Chapter 54

Community Ecology

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: A Sense of Community

- A biological **community** is an assemblage of populations of various species living close enough for potential interaction

Fig. 54-1

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, and symbiosis (parasitism, mutualism, and commensalism)
- 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

Ecological Niches

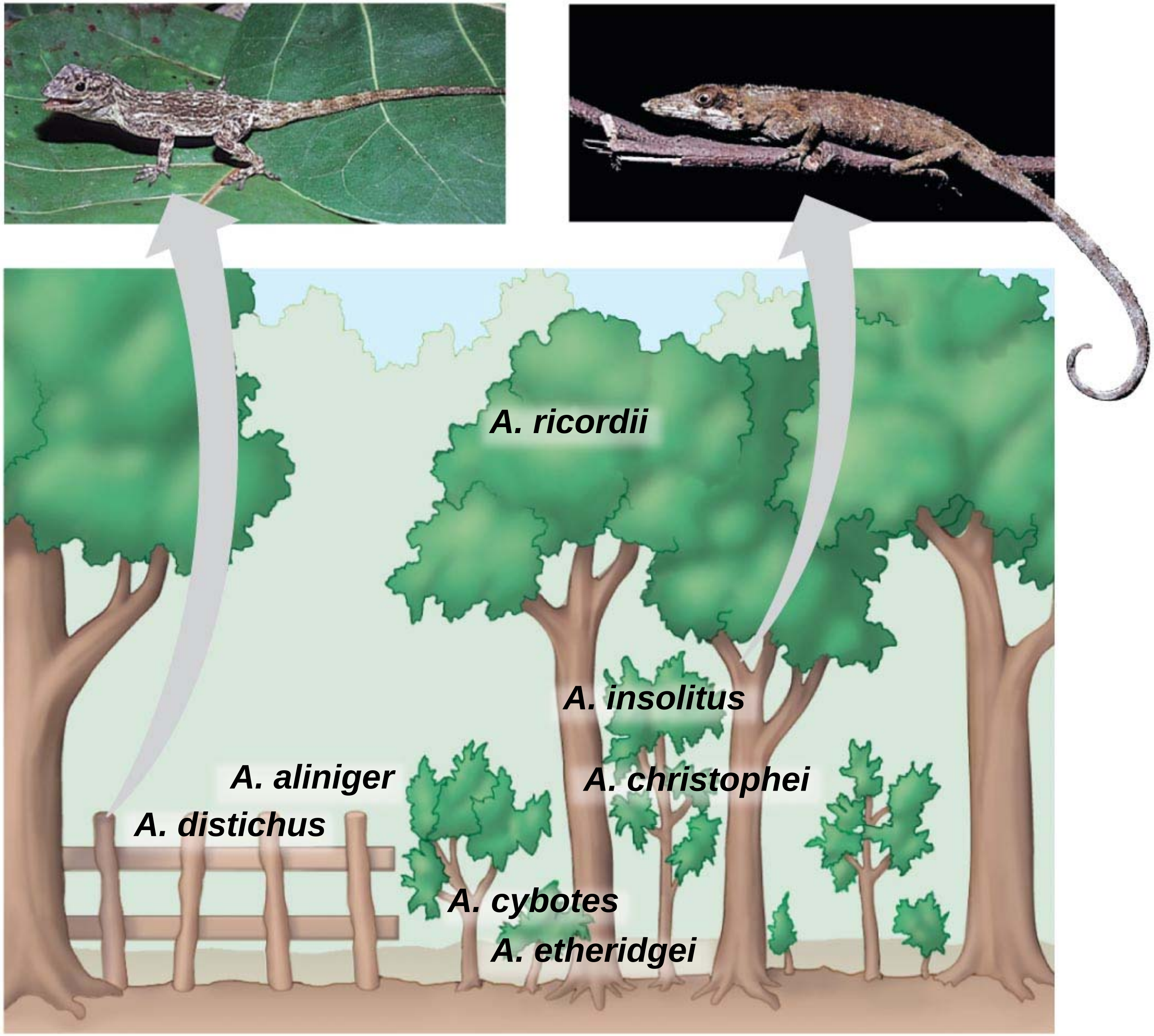
- The total of a species' use of biotic and abiotic resources is called the species' **ecological niche**
- An ecological niche can also be thought of as an organism's ecological role
- Ecologically similar species can coexist in a community if there are one or more significant differences in their niches

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

Fig. 54-2

A. distichus **perches on fence posts and other sunny surfaces.**

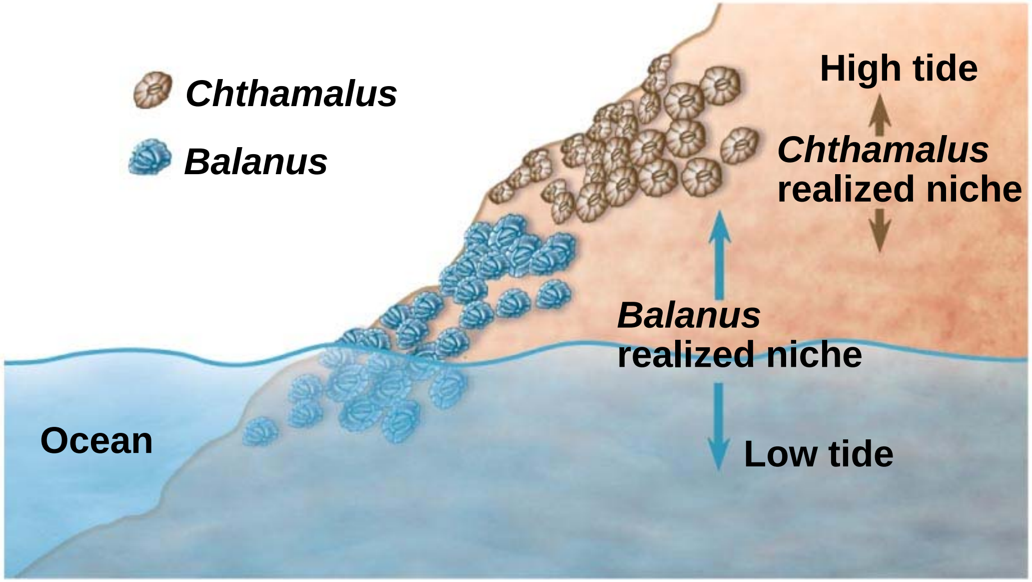
A. insolitus **usually perches on shady branches.**



- As a result of competition, a species' fundamental niche may differ from its realized niche

Fig. 54-3

EXPERIMENT



RESULTS

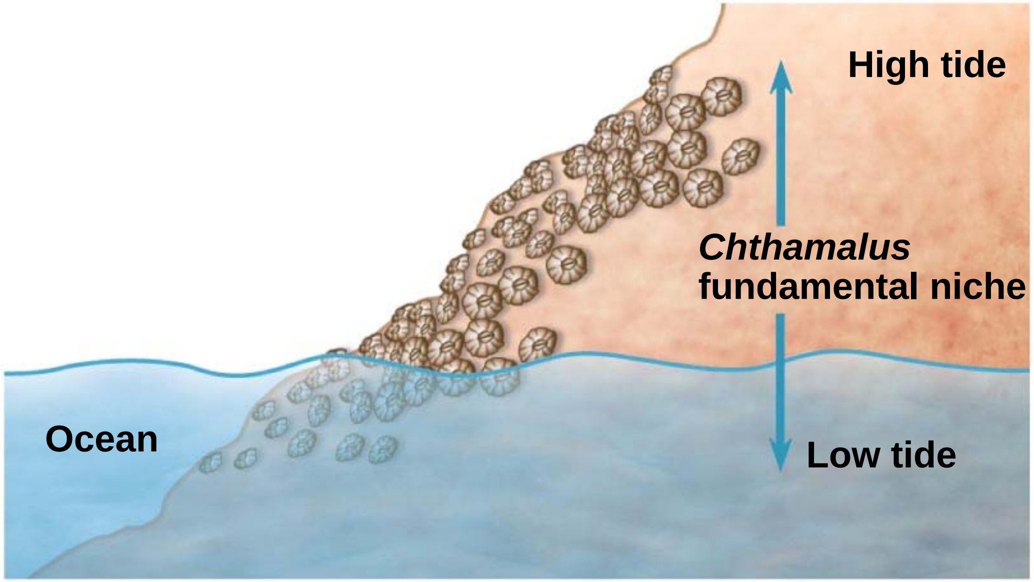


Fig. 54-3a

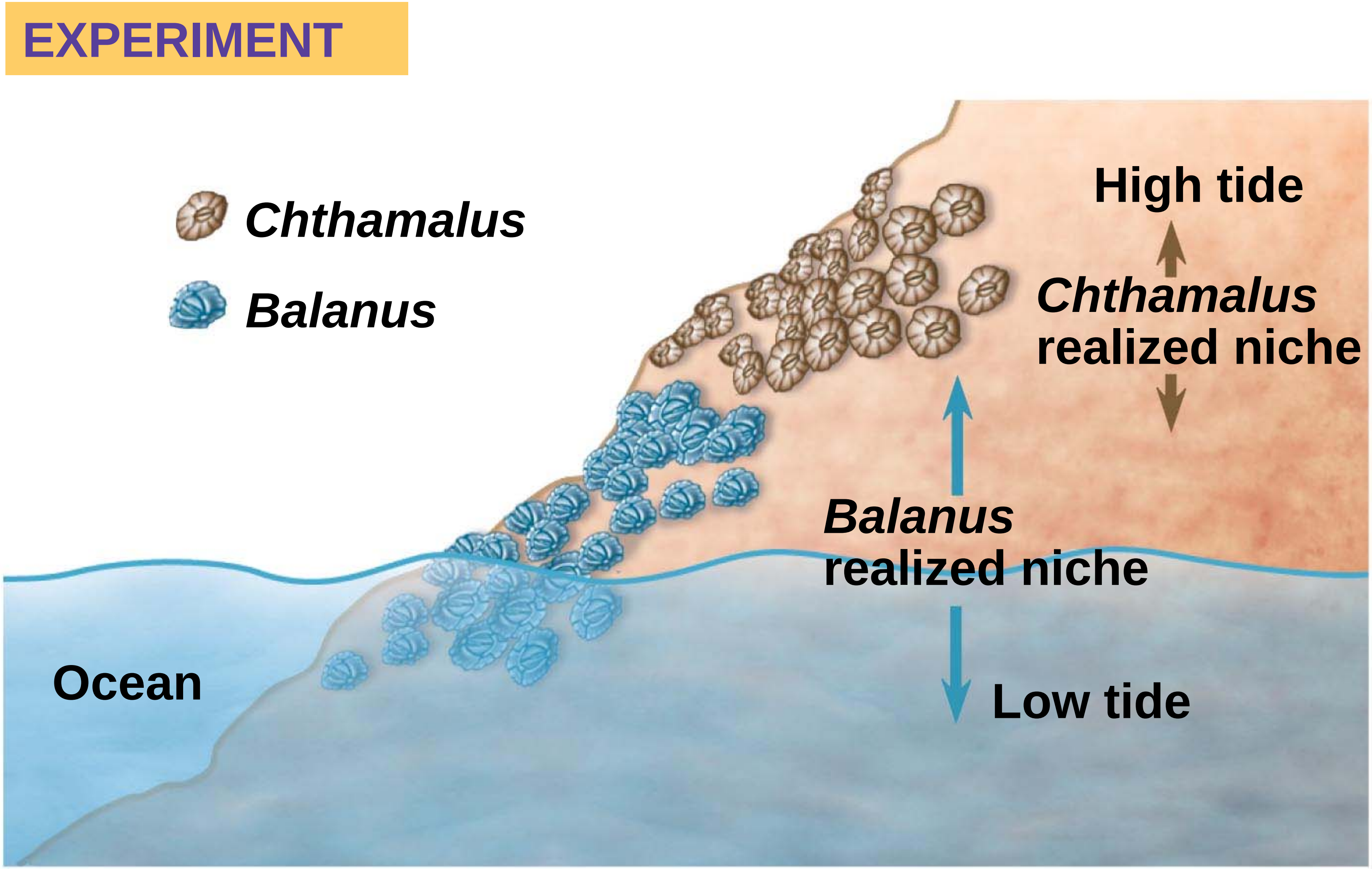
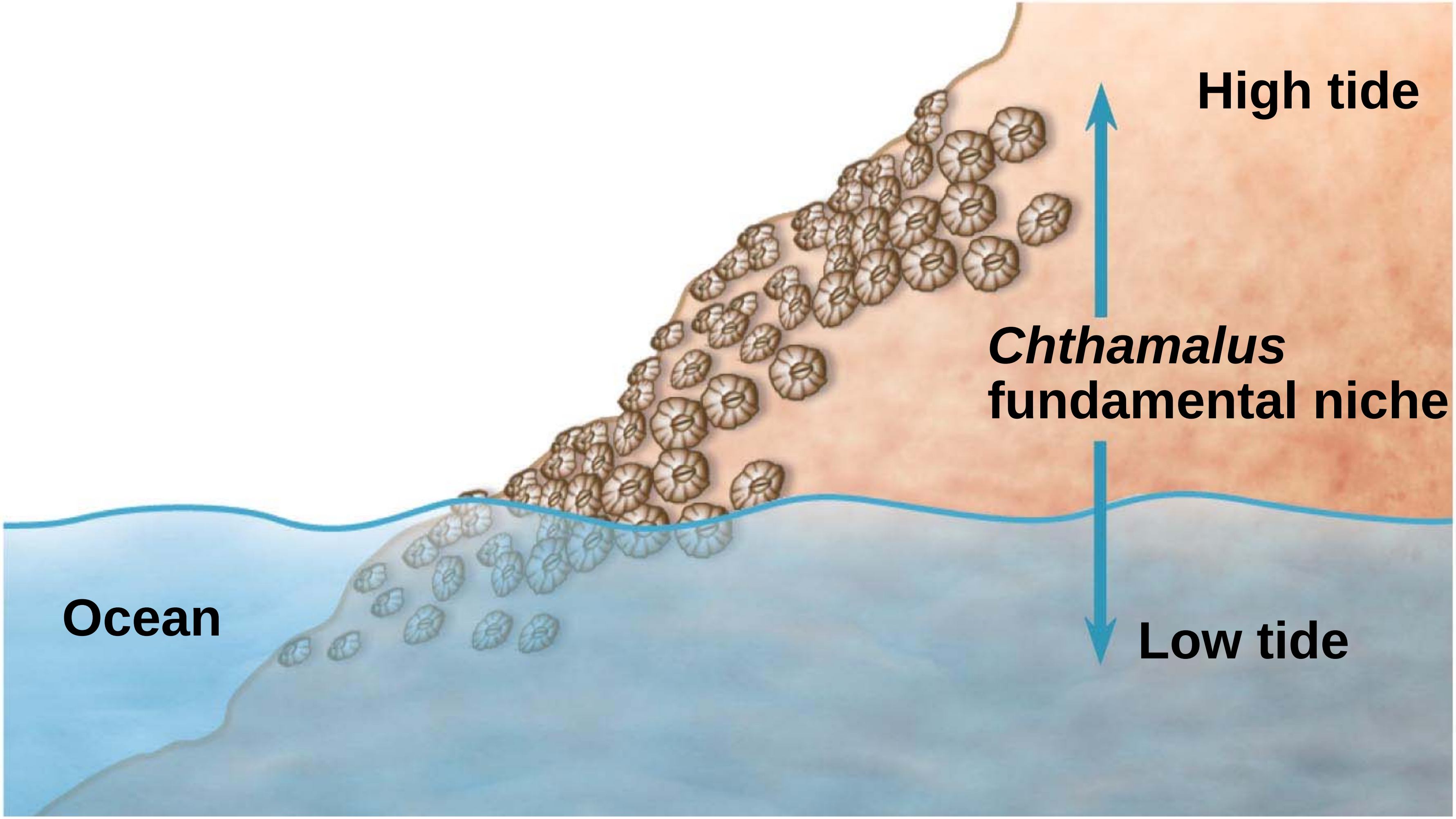

EXPERIMENT
Chthamalus
Balanus
High tide
Chthamalus realized niche
Balanus realized niche
Ocean
Low tide

Fig. 54-3b

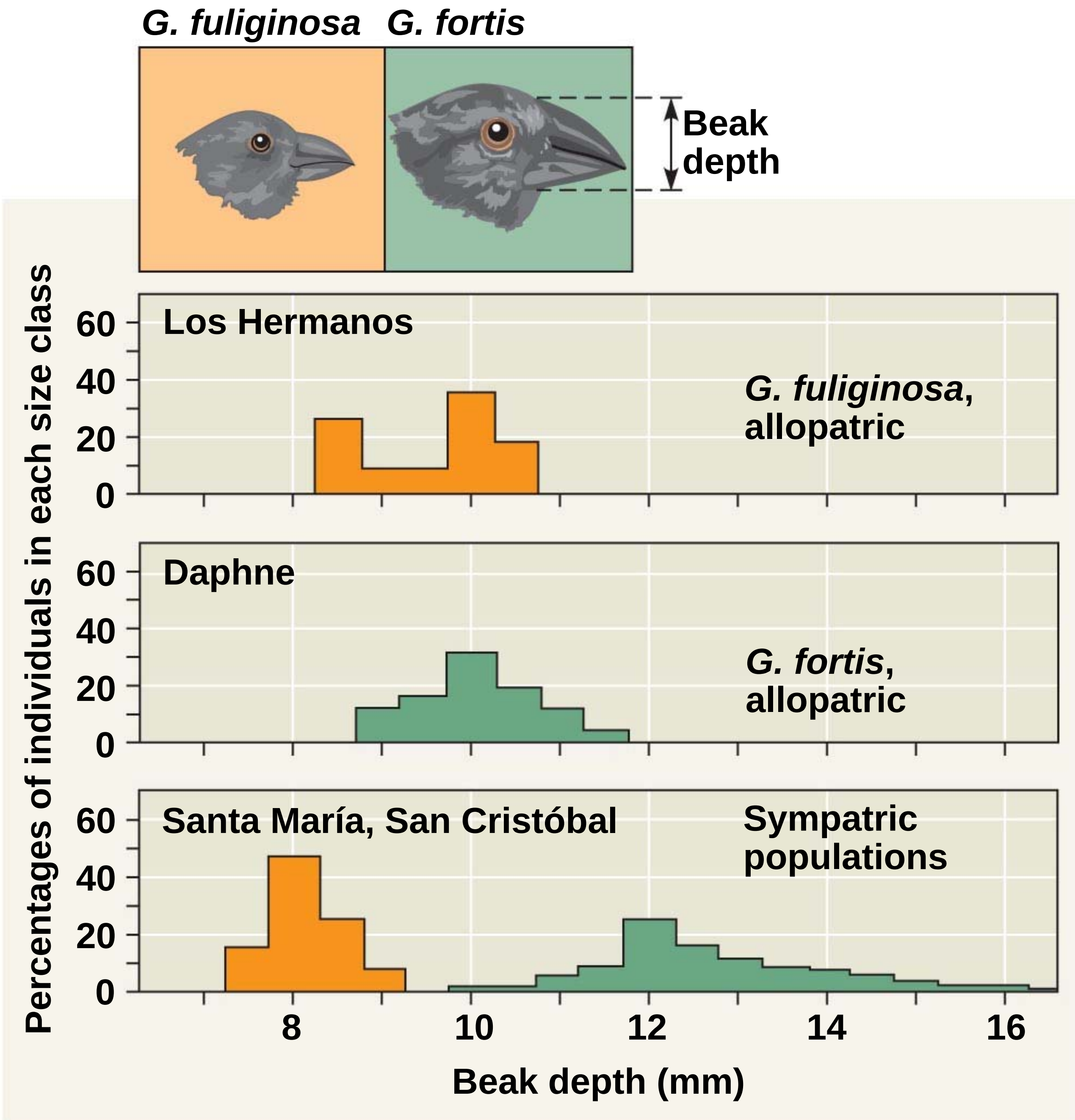
RESULTS



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

Fig. 54-4


G. fuliginosa
G. fortis
Beak depth
Los Hermanos
G. fuliginosa, allopatric
Daphne
G. fortis, allopatric
Santa María, San Cristóbal
Sympatric populations
Percentages of individuals in each size class
60
40
20
0
8
10
12
14
16
Beak depth (mm)

Predation

- **Predation** (+/– interaction) refers to interaction where one species, the predator, kills and eats the other, the prey
- Some feeding adaptations of predators are claws, teeth, fangs, stingers, 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
- **Cryptic coloration**, or camouflage, makes prey difficult to spot

PLAY Video: Seahorse Camouflage

Fig. 54-5

(a) Cryptic coloration

▶ Canyon tree frog

(b) Aposematic coloration

▶ Poison dart frog

(c) Batesian mimicry: A harmless species mimics a harmful one.

◀ Hawkmoth larva

▼ Green parrot snake

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

◀ Cuckoo bee

▼ Yellow jacket

Fig. 54-5a

(a) Cryptic coloration

- **Canyon tree frog**

- 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

Fig. 54-5b

(b) Aposematic coloration

- **Poison dart frog**

- 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

(c) Batesian mimicry: A harmless species mimics a harmful one.

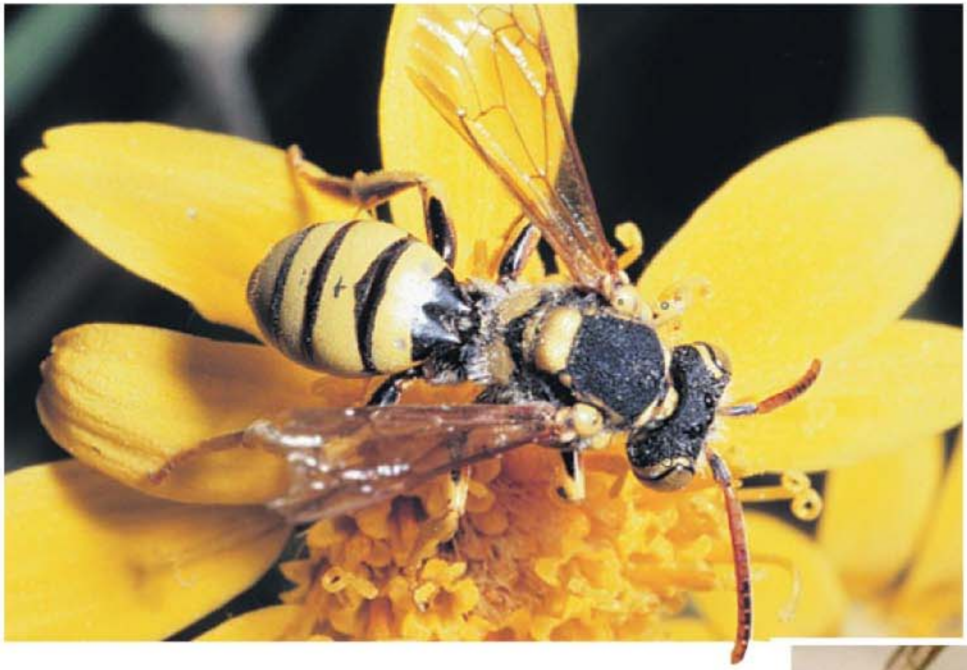
◀ **Hawkmoth larva**

▼ **Green parrot snake**

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

Fig. 54-5d

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



◀ Cuckoo bee

▼ Yellow jacket

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

Fig. 54-6

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 to increase their own fitness

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

PLAY Video: Clownfish and Anemone

Fig. 54-7

(a) Acacia tree and ants (genus *Pseudomyrmex*)

(b) Area cleared by ants at the base of an acacia tree

Fig. 54-7a

(a) Acacia tree and ants (genus *Pseudomyrmex*)

Fig. 54-7b

(b) Area cleared by ants at the base of an acacia tree

Commensalism

- In **commensalism** (+/0 interaction), one species benefits and the other is apparently unaffected
- Commensal interactions are hard to document in nature because any close association likely affects both species

Fig. 54-8

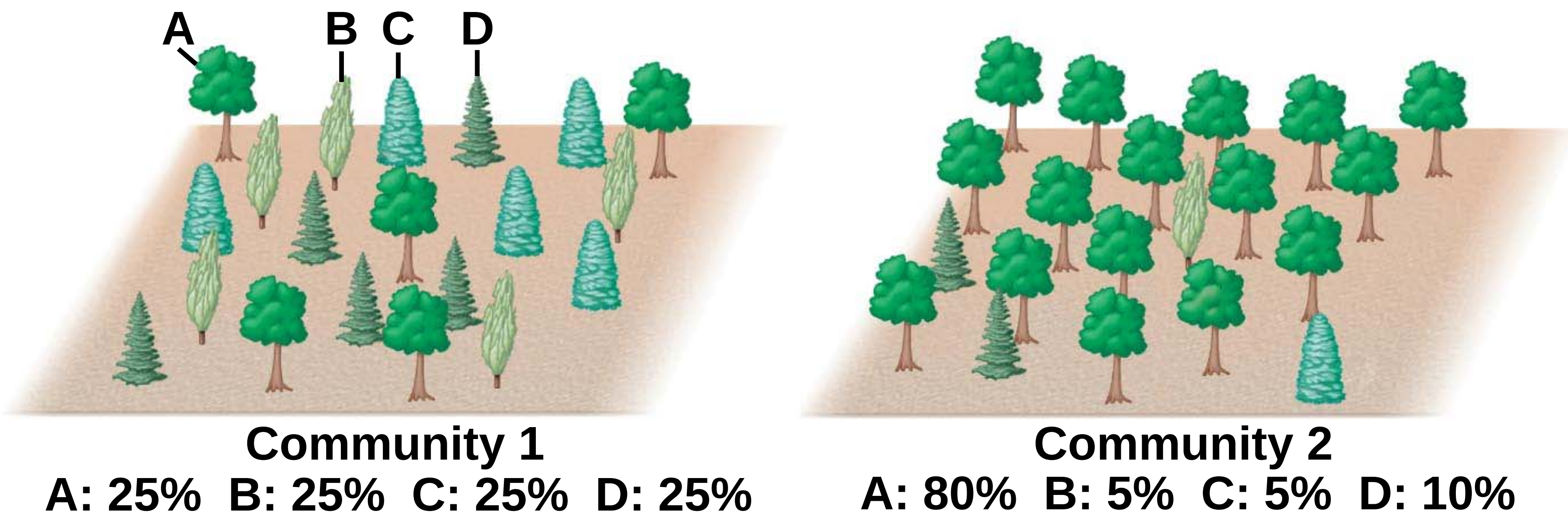
Concept 54.2: Dominant and keystone species exert strong controls on community structure

- 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 total number of different species in the community
- **Relative abundance** is the proportion each species represents of the total individuals in the community

Fig. 54-9



- Two communities can have the same species richness but a different relative abundance

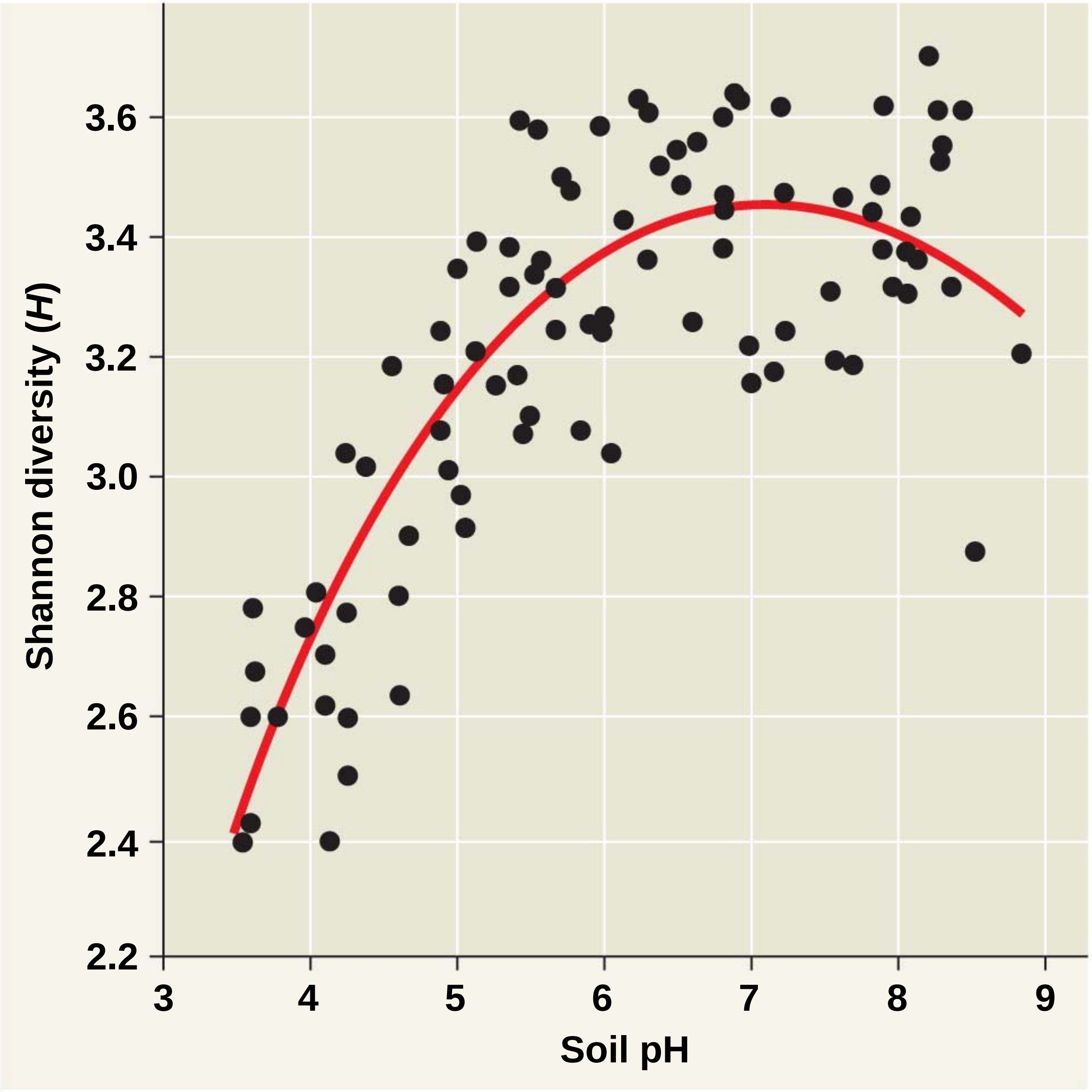
- Diversity can be compared using a diversity index
  - **Shannon diversity** index (H):

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

- 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

Fig. 54-10

RESULTS



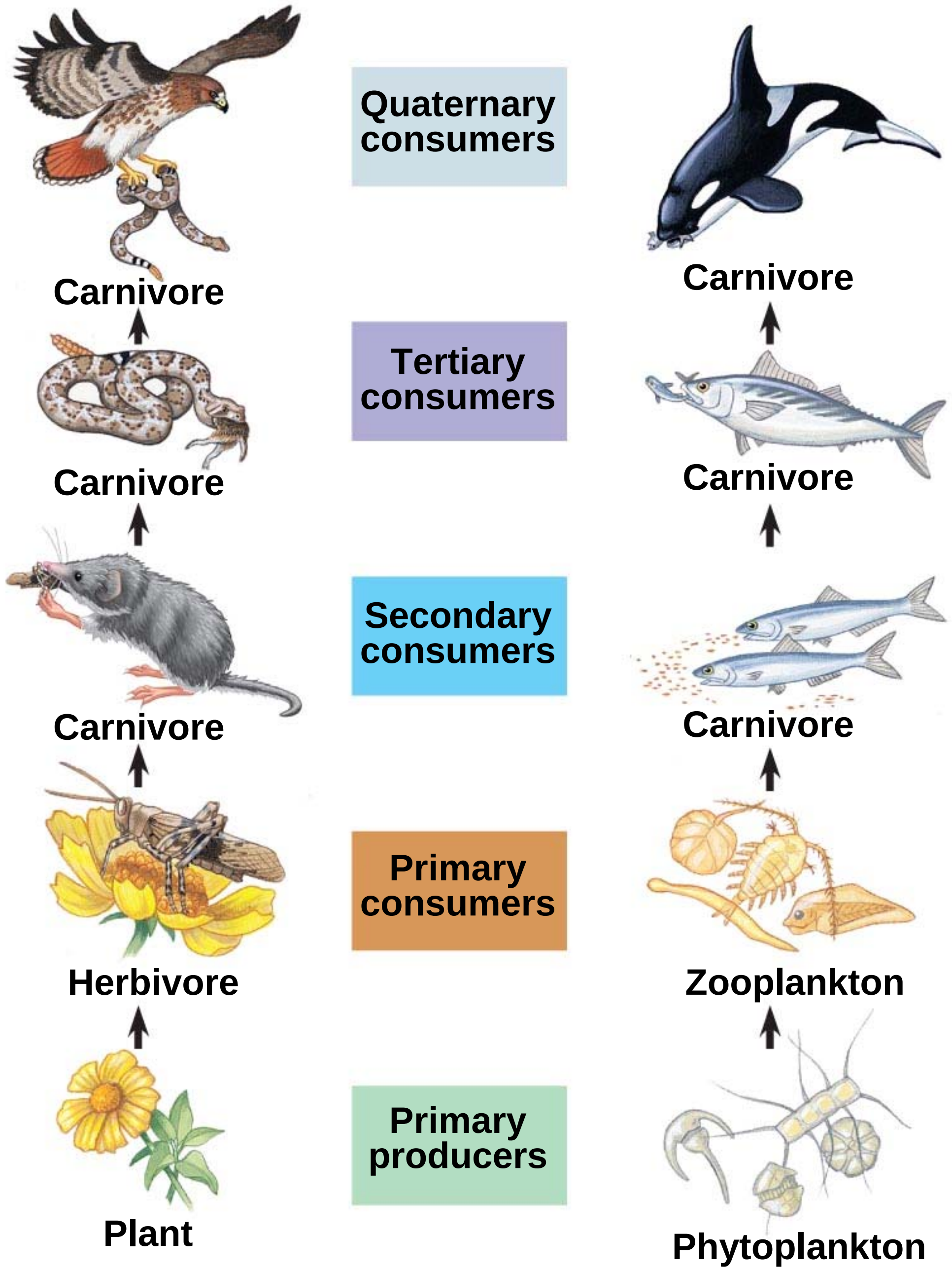
Trophic Structure

- **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

PLAY

Video: Shark Eating a Seal

Fig. 54-11



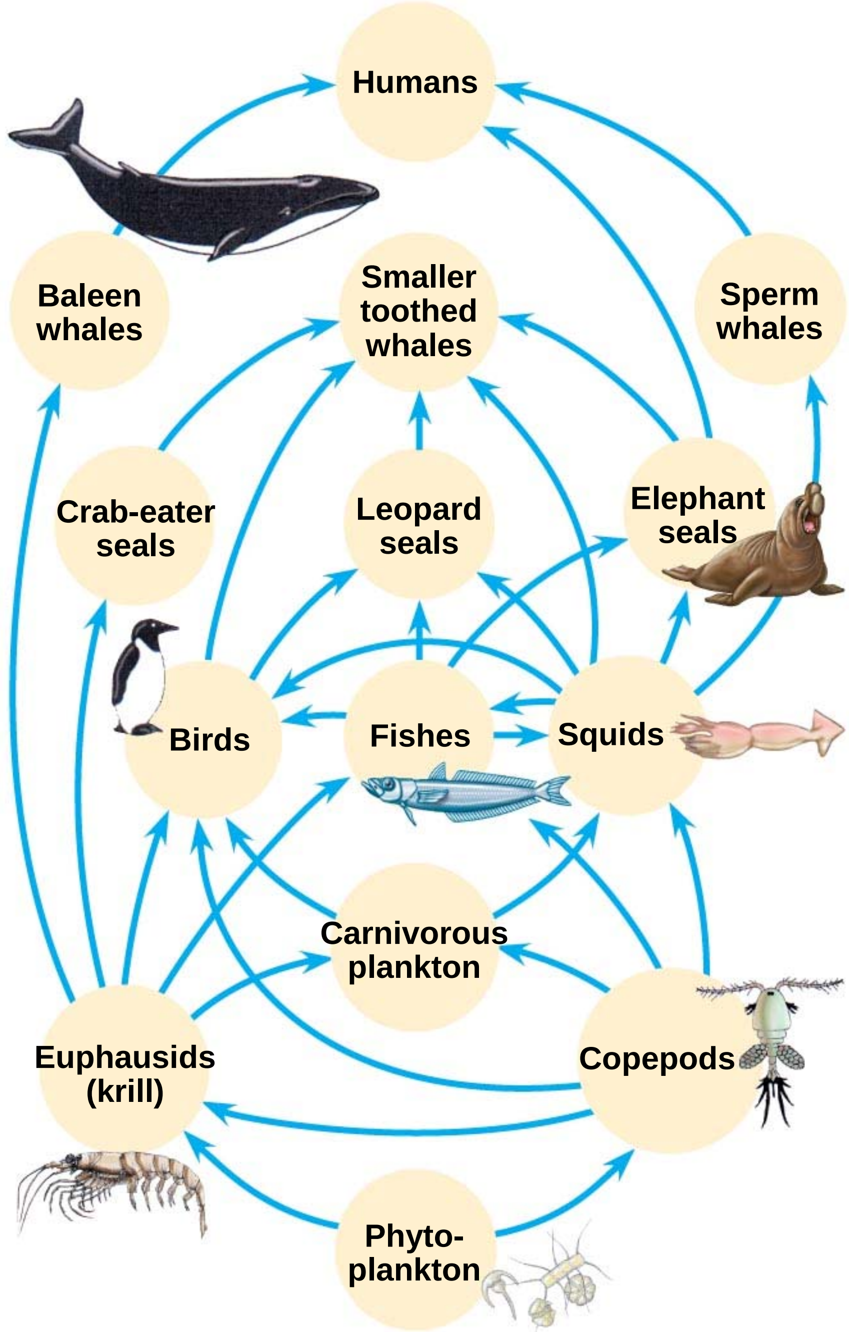
A terrestrial food chain

A marine food chain

Food Webs

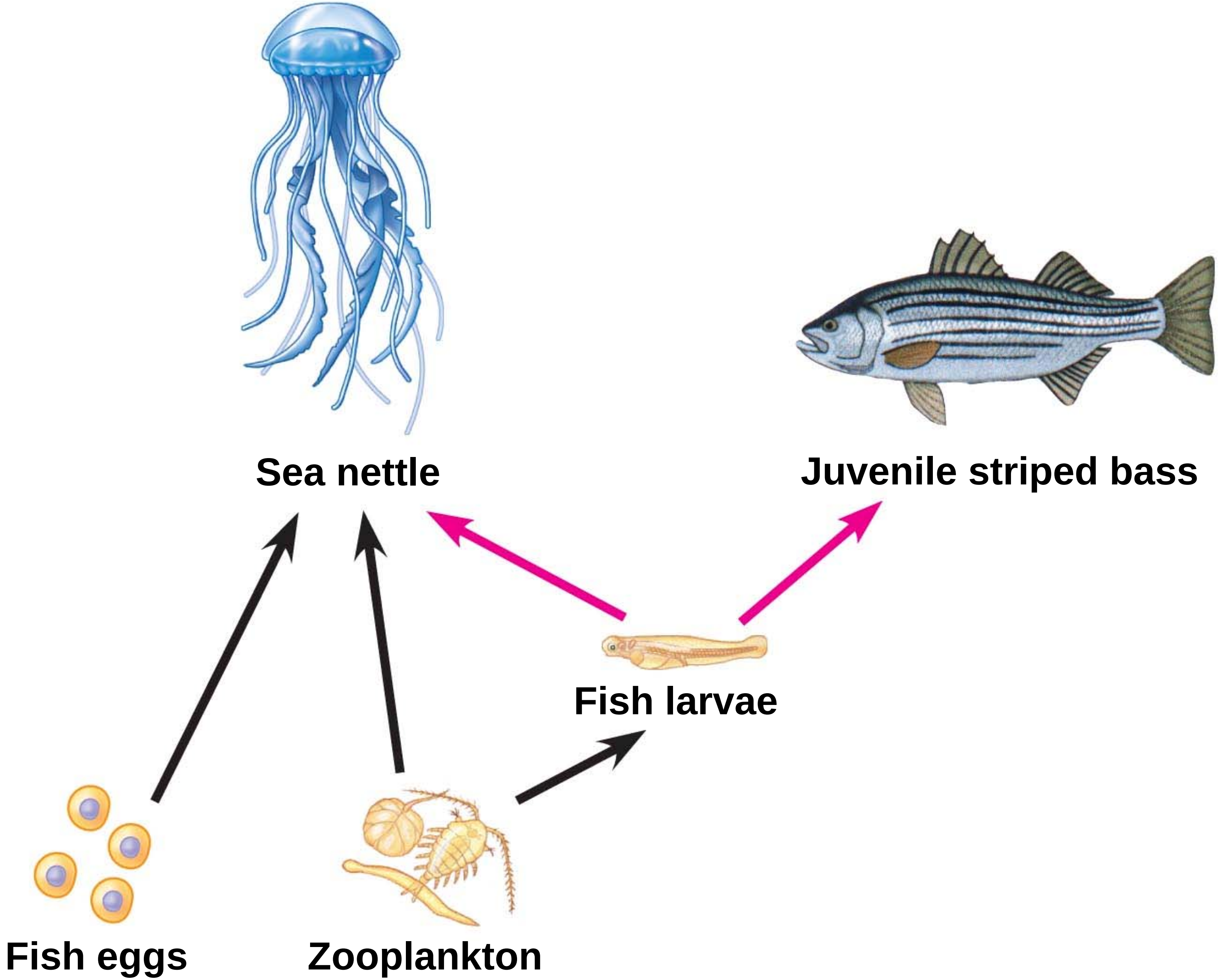
- A **food web** is a branching food chain with complex trophic interactions

Fig. 54-12


Humans
Baleen whales
Smaller toothed whales
Sperm whales
Crab-eater seals
Leopard seals
Elephant seals
Birds
Fishes
Squids
Carnivorous plankton
Euphausids (krill)
Copepods
Phyto-plankton

- Species may play a role at more than one trophic level
- Food webs can be simplified by isolating a portion of a community that interacts very little with the rest of the community

Fig. 54-13

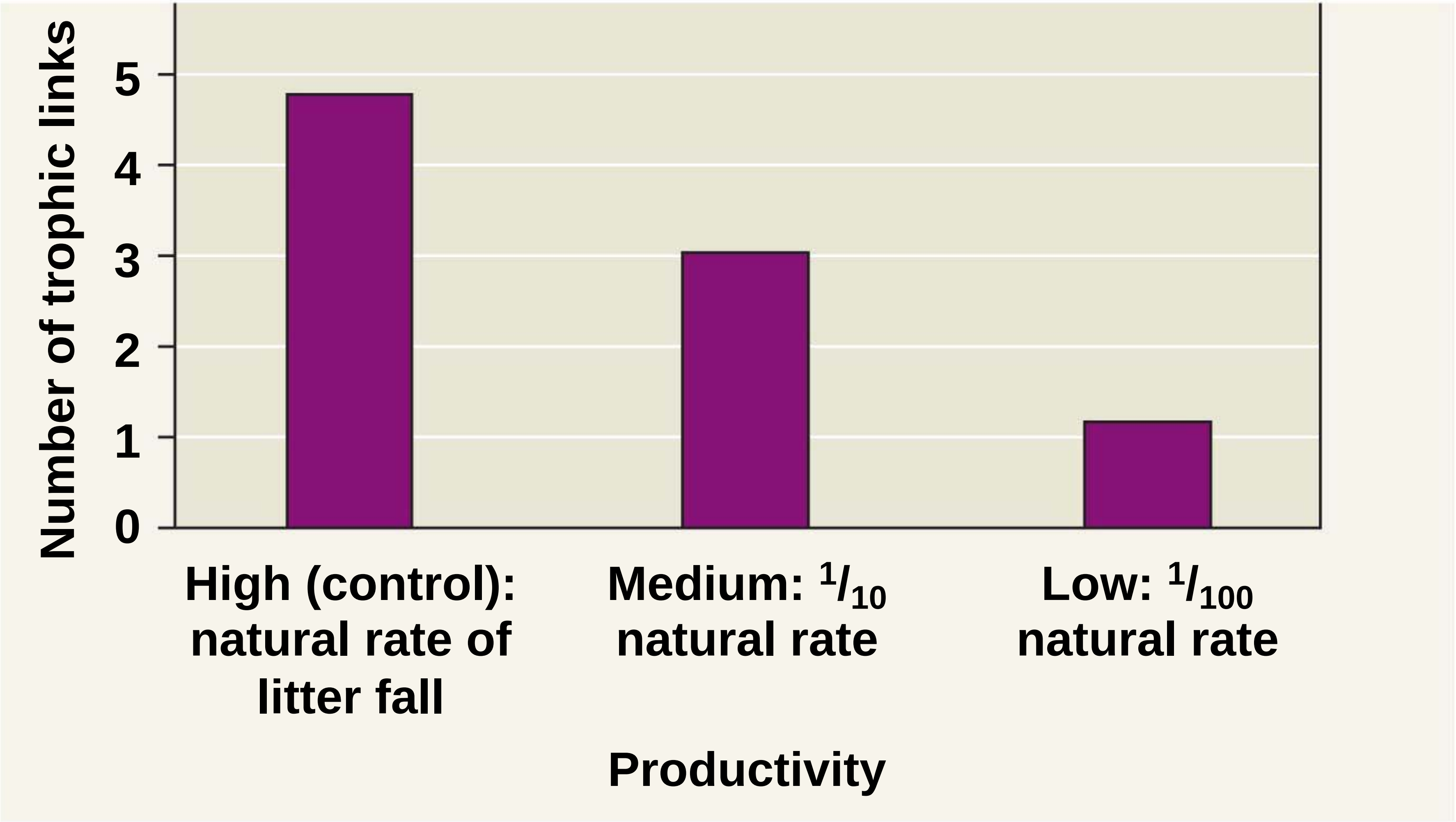

Sea nettle
Juvenile striped bass
Fish larvae
Fish eggs
Zooplankton

Limits on Food Chain Length

- Each food chain in a food web is usually only a few links long
- Two hypotheses attempt to explain food chain length: the energetic hypothesis and the dynamic stability hypothesis

- The **energetic hypothesis** suggests that length is limited by inefficient energy transfer
- The **dynamic stability hypothesis** proposes that long food chains are less stable than short ones
- Most data support the energetic hypothesis

Fig. 54-14


Number of trophic links
5
4
3
2
1
0
High (control): natural rate of litter fall
Medium: 1/10 natural rate
Low: 1/100 natural rate
Productivity

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

- **Dominant species** are those that are most abundant or have the highest biomass
- Biomass is the total mass of all individuals in a population
- Dominant species exert powerful control over the occurrence and distribution of other species

- 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, often lack predators or disease

Keystone Species

- **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 exhibit their role as a keystone species in intertidal communities

Fig. 54-15

EXPERIMENT

RESULTS

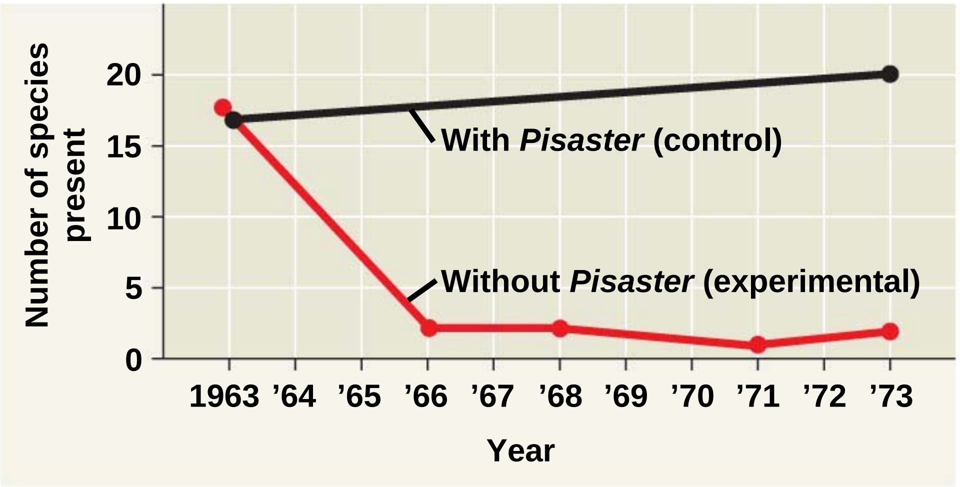
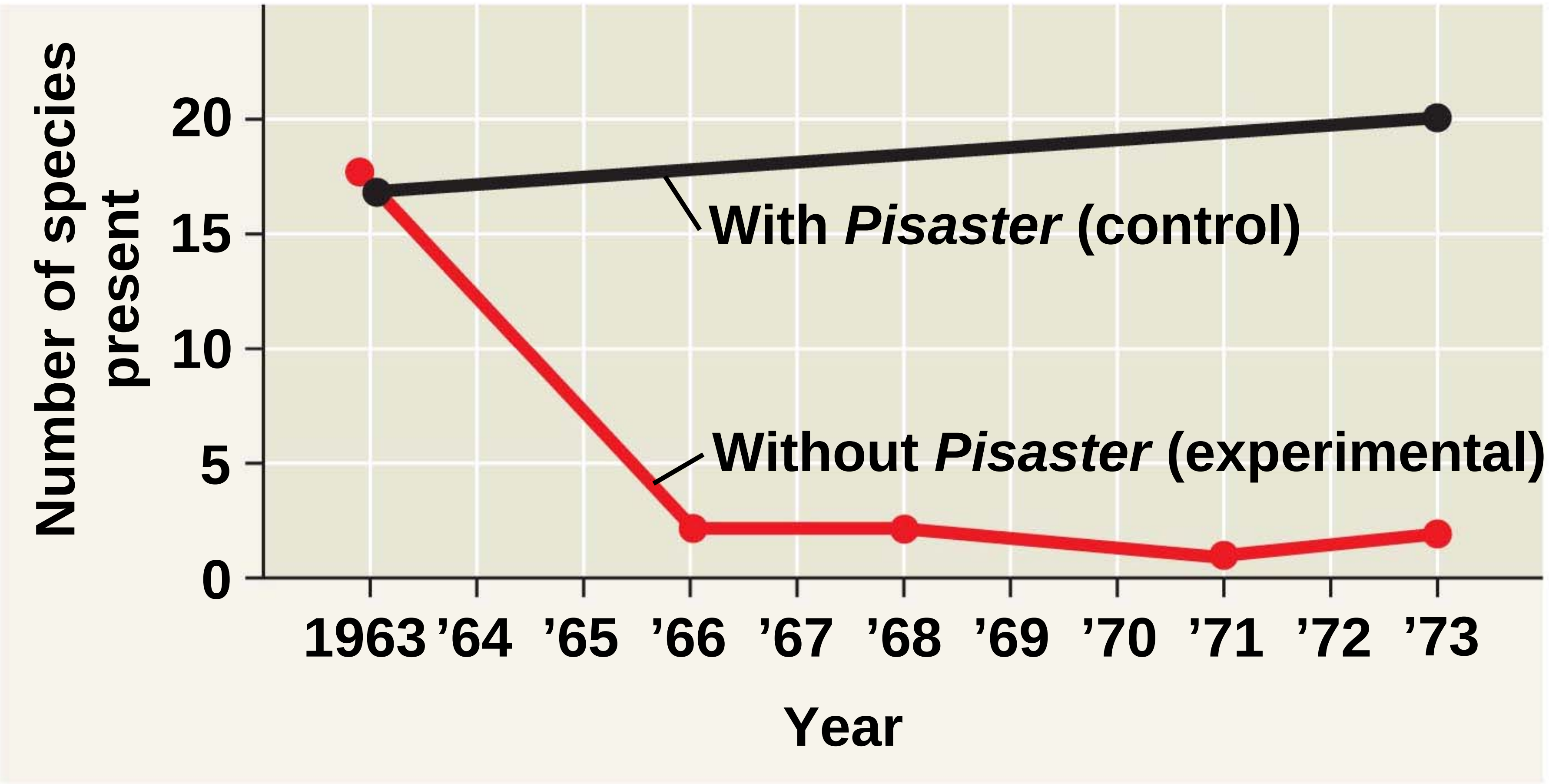


Fig. 54-15a

EXPERIMENT

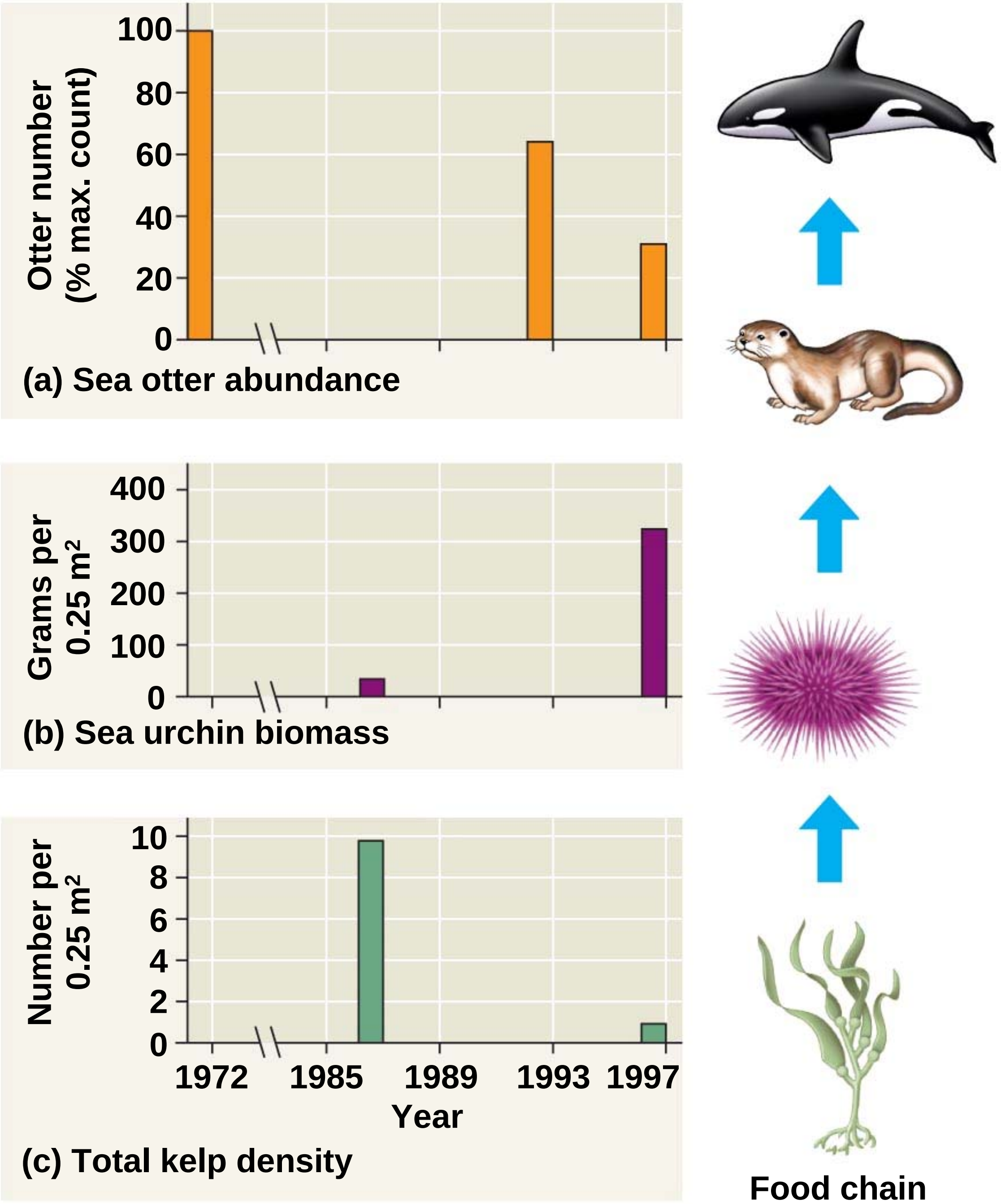
Fig. 54-15b

RESULTS



- Observation of sea otter populations and their predation shows how otters affect ocean communities

Fig. 54-16



Otter number (% max. count)
100
80
60
40
20
0
(a) Sea otter abundance
Grams per 0.25 m²
400
300
200
100
0
(b) Sea urchin biomass
Number per 0.25 m²
10
8
6
4
2
0
1972
1985
1989
1993
1997
Year
(c) Total kelp density
Food chain

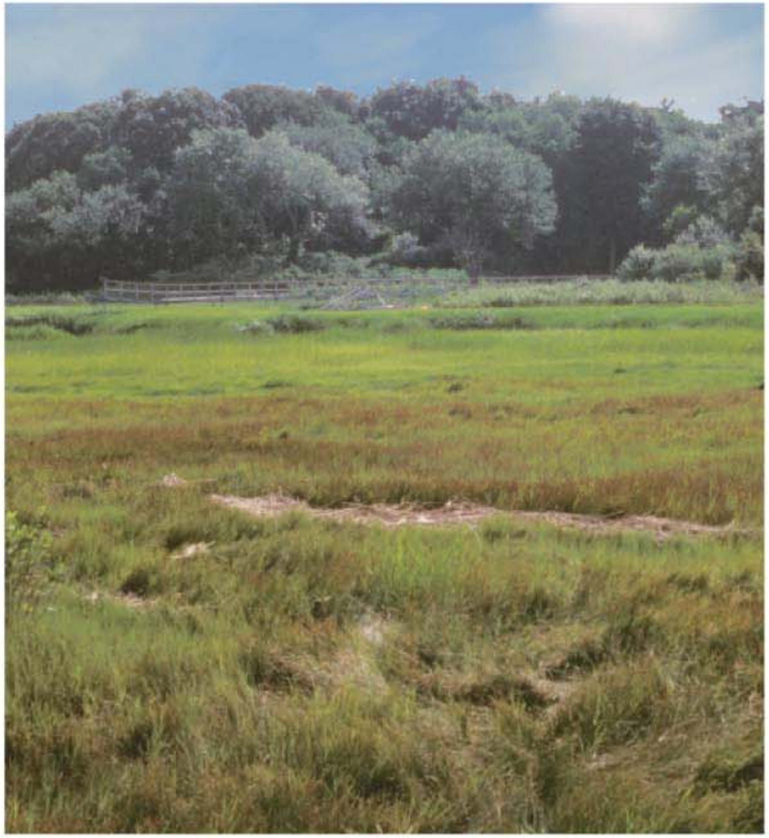
Foundation Species (Ecosystem "Engineers")

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

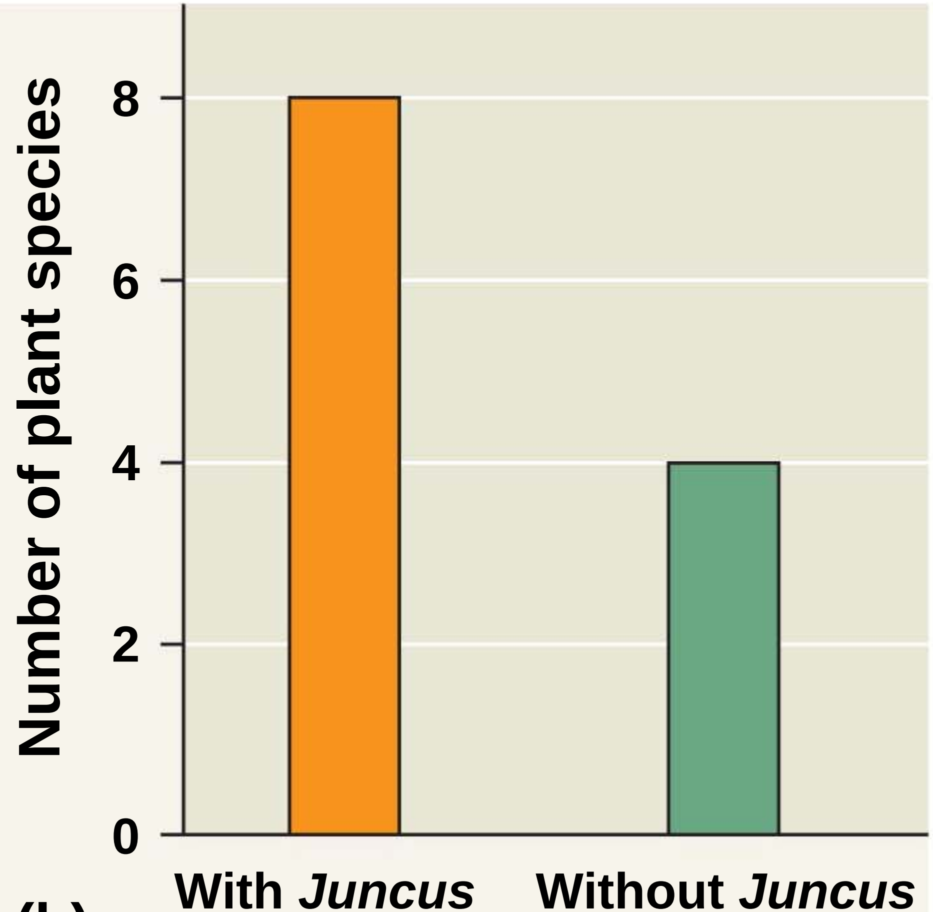
Fig. 54-17

- Some foundation species act as **facilitators** that have positive effects on survival and reproduction of some other species in the community

Fig. 54-18

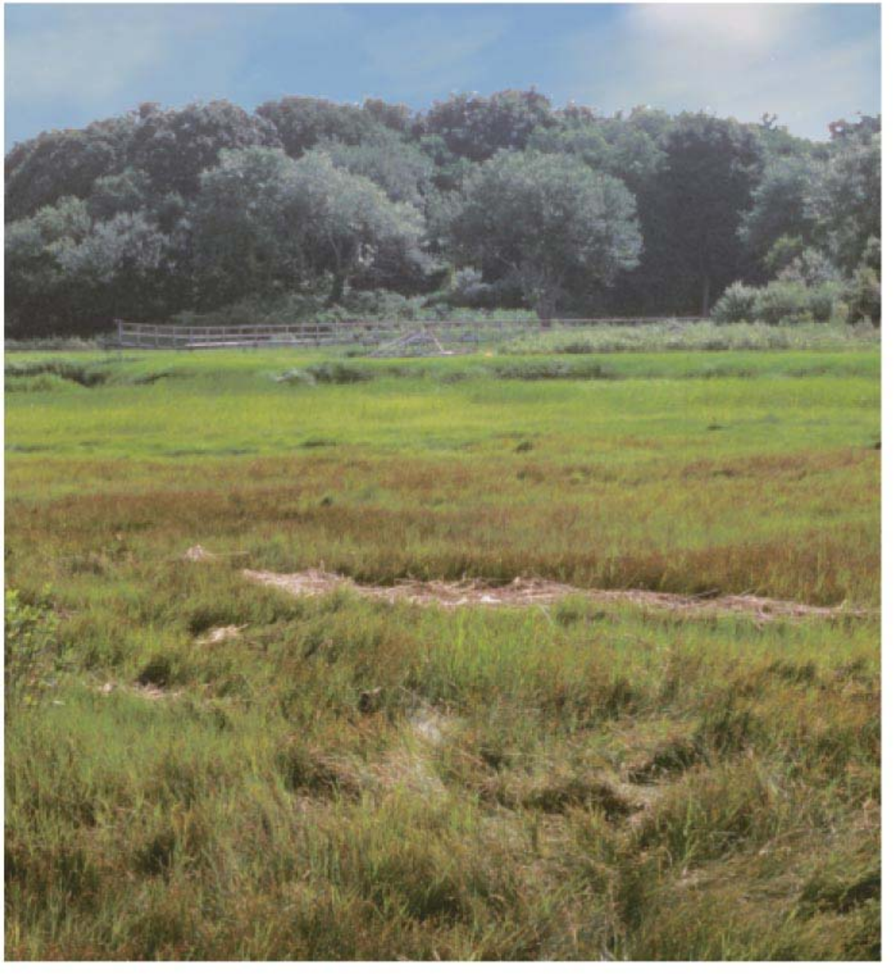


(a) Salt marsh with *Juncus* (foreground)



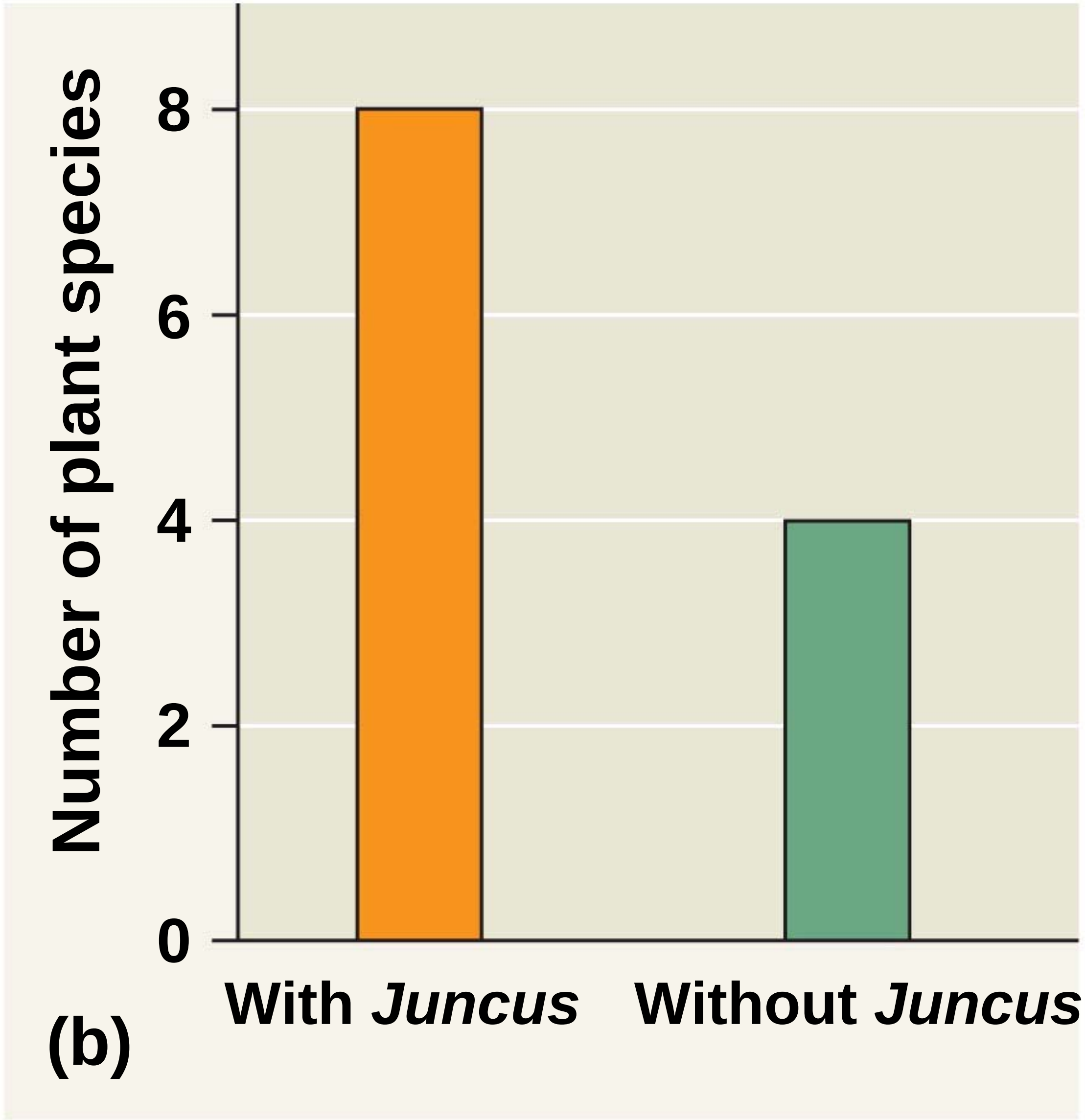
(b)

Fig. 54-18a



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

Fig. 54-18b



Bottom-Up and Top-Down Controls

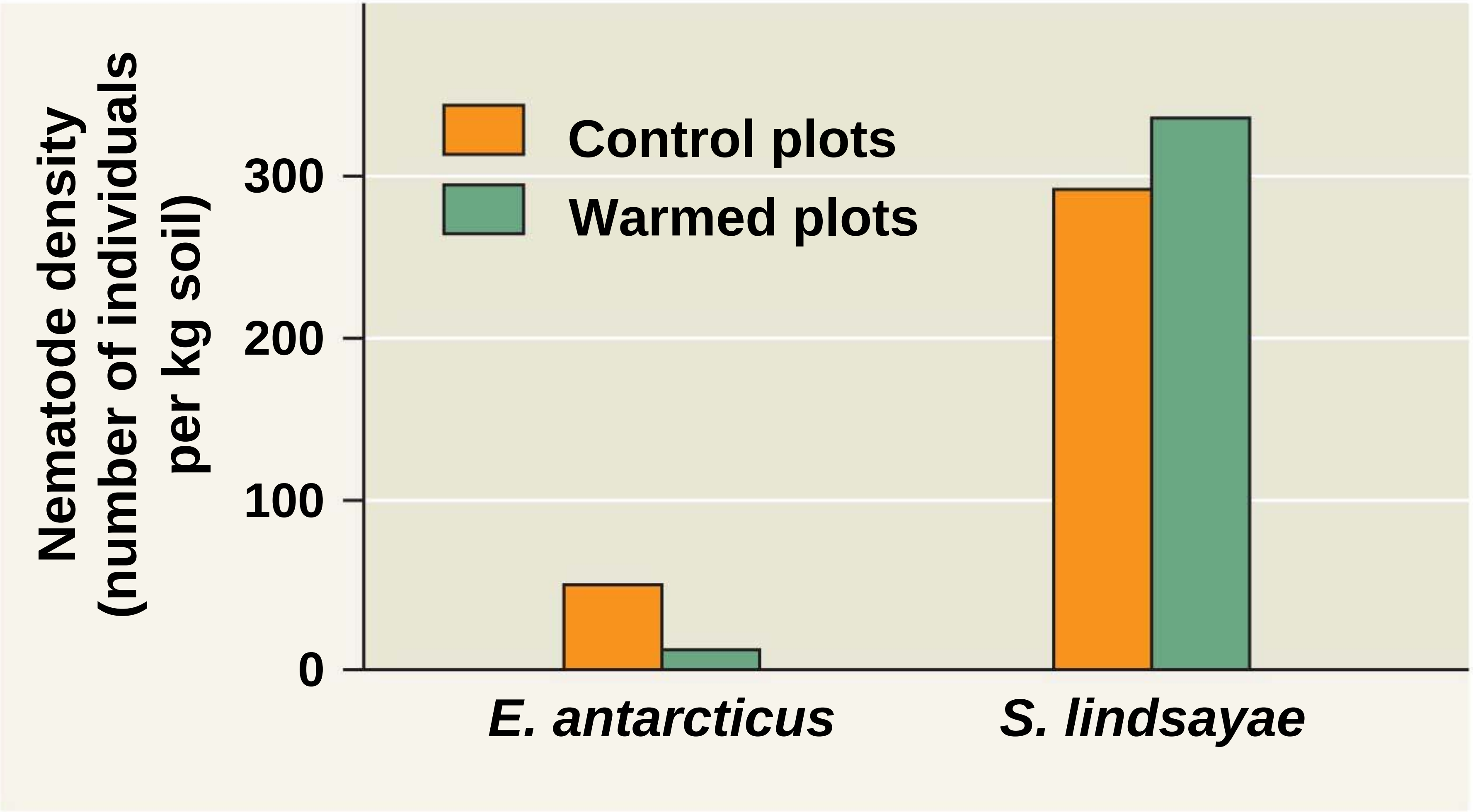
- The **bottom-up model** of community organization proposes a unidirectional influence from lower to higher trophic levels
- In this case, presence or absence of mineral nutrients determines community structure, including abundance of primary producers

- The **top-down model**, also called the trophic cascade model, proposes that control comes from the trophic level above
- In this case, predators control herbivores, which in turn control primary producers

- Long-term experimental studies have shown that communities vary in their relative degree of bottom-up to top-down control

Fig. 54-19

RESULTS



- Pollution can affect community dynamics
- **Biomanipulation** can help restore polluted communities

Fig. 54-UN1

	Polluted State	Restored State
Fish	Abundant	Rare
Zooplankton	Rare	Abundant
Algae	Abundant	Rare

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 species in a climax community function as a superorganism

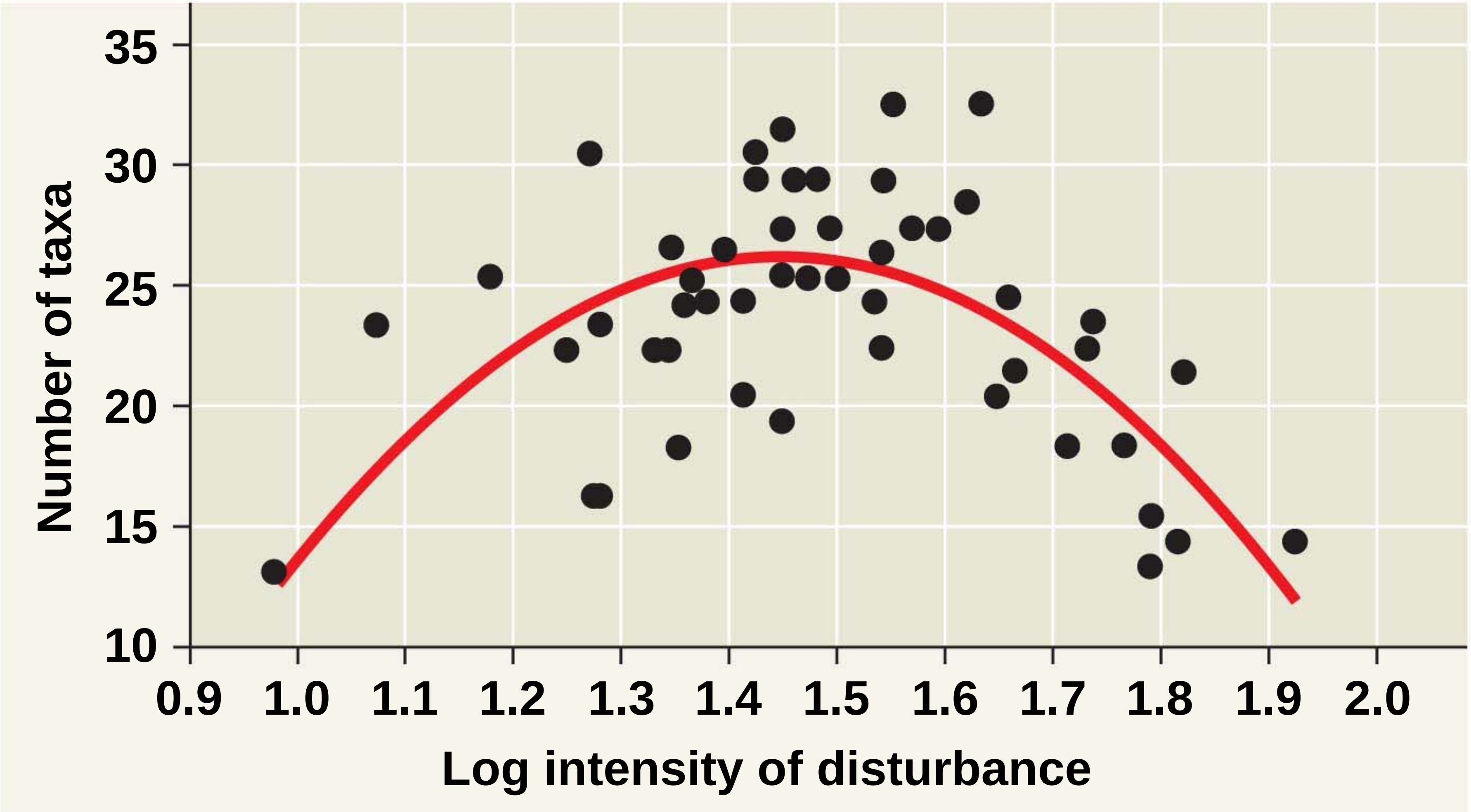
- Other ecologists, including A. G. Tansley and H. A. Gleason, challenged whether communities were at equilibrium
- Recent evidence of change has led to a **nonequilibrium model**, which describes communities as constantly changing after being buffeted by **disturbances**

Characterizing Disturbance

- A disturbance is an event that changes a community, removes organisms from it, and alters resource availability
- Fire is a significant disturbance in most terrestrial ecosystems
- It is often a necessity in some communities

- The **intermediate disturbance hypothesis** suggests 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

Fig. 54-20


35
30
25
20
15
10
Number of taxa
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
Log intensity of disturbance

- The large-scale fire in Yellowstone National Park in 1988 demonstrated that communities can often respond very rapidly to a massive disturbance

Fig. 54-21

(a) Soon after fire

(b) One year after fire

Fig. 54-21a

(a) Soon after fire

Fig. 54-21b

(b) One year after fire

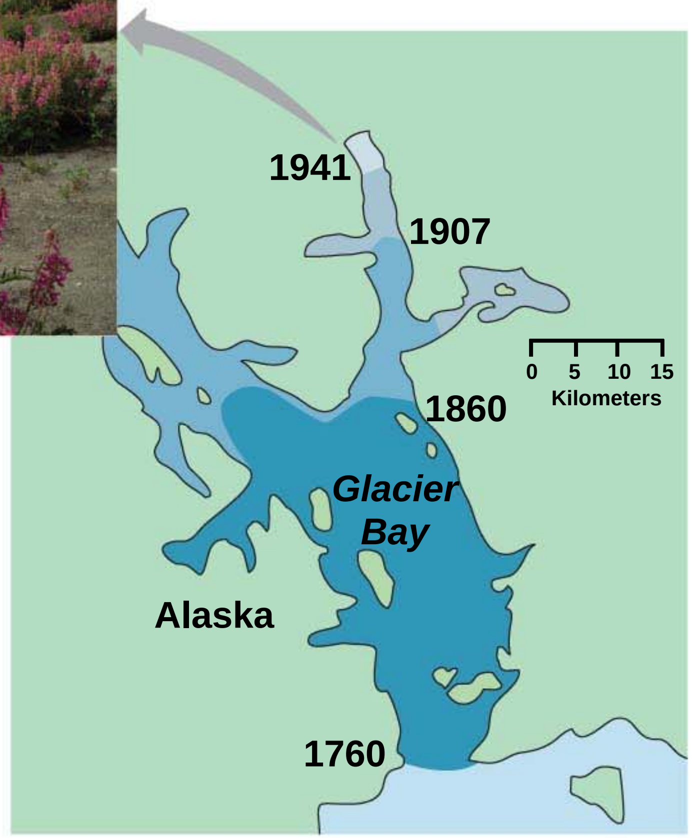
Ecological Succession

- **Ecological succession** is the sequence of community and ecosystem changes after a disturbance
- **Primary succession** occurs where no soil exists when succession begins
- **Secondary succession** begins in an area where soil remains after a disturbance

- Early-arriving species and later-arriving species may be linked in one of three processes:
  - Early arrivals may facilitate appearance of later species by making the environment favorable
  - They may inhibit 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 succession
- Succession on the moraines in Glacier Bay, Alaska, follows a predictable pattern of change in vegetation and soil characteristics

Fig. 54-22-1



1 **Pioneer stage, with fireweed dominant**

Fig. 54-22-2

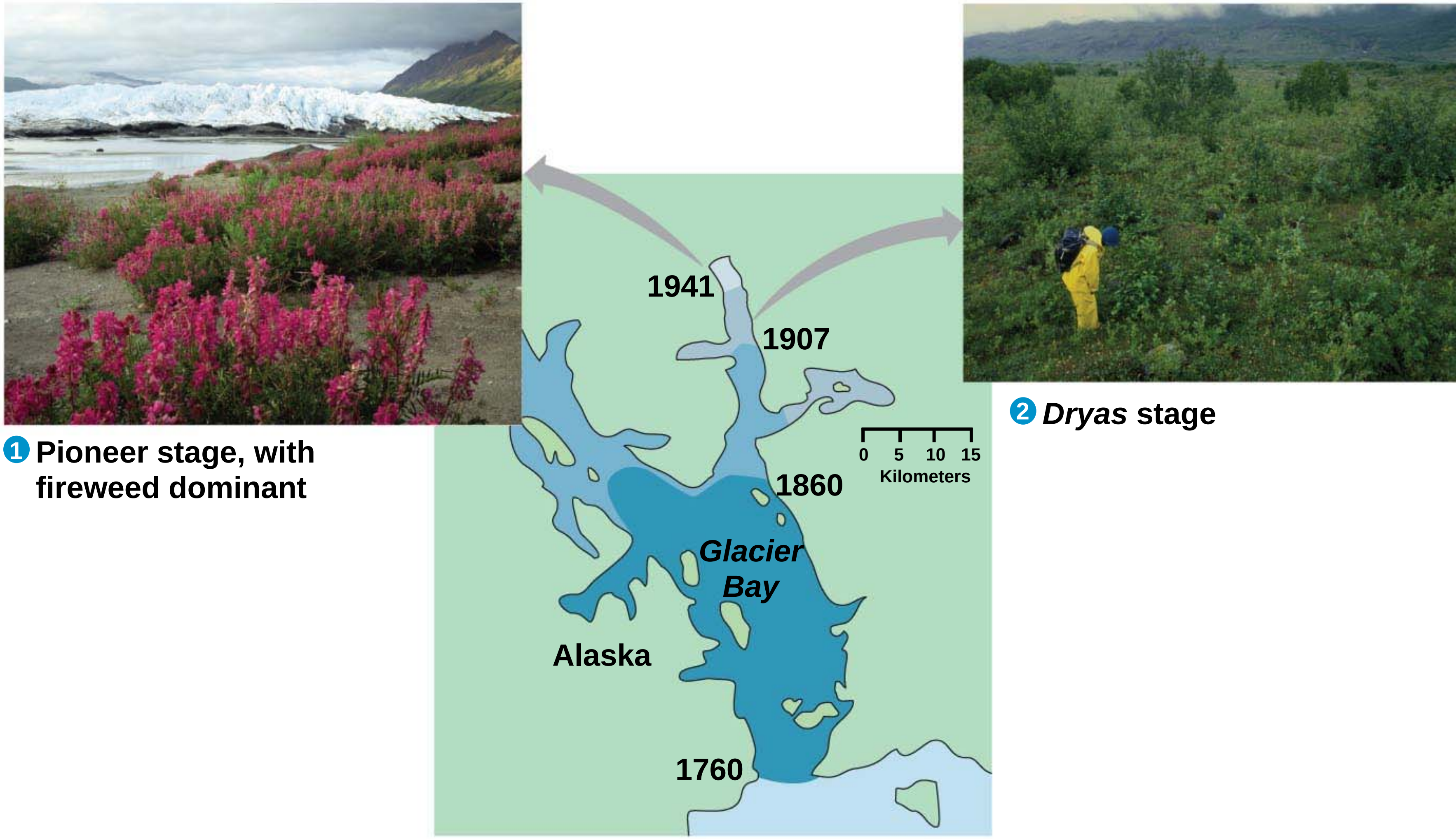
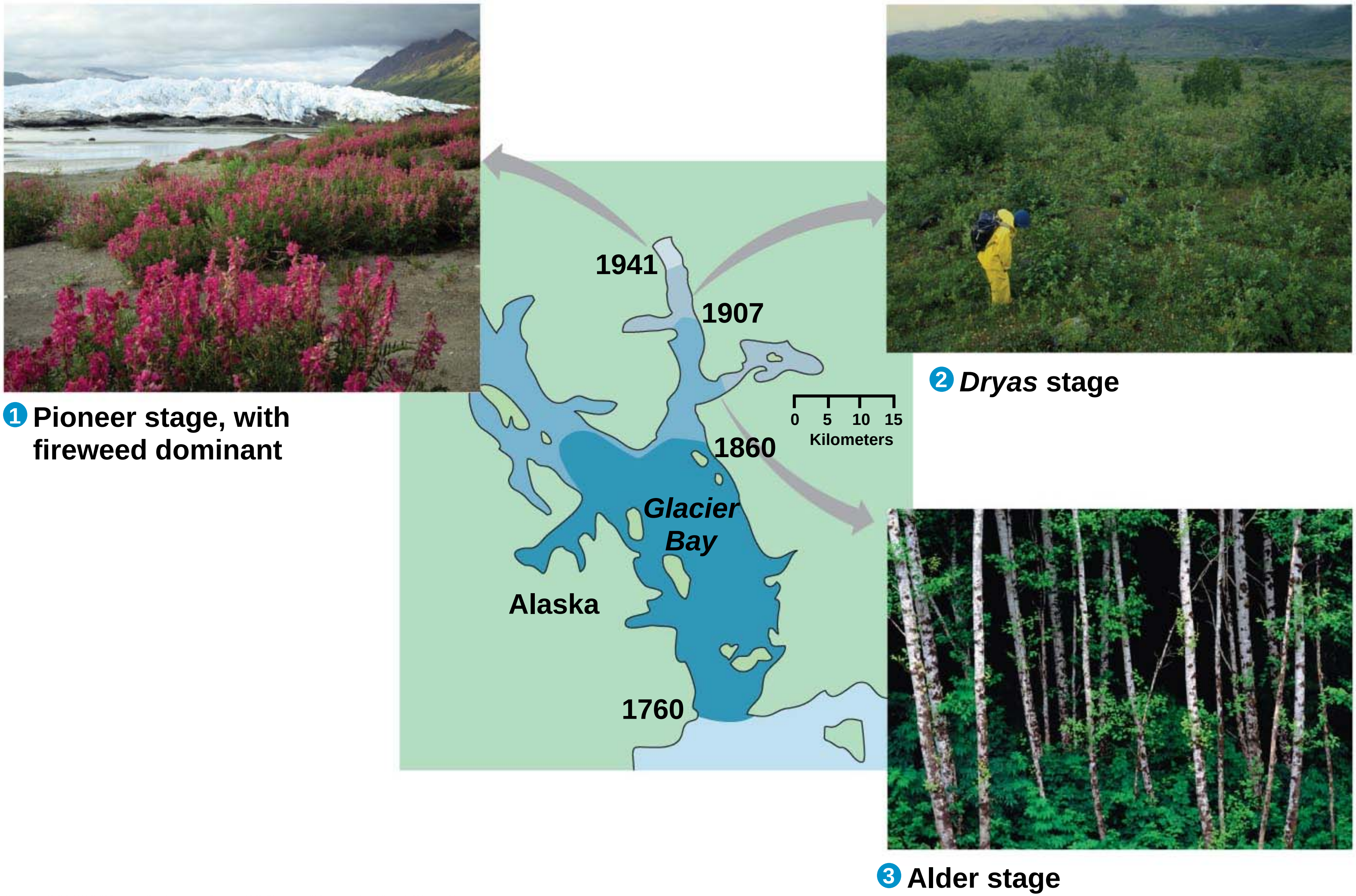
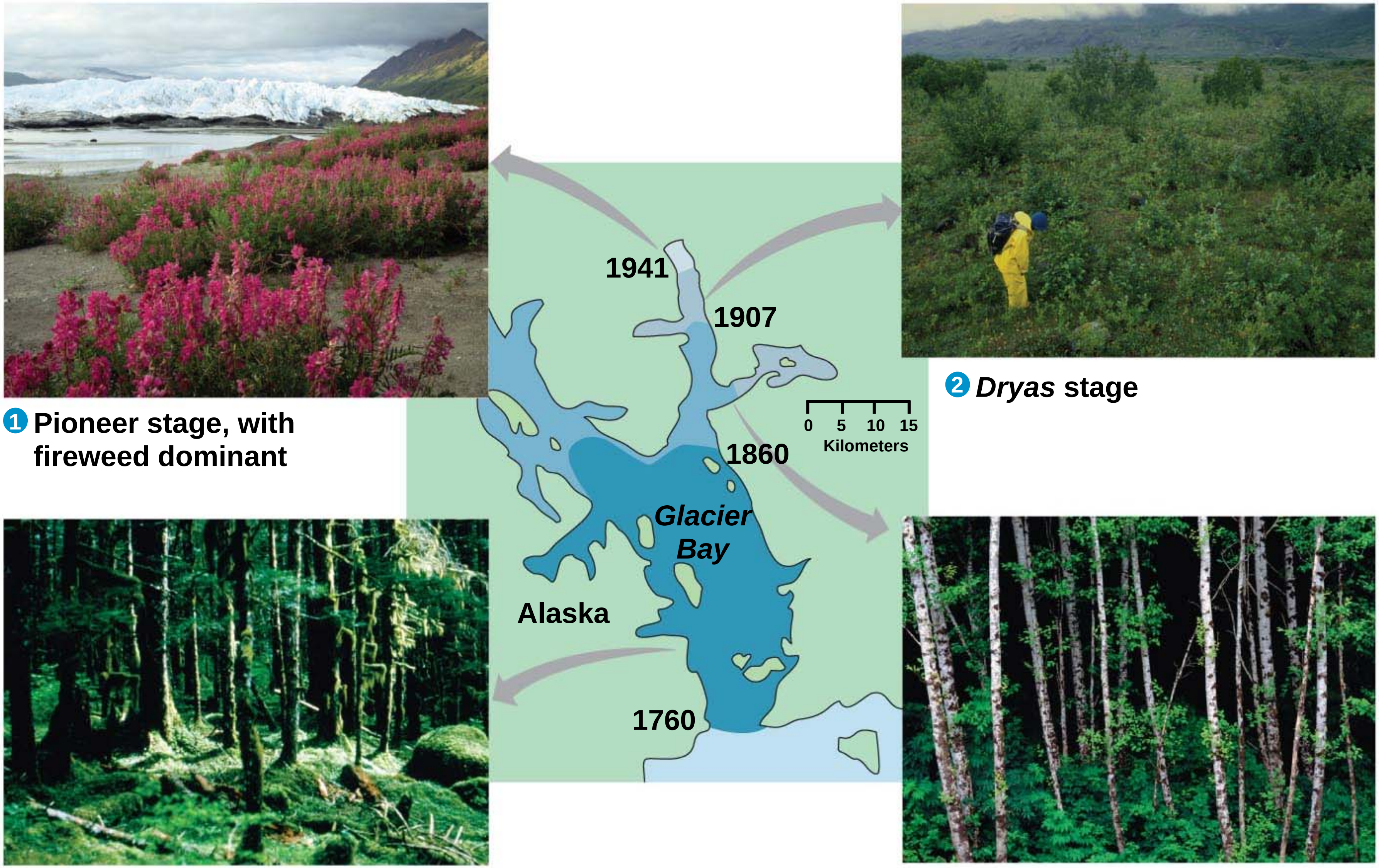

1 Pioneer stage, with fireweed dominant
2 *Dryas* stage
1941
1907
1860
1760
0 5 10 15
Kilometers
Glacier Bay
Alaska

Fig. 54-22-3



1 Pioneer stage, with fireweed dominant
2 *Dryas* stage
3 Alder stage
1941
1907
1860
1760
Glacier Bay
Alaska
0 5 10 15
Kilometers

Fig. 54-22-4



1 Pioneer stage, with fireweed dominant

2 *Dryas* stage

3 Alder stage

4 Spruce stage

Fig. 54-22a

1 **Pioneer stage, with fireweed dominant**

Fig. 54-22b

2 *Dryas* stage

Fig. 54-22c

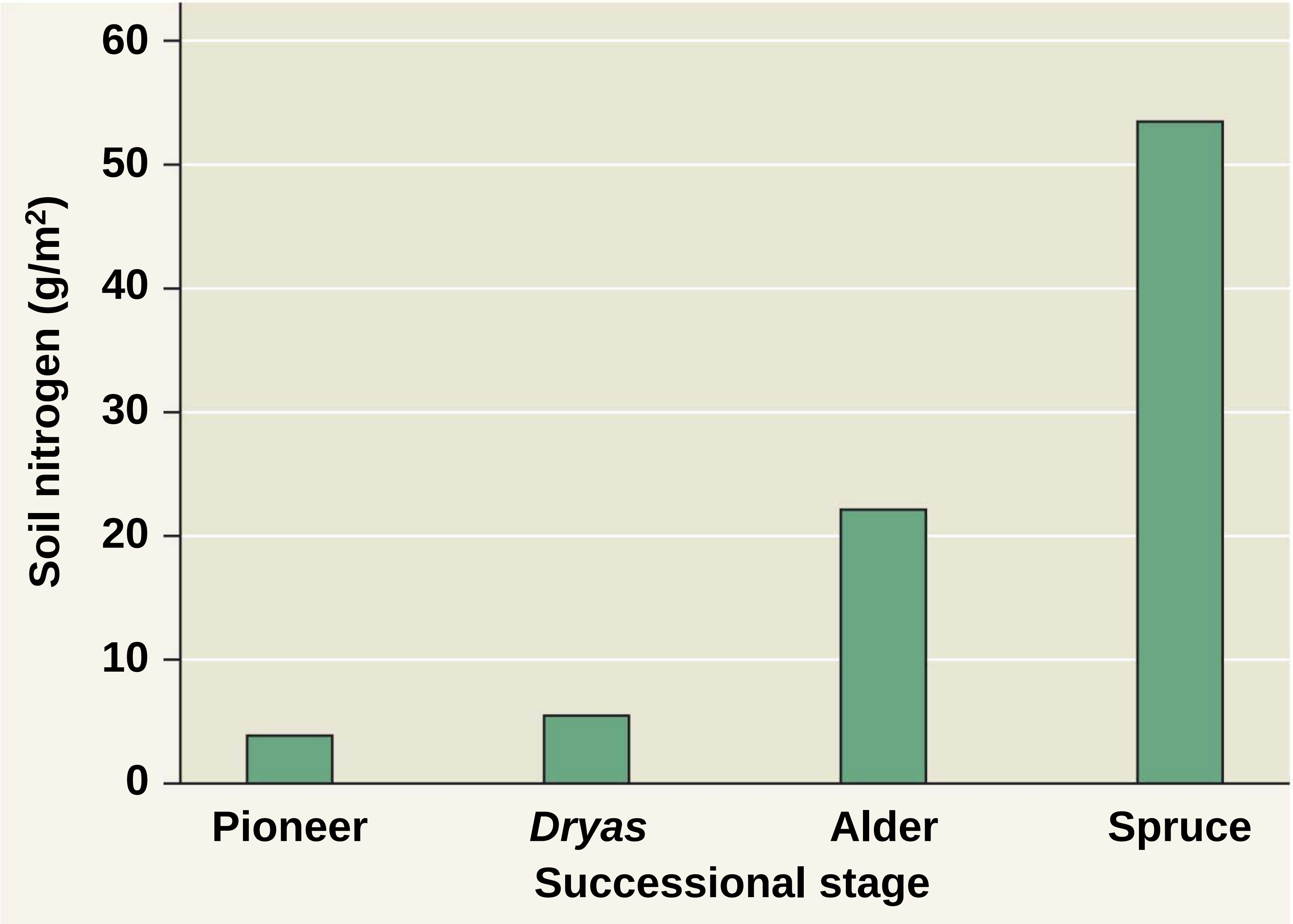
3 **Alder stage**

Fig. 54-22d

4 **Spruce stage**

- Succession is the result of changes induced by the vegetation itself
- On the glacial moraines, vegetation lowers the soil pH and increases soil nitrogen content

Fig. 54-23



Soil nitrogen (g/m²)
60
50
40
30
20
10
0
Pioneer
Dryas
Alder
Spruce
Successional stage

Human Disturbance

- Humans have the greatest impact on biological communities worldwide
- Human disturbance to communities usually reduces species diversity
- Humans also prevent some naturally occurring disturbances, which can be important to community structure

Fig. 54-24

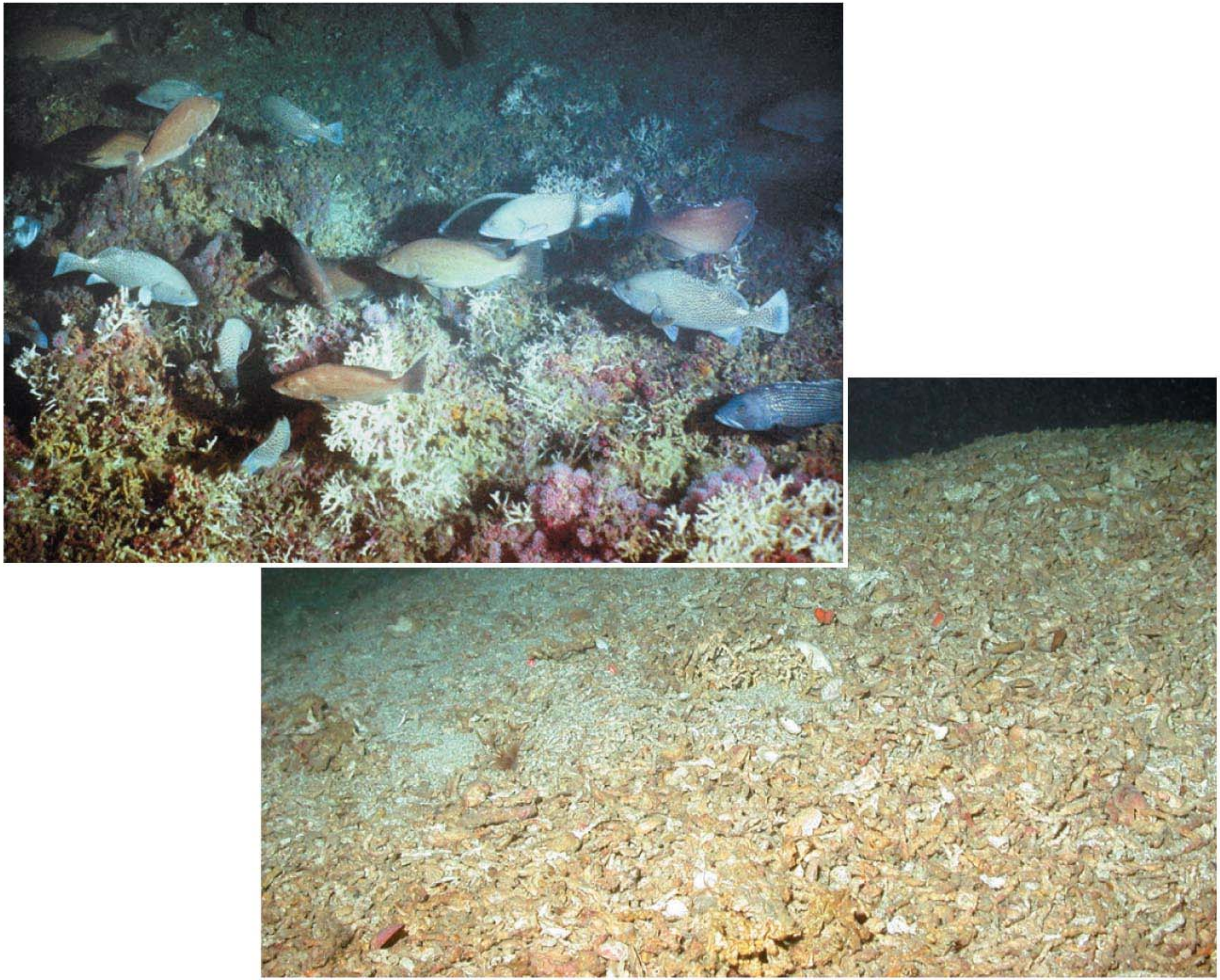
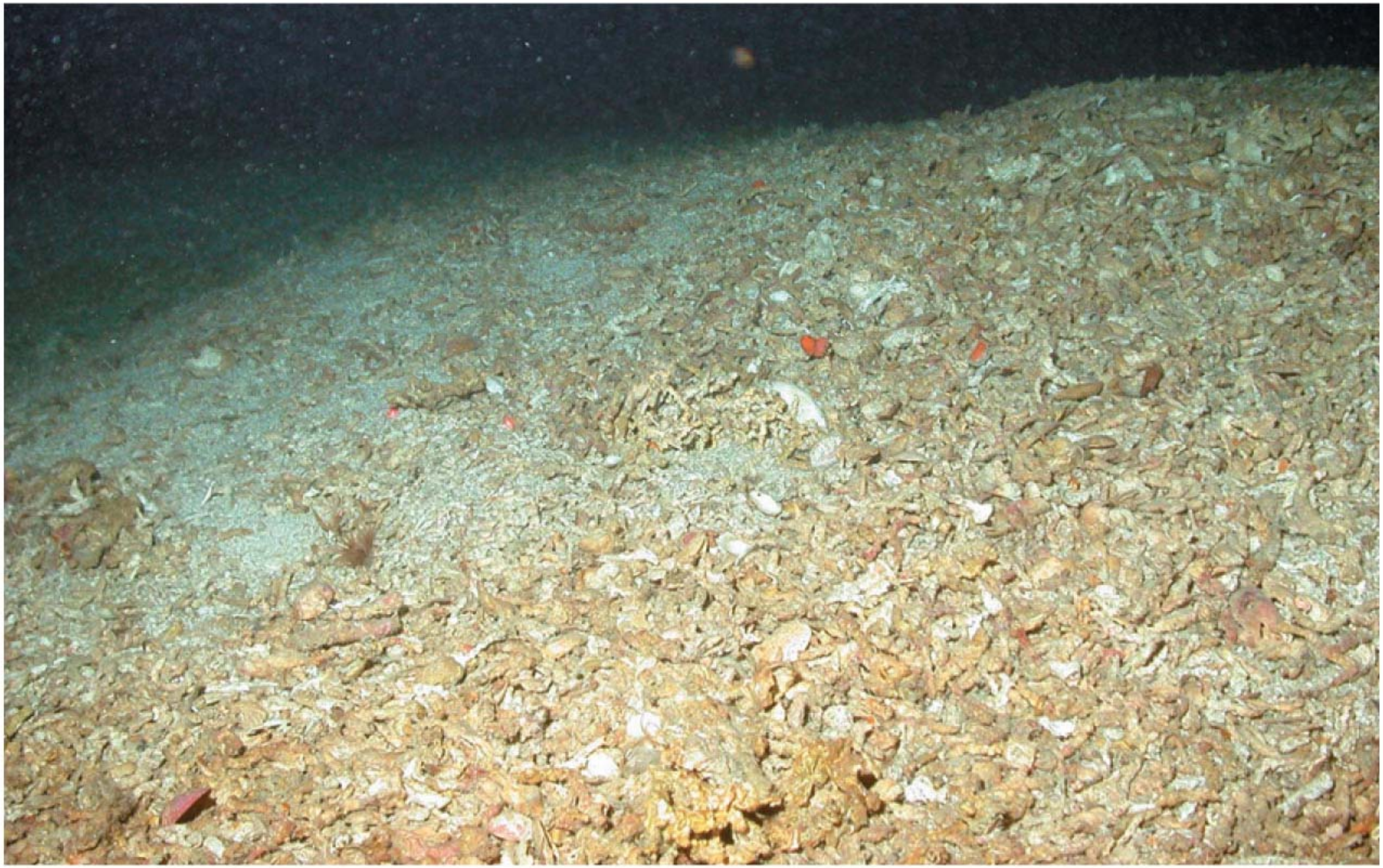


Fig. 54-24a

Fig. 54-24b



Concept 54.4: Biogeographic factors affect community biodiversity

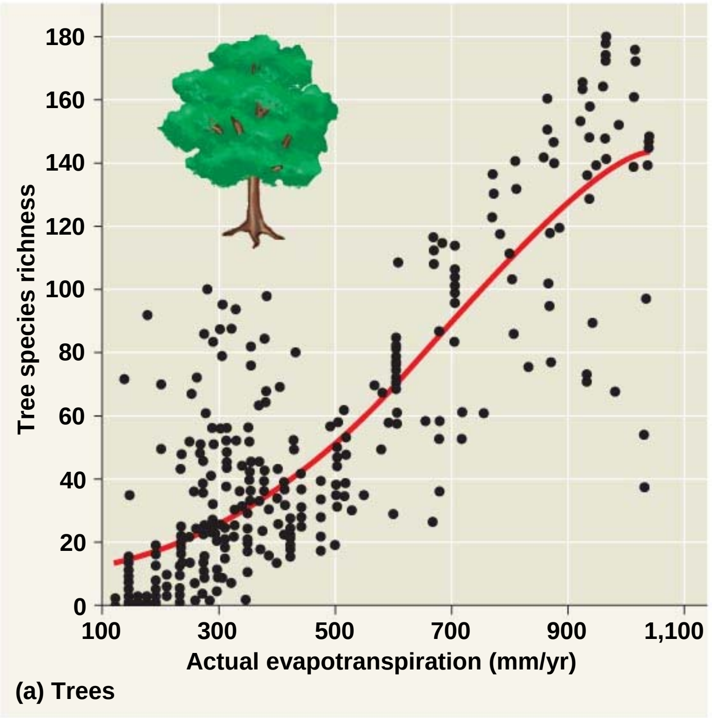
- Latitude and area are two key factors that affect a community’s species diversity

Latitudinal Gradients

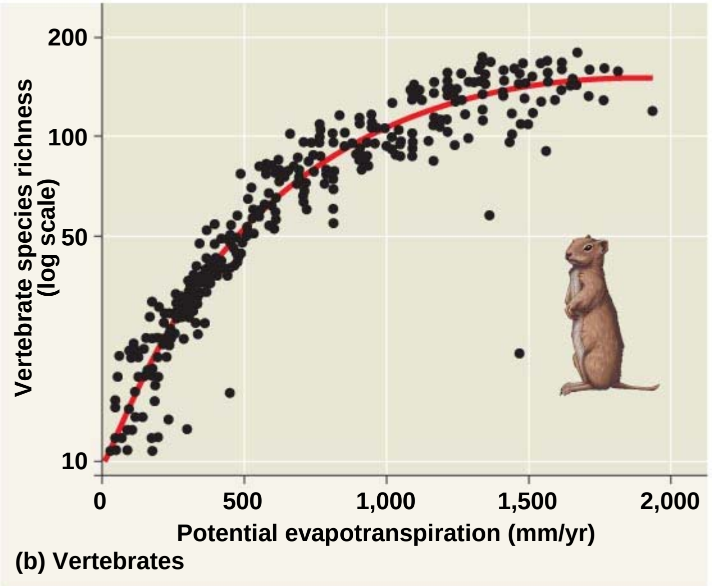
- Species richness generally declines along an equatorial-polar gradient and is especially great in the tropics
- Two key factors in equatorial-polar gradients of species richness are probably evolutionary history and climate
- The greater age of tropical environments may account for the greater species richness

- Climate is likely the primary cause of the latitudinal gradient in biodiversity
- Two main climatic factors correlated with biodiversity are solar energy and water availability
- 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

Fig. 54-25

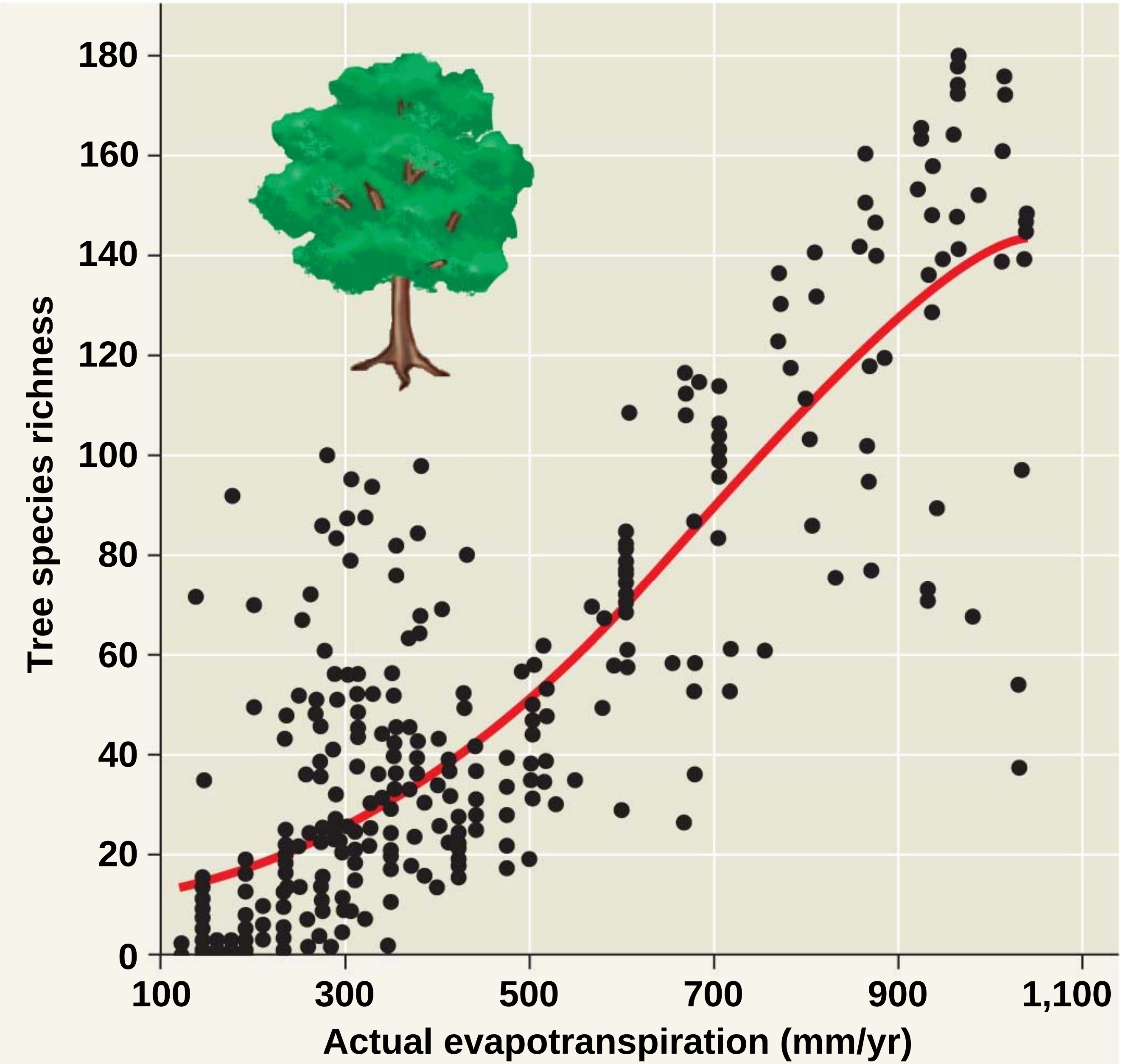


Tree species richness
180
160
140
120
100
80
60
40
20
0
100
300
500
700
900
1,100
Actual evapotranspiration (mm/yr)
(a) Trees



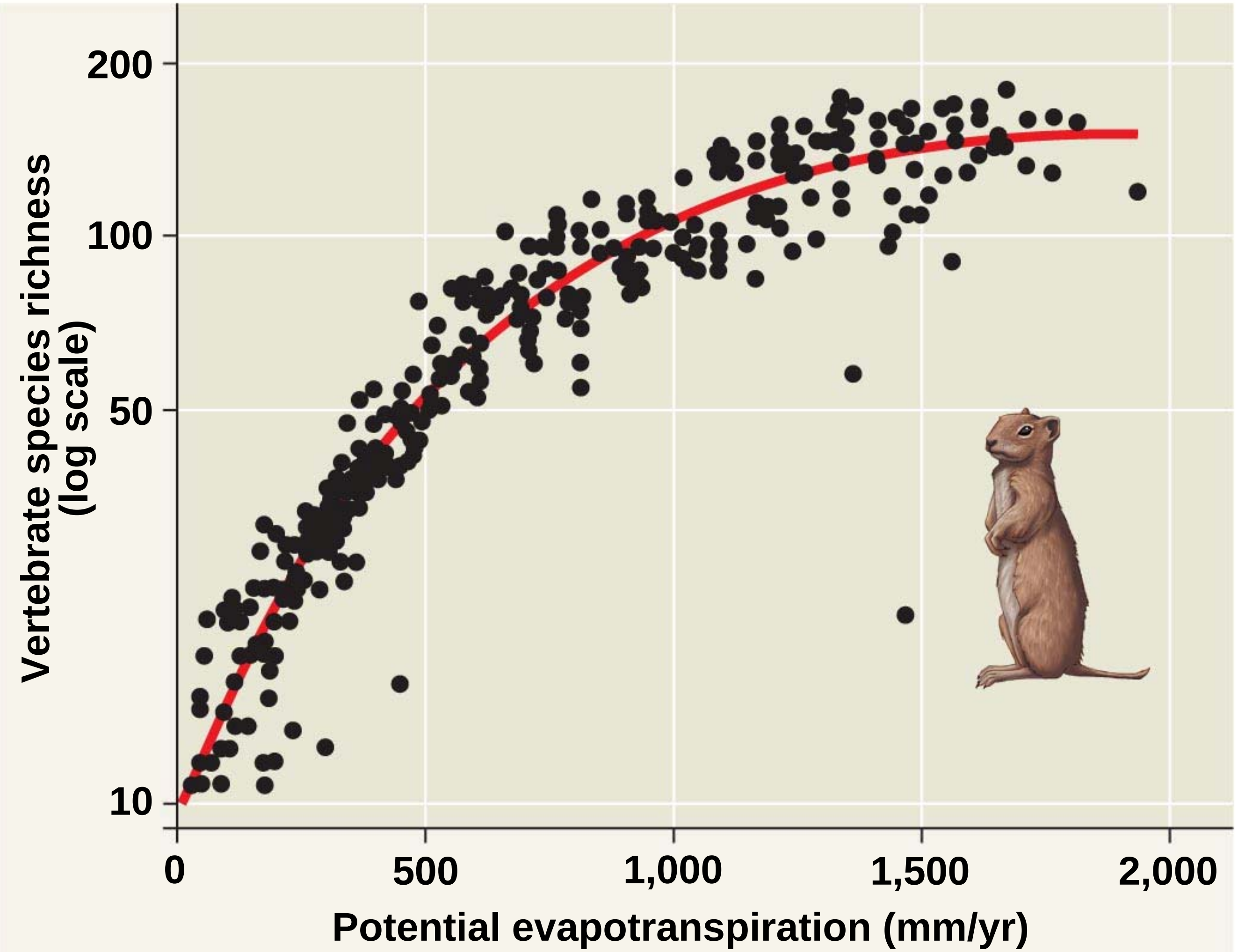
Vertebrate species richness
(log scale)
200
100
50
10
0
500
1,000
1,500
2,000
Potential evapotranspiration (mm/yr)
(b) Vertebrates

Fig. 54-25a



(a) Trees

Fig. 54-25b

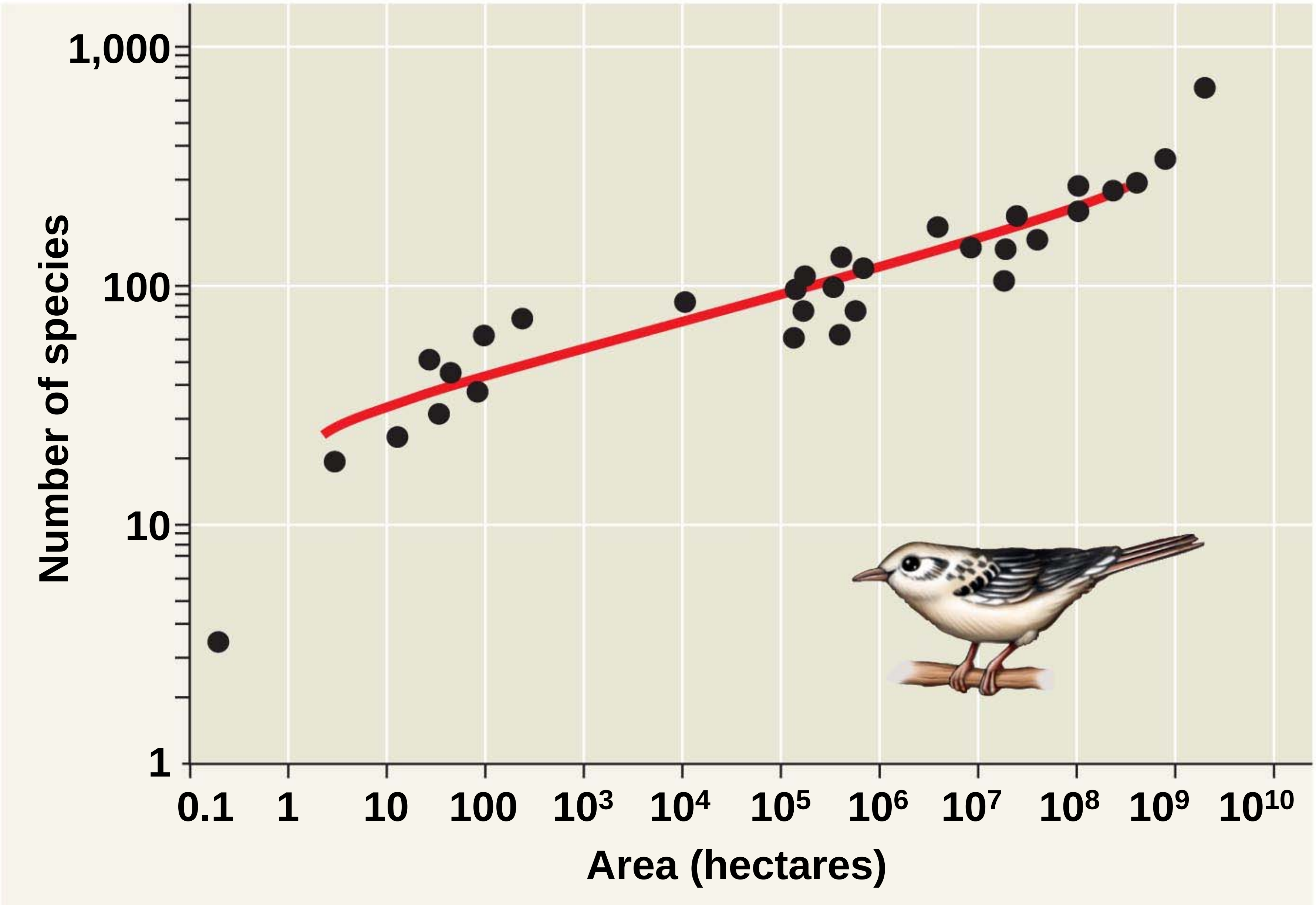


(b) Vertebrates

Area Effects

- The **species-area curve** quantifies the idea that, all other factors being equal, a larger geographic area has more species
- A species-area curve of North American breeding birds supports this idea

Fig. 54-26

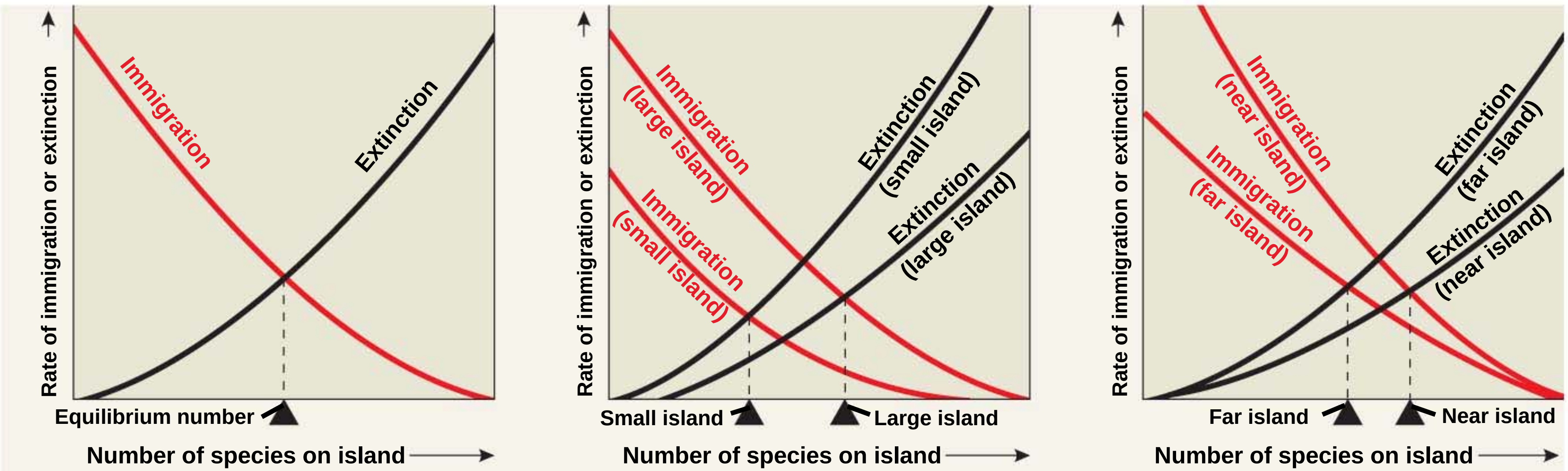


Number of species
1,000
100
10
1
0.1
1
10
100
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^10
Area (hectares)

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

Fig. 54-27

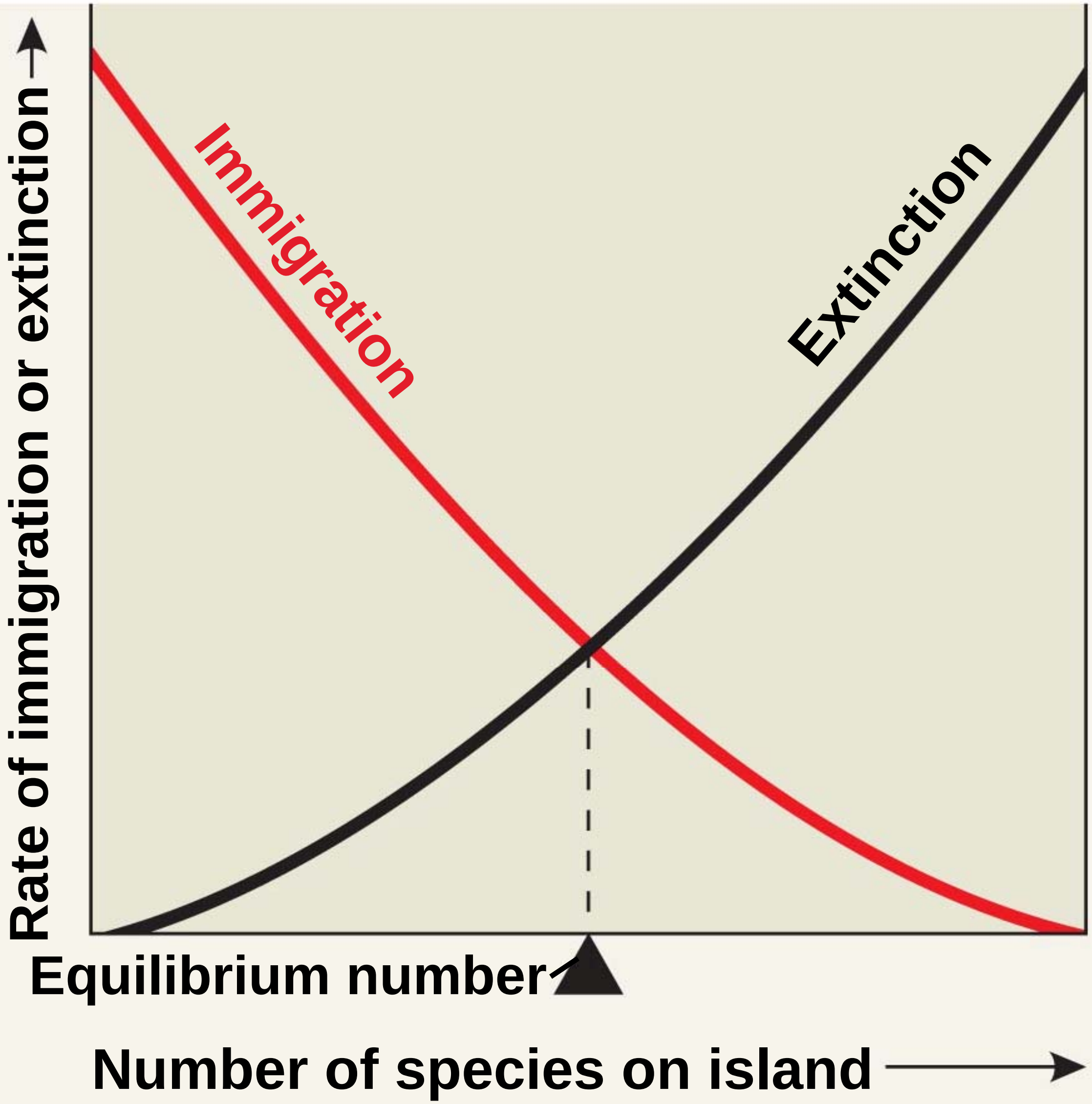


(a) Immigration and extinction rates

(b) Effect of island size

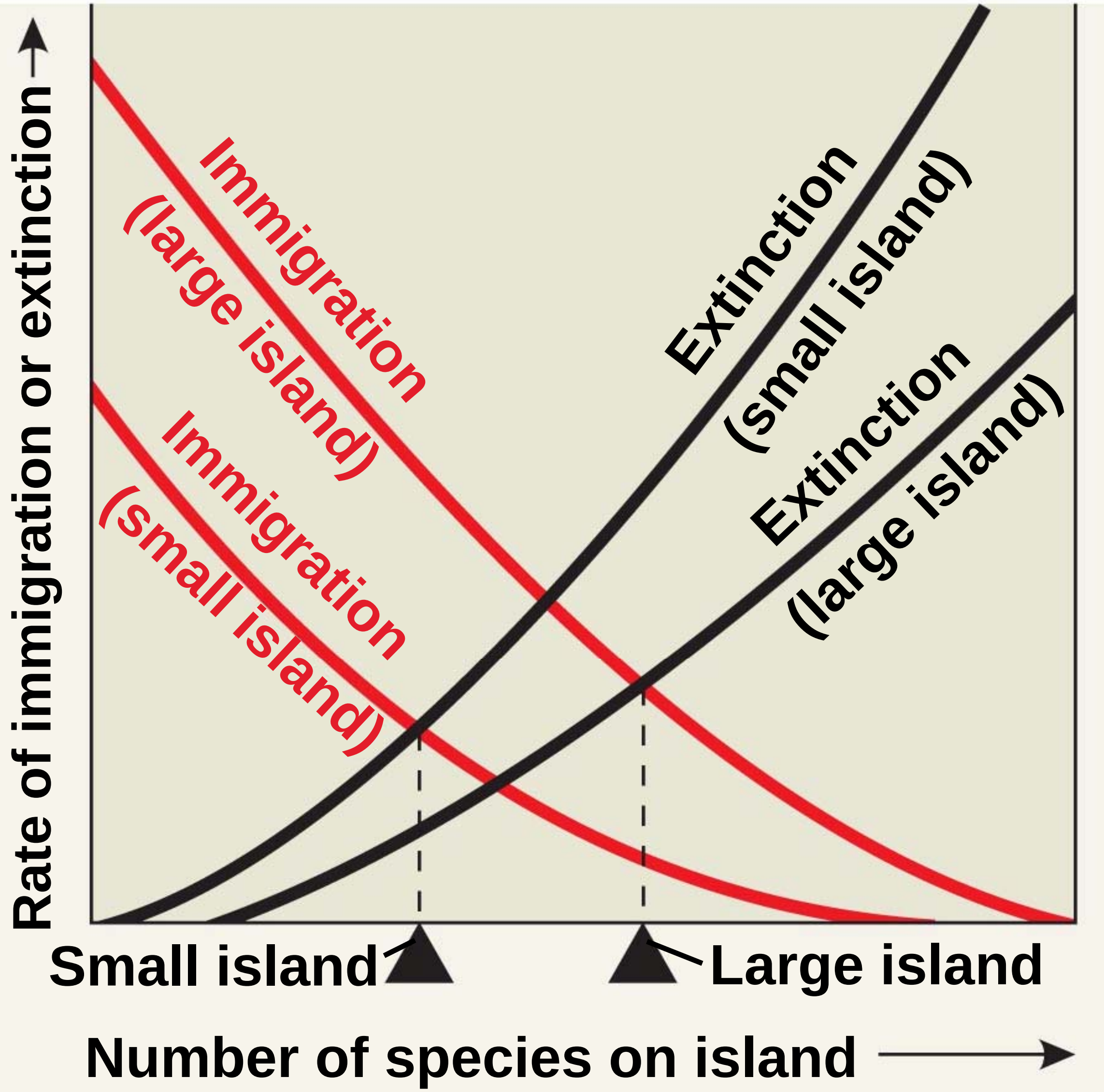
(c) Effect of distance from mainland

Fig. 54-27a



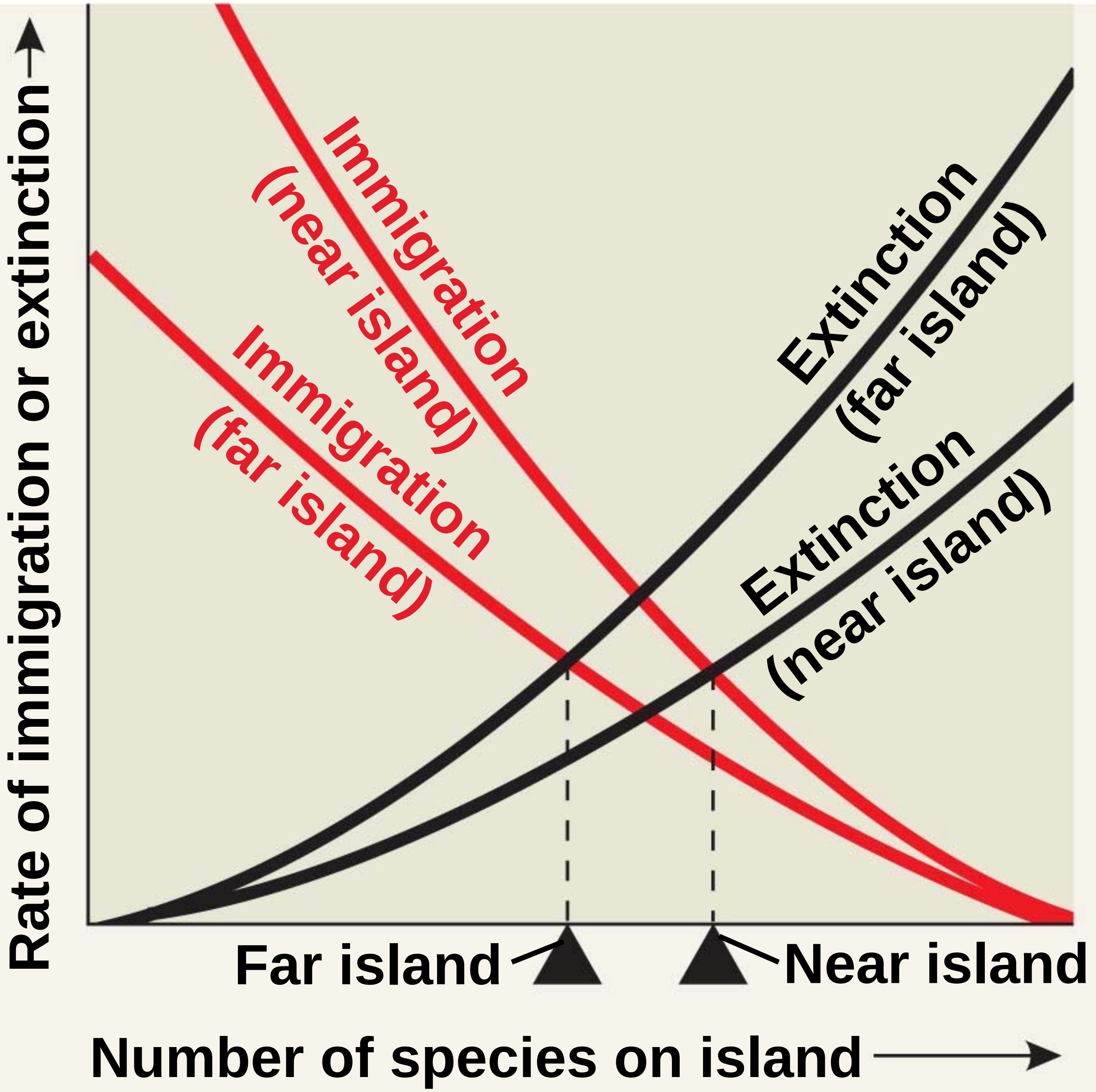
(a) Immigration and extinction rates

Fig. 54-27b



(b) Effect of island size

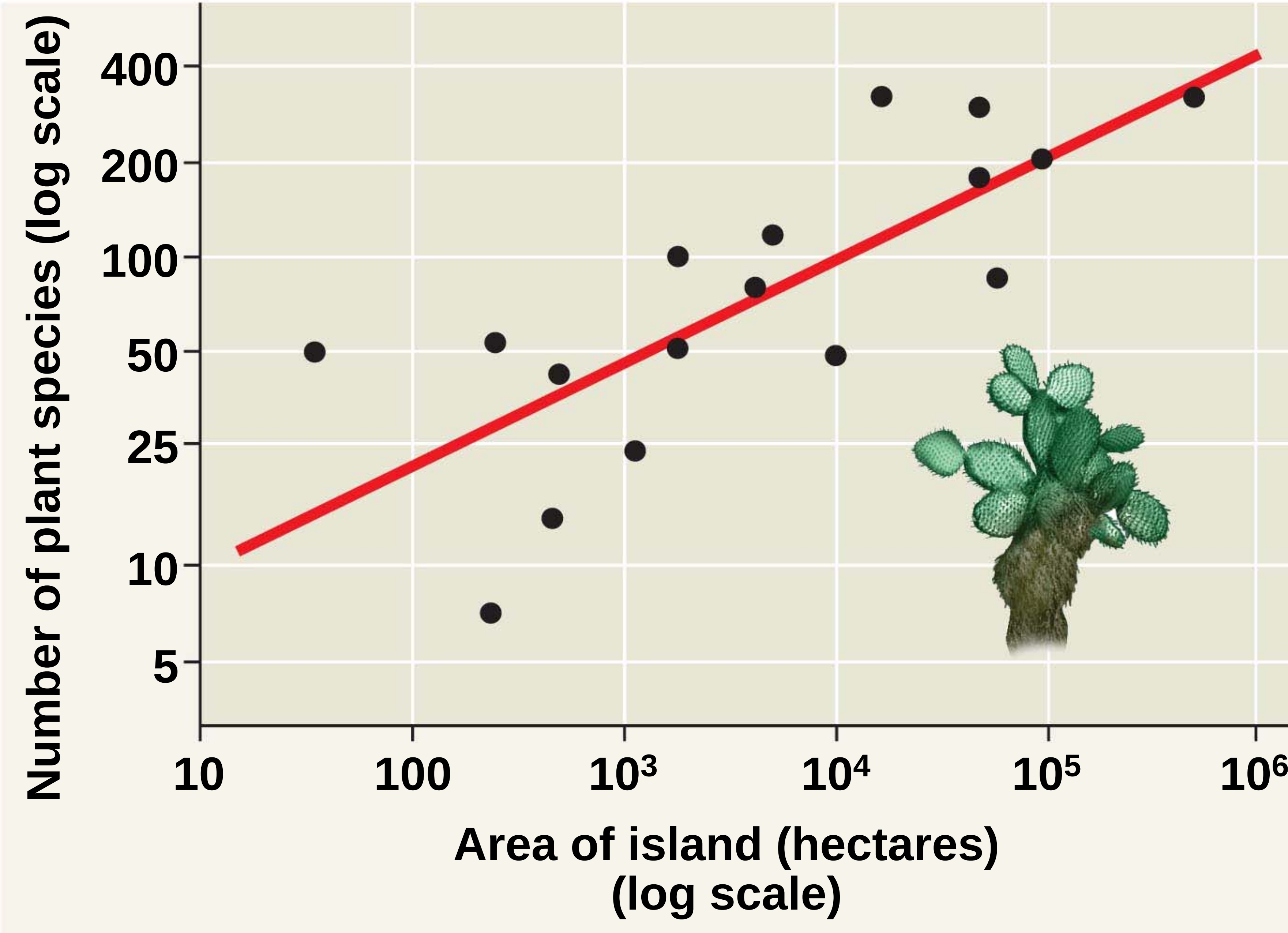
Fig. 54-27c



(c) Effect of distance from mainland

- Studies of species richness on the Galápagos Islands support the prediction that species richness increases with island size

Fig. 54-28



Number of plant species (log scale)
400
200
100
50
25
10
5
10
100
10^3
10^4
10^5
10^6
Area of island (hectares)
(log scale)

Concept 54.5: Community ecology is useful for understanding pathogen life cycles and controlling human disease

- Ecological communities are universally affected by **pathogens**, which include disease-causing microorganisms, viruses, viroids, and prions
- Pathogens can alter community structure quickly and extensively

Pathogens and Community Structure

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

Fig. 54-29

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

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

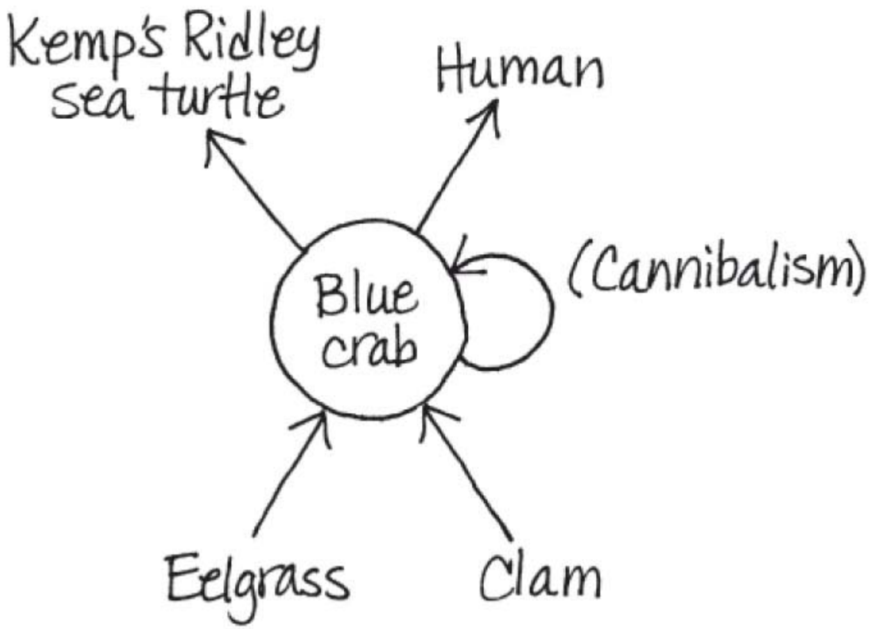
- Avian flu is a highly contagious virus of birds
- Ecologists are studying the potential spread of the virus from Asia to North America through migrating birds

Fig. 54-30

Fig. 54-UN2

Interspecific Interaction	Description
Competition (−/−)	Two or more species compete for a resource that is in short supply. The competitive exclusion principle states that two species cannot coexist in the same community if their niches (ecological roles) are identical.
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. Plants have various chemical and mechanical defenses against herbivory, and herbivores have specialized adaptations for feeding.
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.

Fig. 54-UN3


Kemp's Ridley
sea turtle
Human
(Cannibalism)
Blue
crab
Eelgrass
Clam

You should now be able to:

1. Distinguish between the following sets of terms: competition, predation, herbivory, symbiosis; fundamental and realized niche; cryptic and aposematic coloration; Batesian mimicry and Müllerian mimicry; parasitism, mutualism, and commensalism; endoparasites and ectoparasites; species richness and relative abundance; food chain and food web; primary and secondary succession

2. Define an ecological niche and explain the competitive exclusion principle in terms of the niche concept
3. Explain how dominant and keystone species exert strong control on community structure
4. Distinguish between bottom-up and top-down community organization
5. Describe and explain the intermediate disturbance hypothesis

6. Explain why species richness declines along an equatorial-polar gradient
7. Define zoonotic pathogens and explain, with an example, how they may be controlled