)	An herbivore eats part of a plant or alga.
Symbiosis	Individuals of two or more species live in close contact with one another. Symbiosis includes parasitism, mutualism and commensalism.
Parasitism (+/−)	The parasite derives its nourishment from a second organism, its host, which is harmed.
Mutualism (+/+)	Both species benefit from the interaction.
Commensalism (+/0)	One species benefits from the interaction, while the other is unaffected by it.
Facilitation (+/+ or 0/+)	Species have positive effects on the survival and reproduction of other species without the intimate contact of a symbiosis.

Figure 54.UN07a

Interspecific Interaction	Description
Interspecific competition (−/−)	Two or more species compete for a resource that is in short supply.
Predation (+/−)	One species, the predator, kills and eats the other, the prey. Predation has led to diverse adaptations, including mimicry.
Herbivory (+/−)	An herbivore eats part of a plant or alga.
Symbiosis	Individuals of two or more species live in close contact with one another. Symbiosis includes parasitism, mutualism and commensalism.

Figure 54.UN07b

Interspecific Interaction	Description
Parasitism (+/−)	The parasite derives its nourishment from a second organism, its host, which is harmed.
Mutualism (+/+)	Both species benefit from the interaction.
Commensalism (+/0)	One species benefits from the interaction, while the other is unaffected by it.
Facilitation (+/+ or 0/+)	Species have positive effects on the survival and reproduction of other species without the intimate contact of a symbiosis.

Figure 54.UN08