Community **E**cology

Aquatic Ecology and Evolution

EAWAG

UNIVERSITÄT BERN

All the organisms that inhabit a particular area; an assemblage of populations of different species living close enough together for potential interaction

Community

Communities differ:

in their species composition,

their species richness,

the number of species they contain,

the relative abundance of different species.

Relationships between species of a community.

interspecific interactions

competition

predation

herbivory

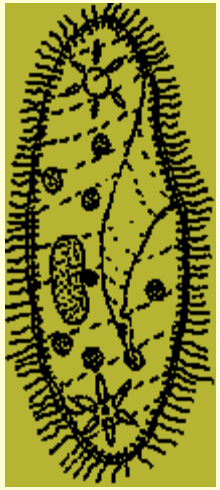
symbiosis
(parasitism, mutualism, and commensalism)

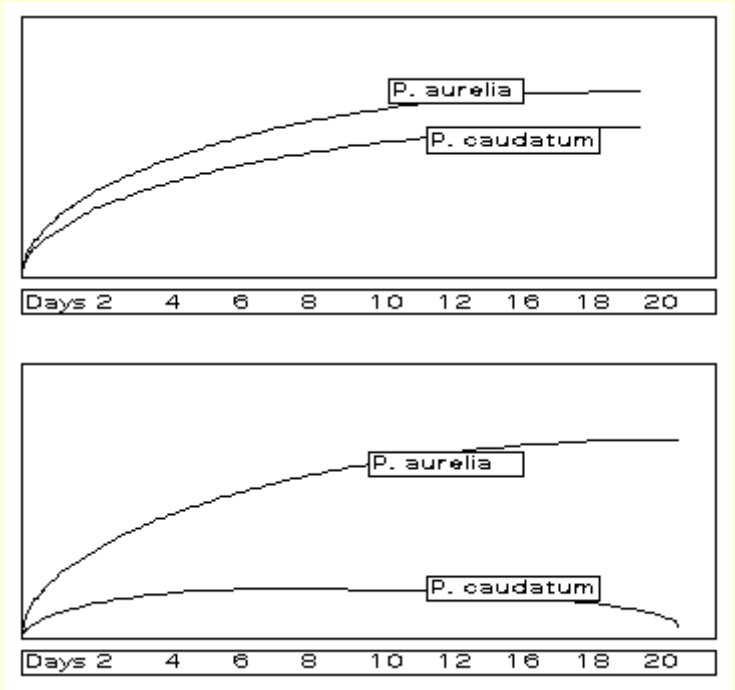
disease

Interspecific competition occurs when species compete for a particular resource that is in short supply

Strong competition can lead to the local elimination of one of the two competing species, a process called **competitive exclusion**.

1934, the Russian ecologist G. F. Gause





separate

together

The total sum of a species' use of the biotic and abiotic resources in its environment.

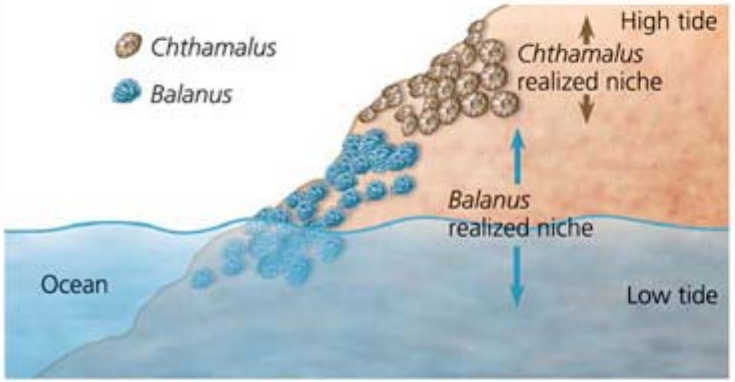
ecological niche

Realized niche
Fundamental niche

Figure 53.2

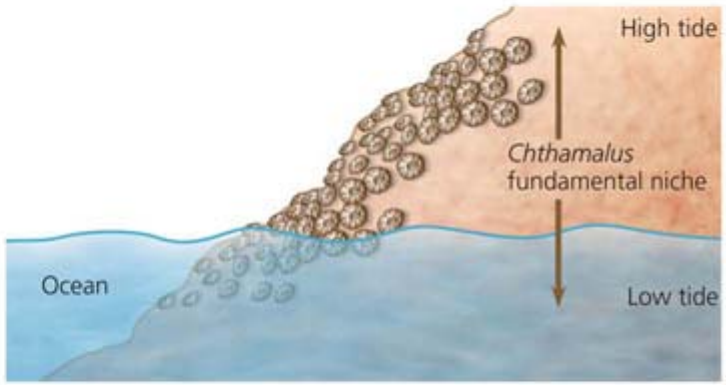
Inquiry Can a species' niche be influenced by interspecific competition?

EXPERIMENT Ecologist Joseph Connell studied two barnacle species—*Balanus balanoides* and *Chthamalus stellatus*—that have a stratified distribution on rocks along the coast of Scotland.



In nature, *Balanus* fails to survive high on the rocks because it is unable to resist desiccation (drying out) during low tides. Its realized niche is therefore similar to its fundamental niche. In contrast, *Chthamalus* is usually concentrated on the upper strata of rocks. To determine the fundamental niche of *Chthamalus*, Connell removed *Balanus* from the lower strata.

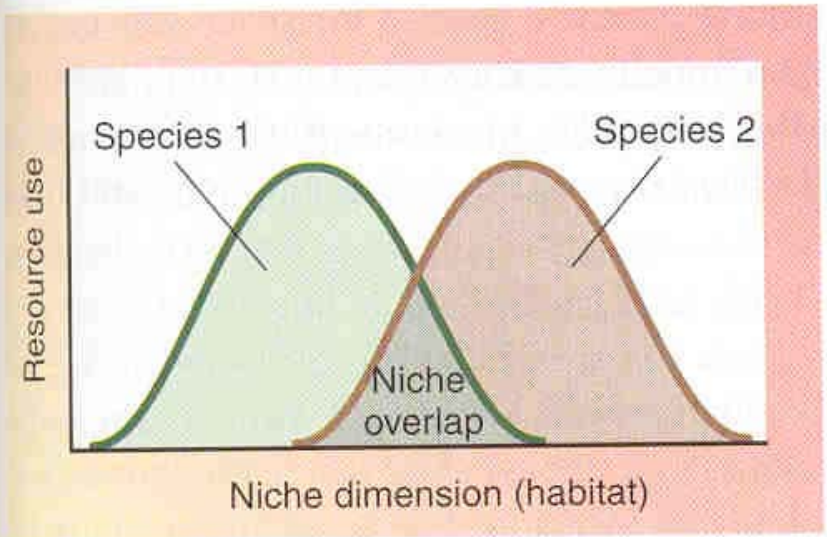
RESULTS When Connell removed *Balanus* from the lower strata, the *Chthamalus* population spread into that area.



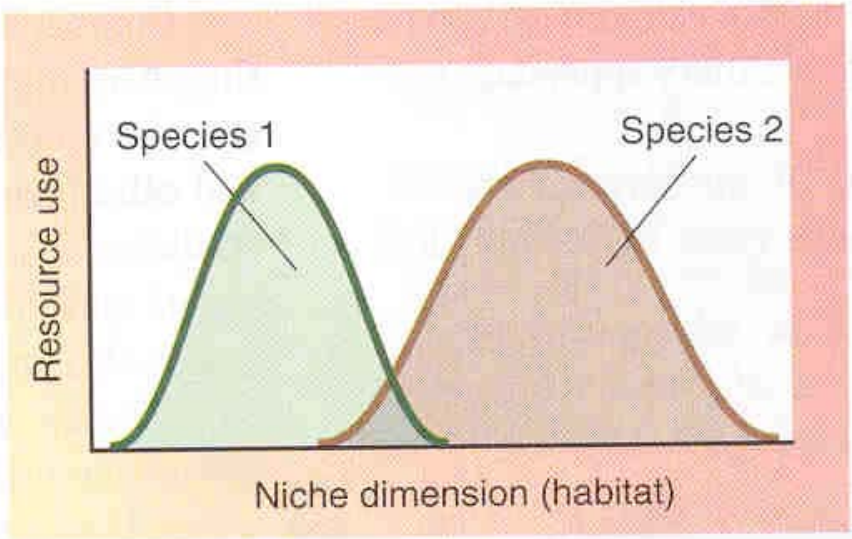
CONCLUSION The spread of *Chthamalus* when *Balanus* was removed indicates that competitive exclusion makes the realized niche of *Chthamalus* much smaller than its fundamental niche.

(a)

(b)


Species 1
Species 2
Resource use
Niche
overlap
Niche dimension (habitat)

(c)


Species 1
Species 2
Resource use
Niche dimension (habitat)

(d)

a species' **fundamental niche**, which is the niche potentially occupied by that species, may be different from its **realized niche**, the niche it actually occupies in a particular environment.

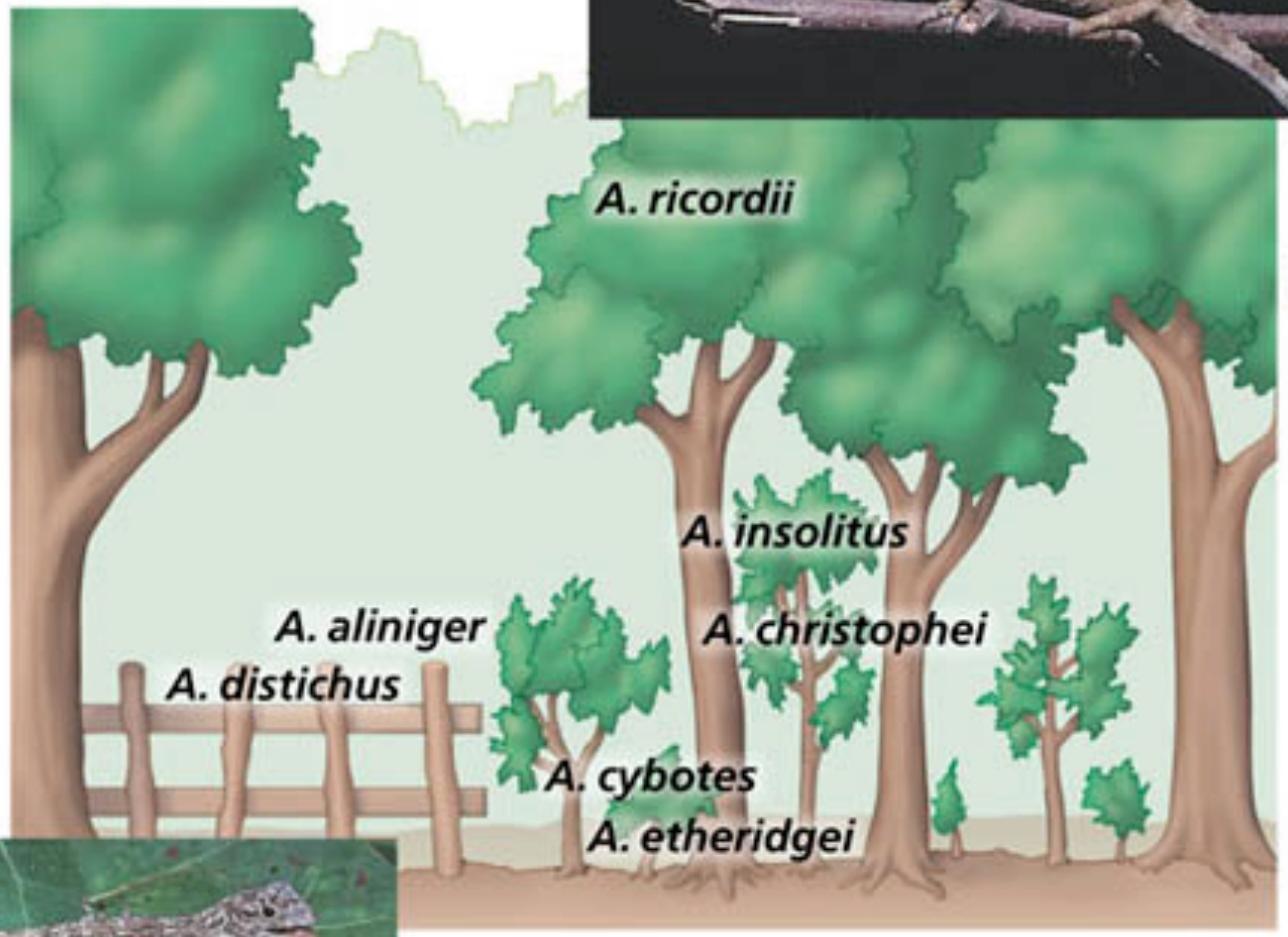
When competition between species having identical niches does not lead to local extinction of either species, it is generally because one species' niche becomes modified

Resource Partitioning

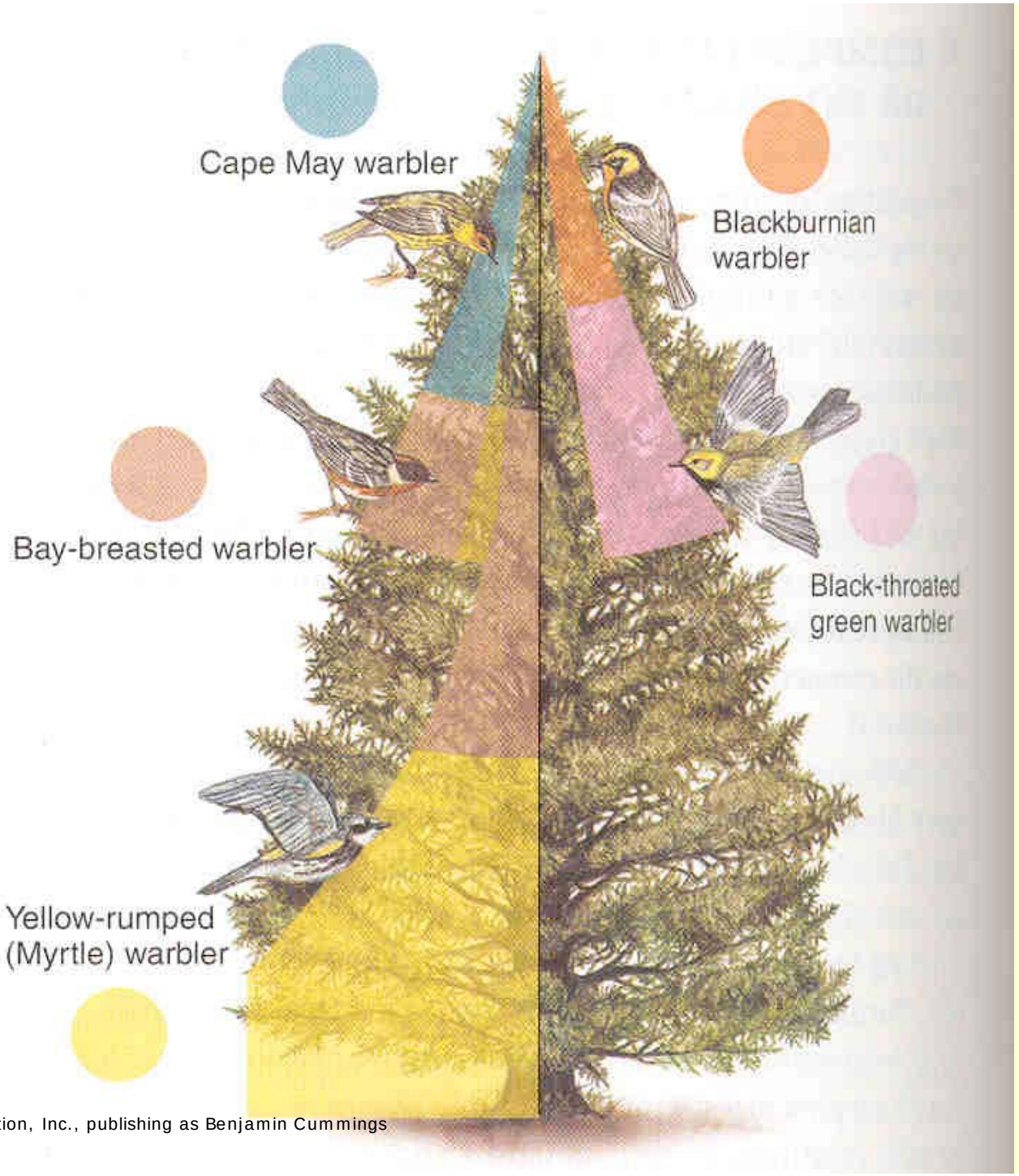
The division of environmental resources by coexisting species.

The niche of each species differs by one or more significant factors from the niches of all coexisting species.

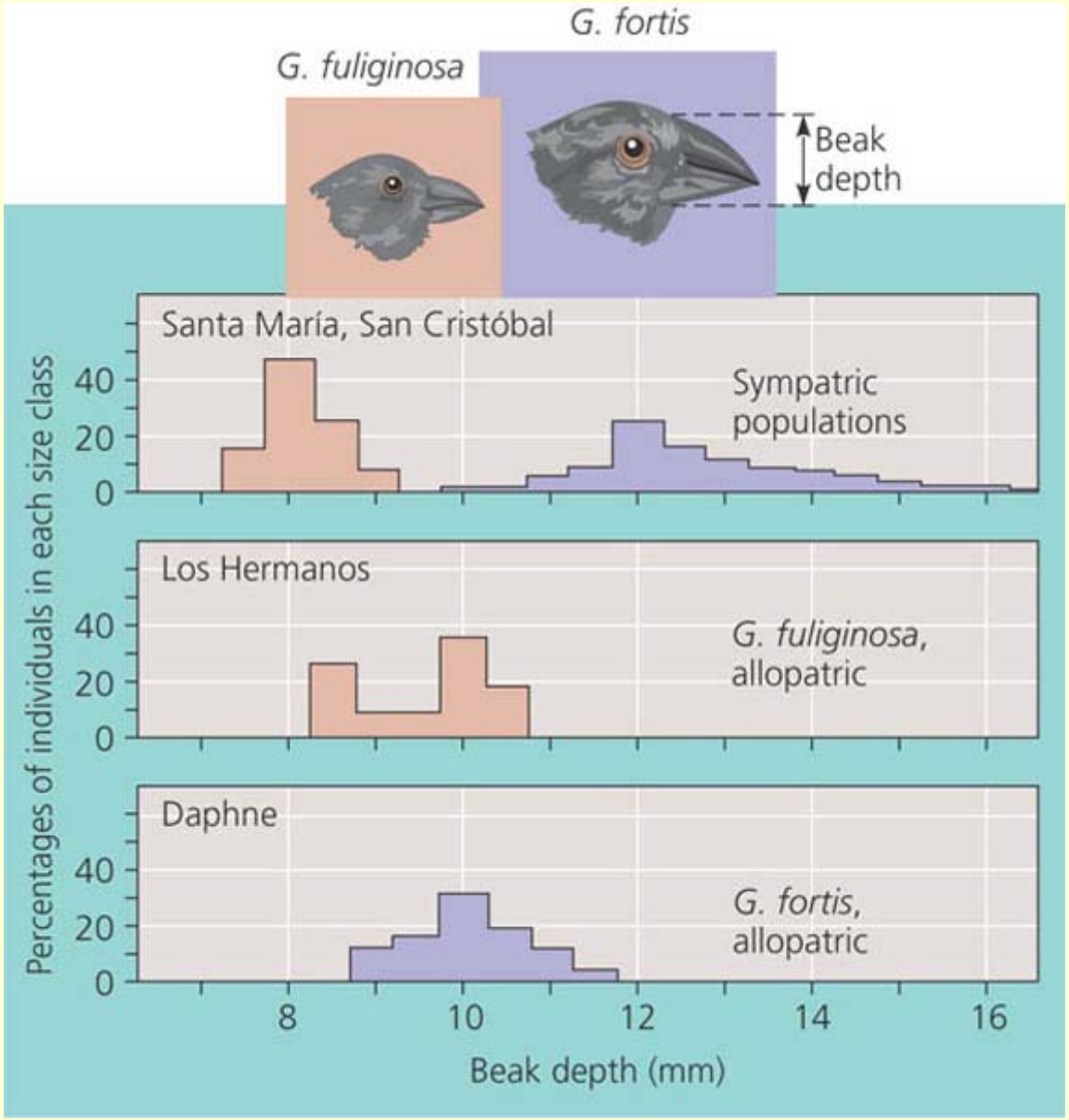
A. insolitus usually perches on shady branches.



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



Comparisons of closely related species whose populations are sometimes allopatric (geographically separate) and sometimes sympatric (geographically overlapping) gives evidence for the effects of competition



character displacement

competition

predation

herbivory

symbiosis
(parasitism, mutualism, and commensalism)

disease

A **predator** eats other animals as prey

A **herbivore** eats plants

Predator adaptations: many important feeding adaptations of predators are both obvious and familiar.

Claws, teeth, fangs, poison, heat-sensing organs, speed, and agility.

Herbivore: digestive system, teeth

Anti-predator defenses

Plant defenses against herbivores include chemical compounds that are toxic.

Animal behavioral defenses include fleeing, hiding, self-defense, noises, and mobbing (think of a blackbird and a cat).

Hiding involves camouflage for which
cryptic coloration
has evolved and deceptive markings

Mechanical defenses include spines.

Chemical defenses include odors and toxins

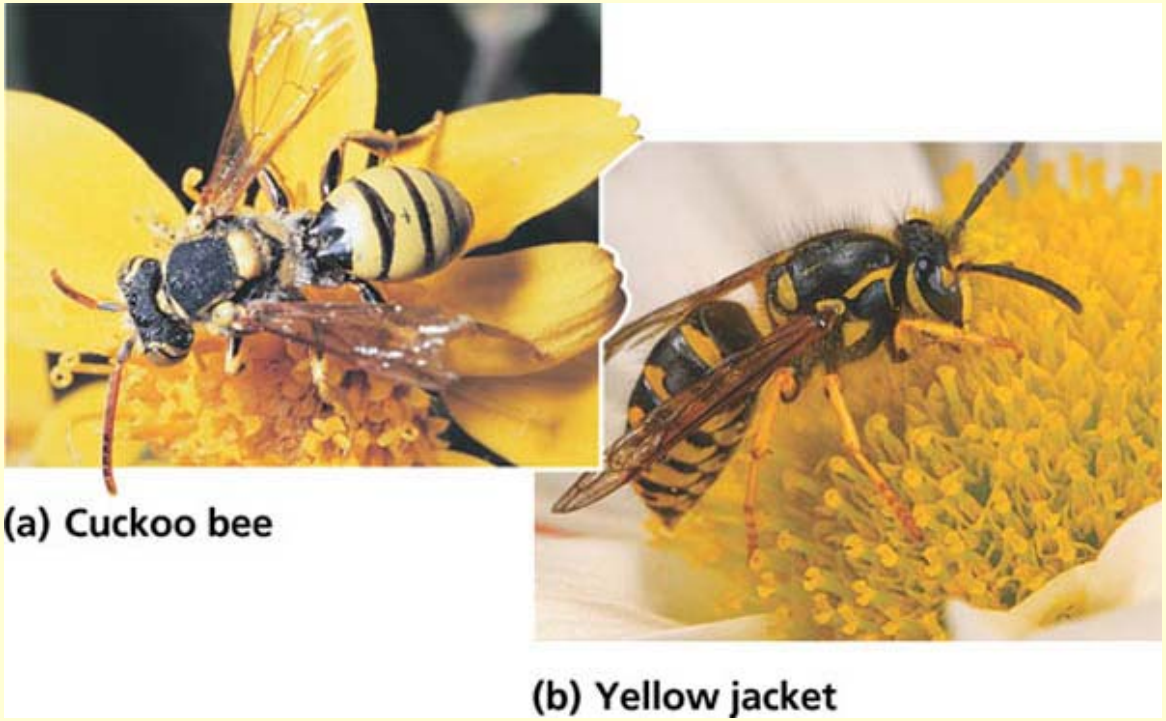
Aposematic coloration

is indicated by warning colors, and is sometimes associated with other defenses (toxins).

Prey species may gain significant protection by mimicking the appearance of another.

(a) Hawkmoth larva

(b) Green parrot snake



a palatable or harmless species mimics an unpalatable or harmful model

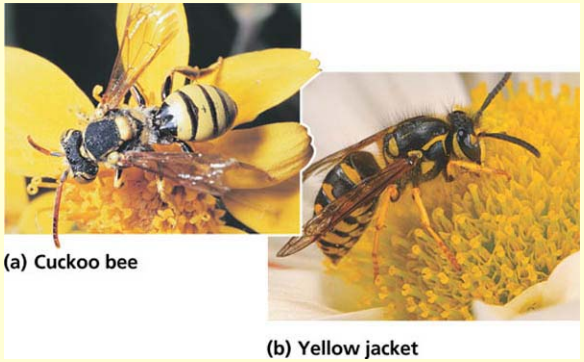
Batesian mymicry


(a) Hawkmoth larva

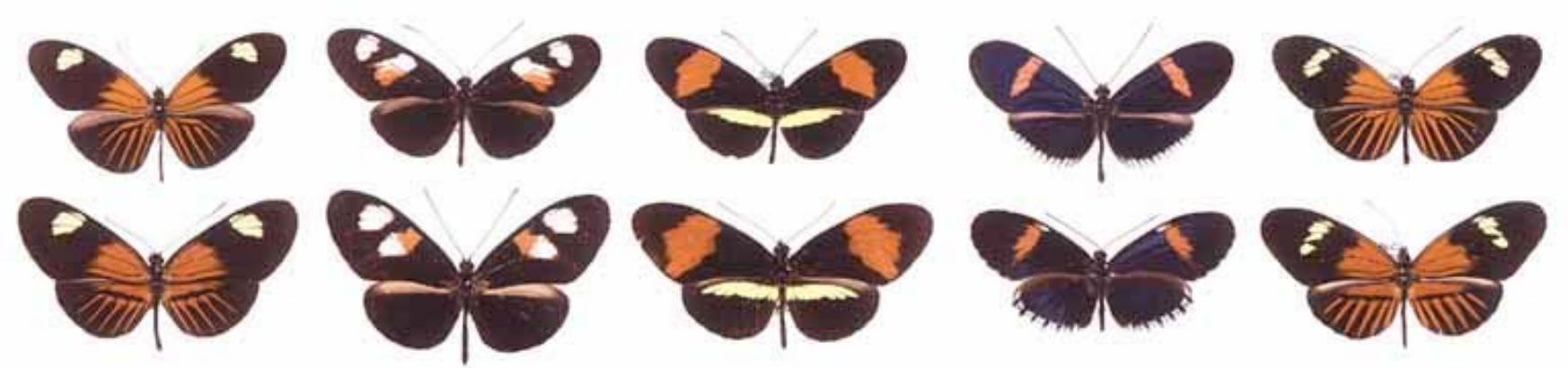
(b) Green parrot snake

A mutual mimicry by two unpalatable species.

Mullerian mymicry


(a) Cuckoo bee

(b) Yellow jacket



Heliconius erato (above), and *H. melpomene* (below), a pair of **Müllerian mimics** from different areas of Ecuador and Northern Peru. Within any area, the two species are extremely accurate mimics of one another, but major geographic differences in colour pattern have evolved within each species. This geographic diversity is extraordinary by temperate zone standards: the area (about 600km x 300km) of the Andean foothills from which all these forms can be found is less than the size of Britain.

competition

predation

herbivory

symbiosis
(parasitism, mutualism, and commensalism)

disease

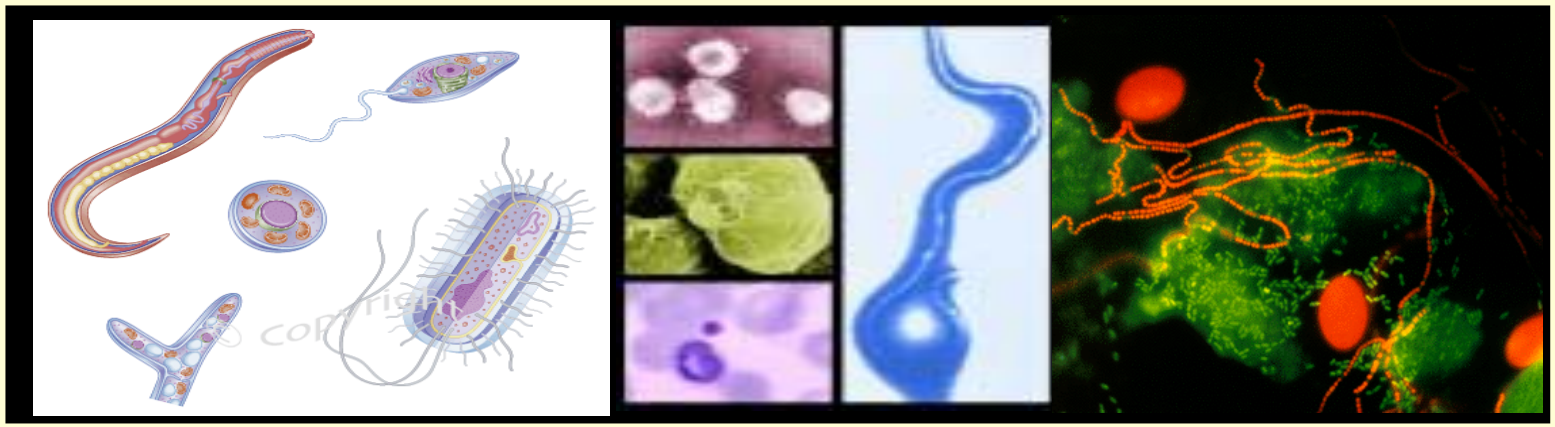
Parasites and **pathogens** are special types of predators.

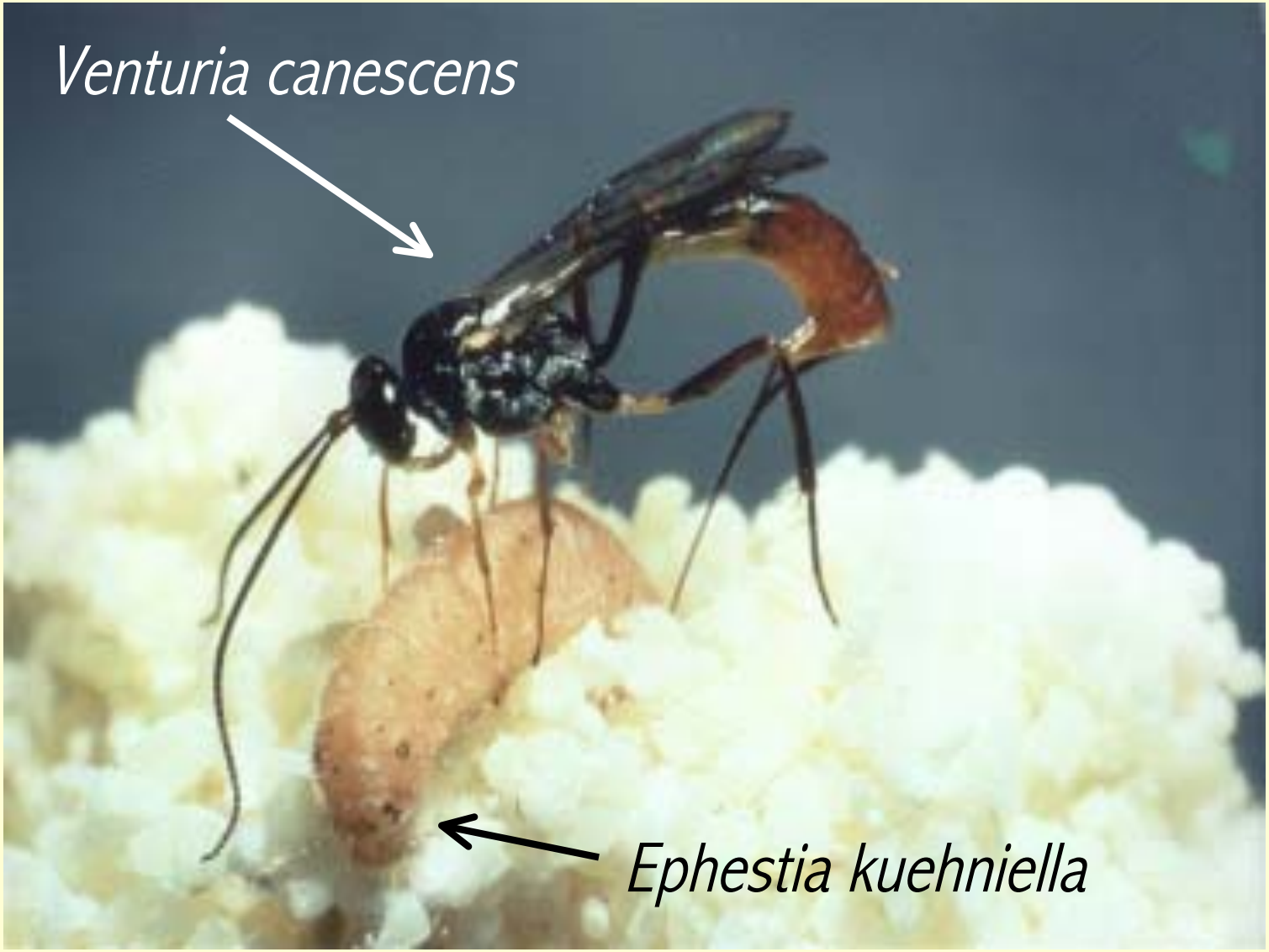
A parasite derives nourishment from a host, which is harmed in the process.

Endoparasites live inside the host and ectoparasites live on the surface of the host.

Parasitoidism is a special type of parasitism where the parasite eventually kills the host.

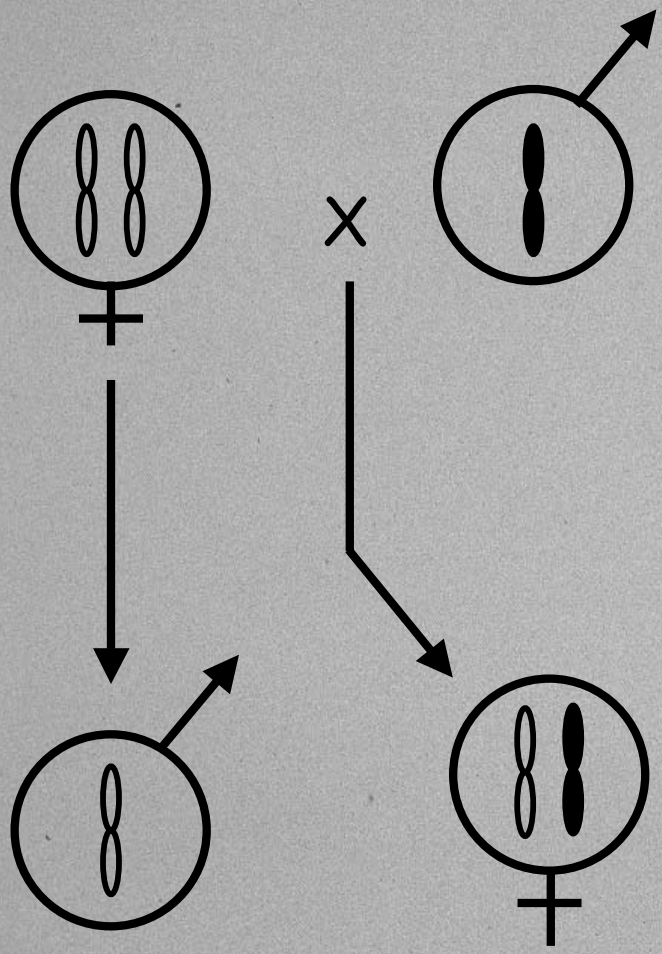
Pathogens are disease-causing organisms that can be considered predators.

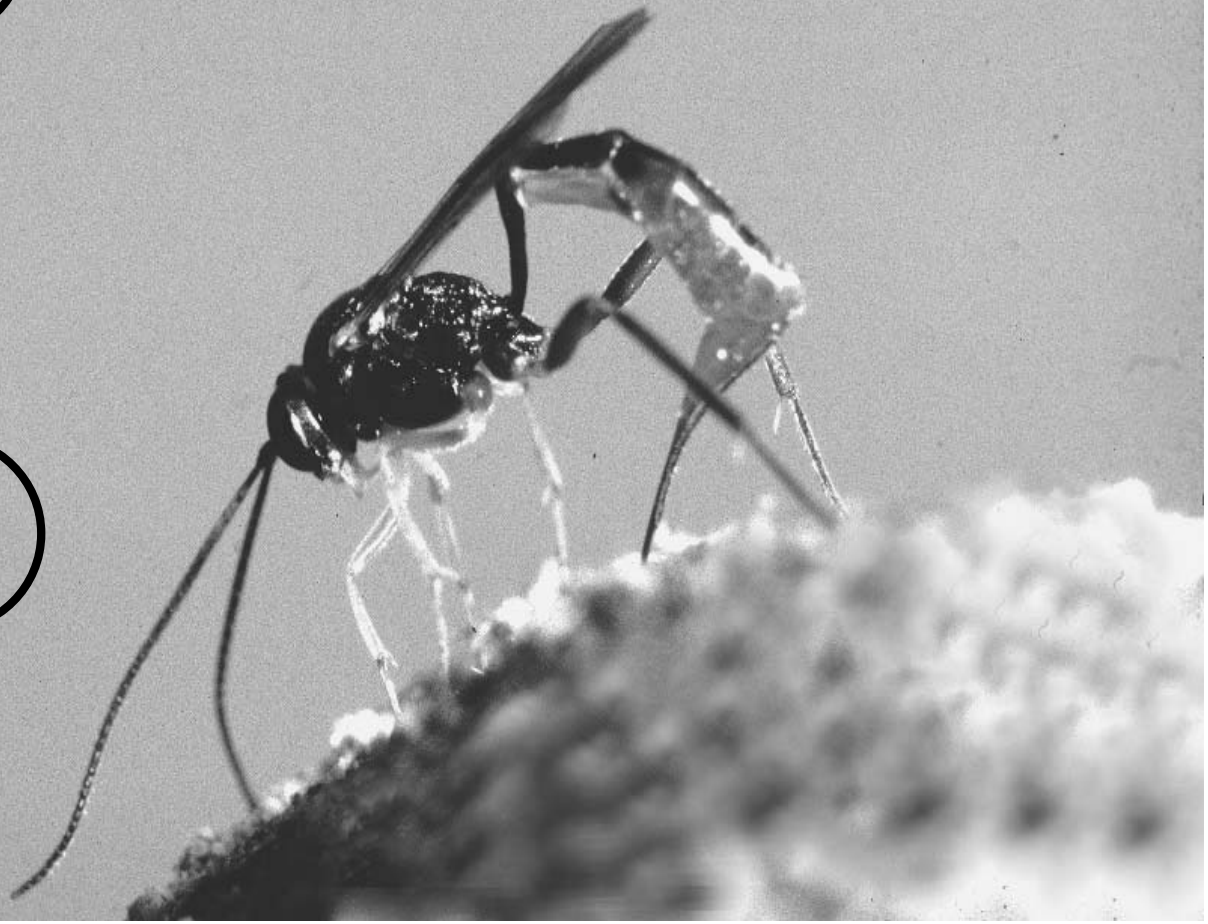



Venturia canescens
Ephestia kuehniella

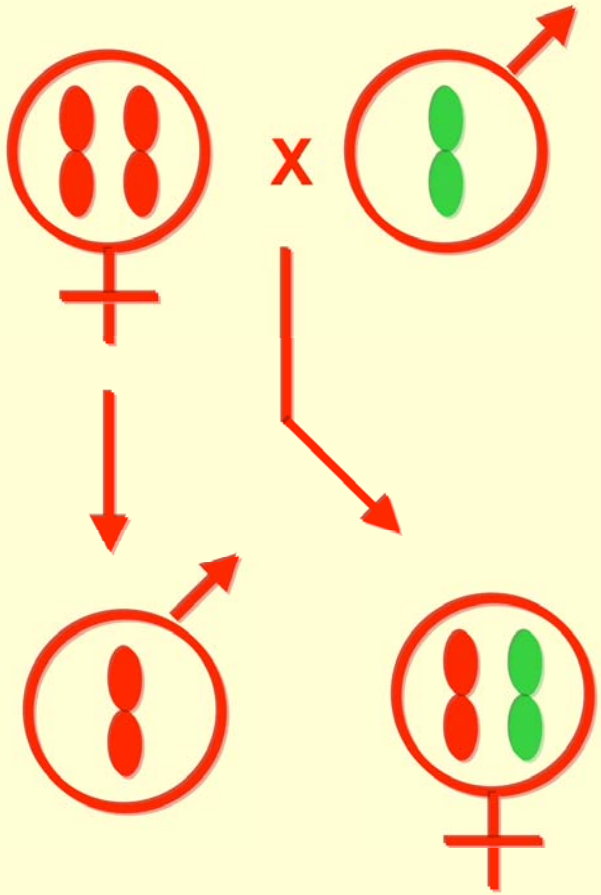
carobs, dates, figs, almonds

HAPLODIPLOID SEX DETERMINATION

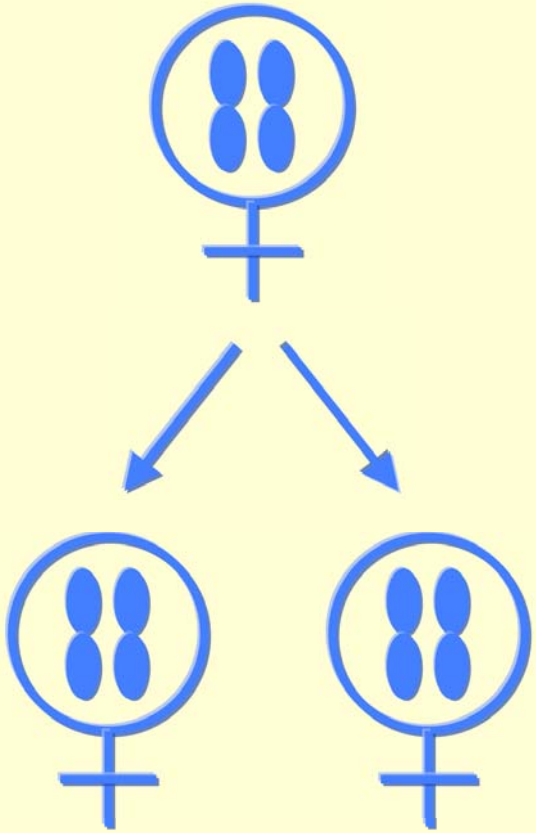




Arrhenotoky (=sexual)

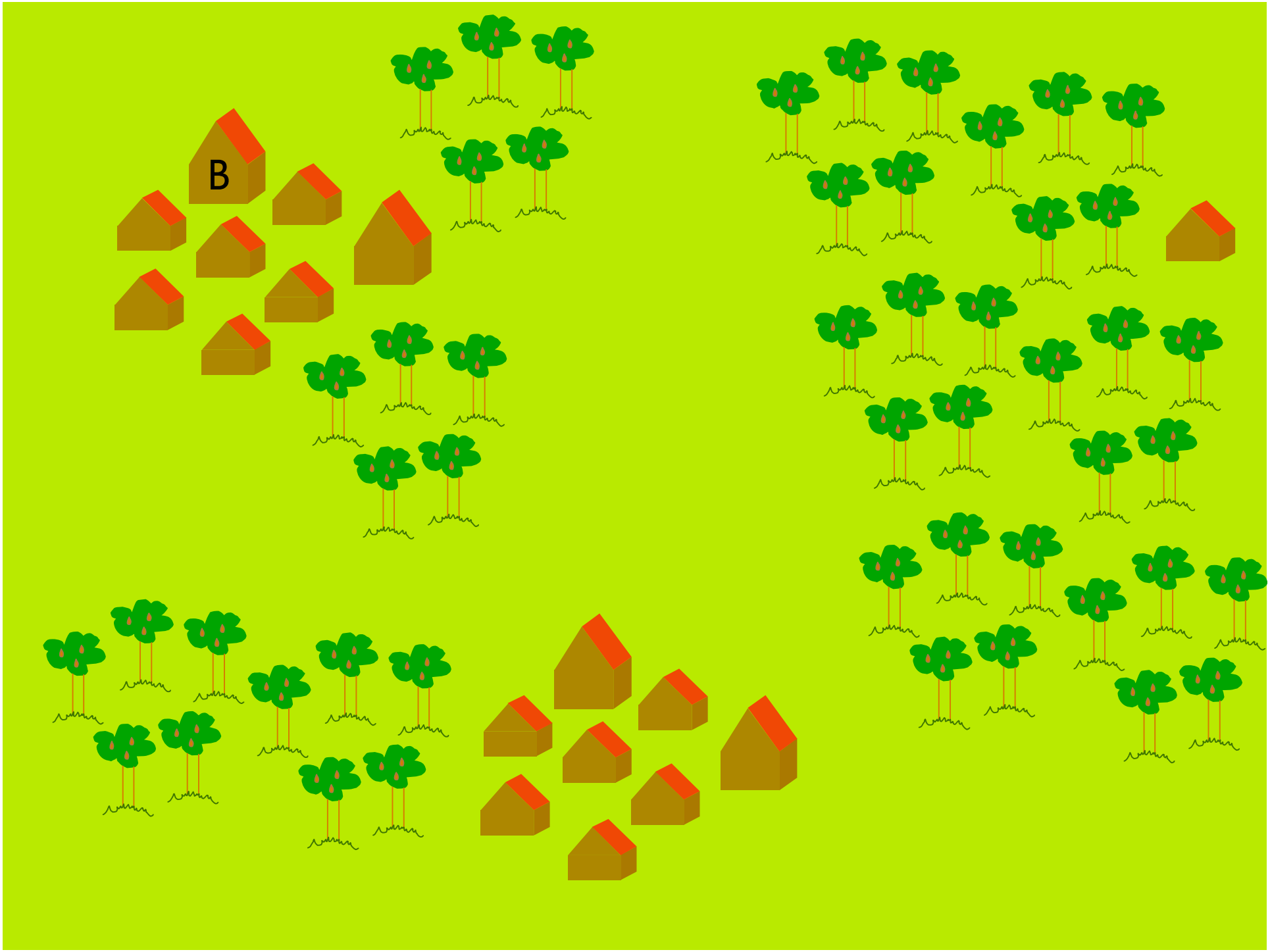


Thelytoky (=parthenogenetic)



South of France field work


Inst. Nat. Rech. Agroculture
Antibes
Recherche Biologique
Ne touchez pas, s.v.p.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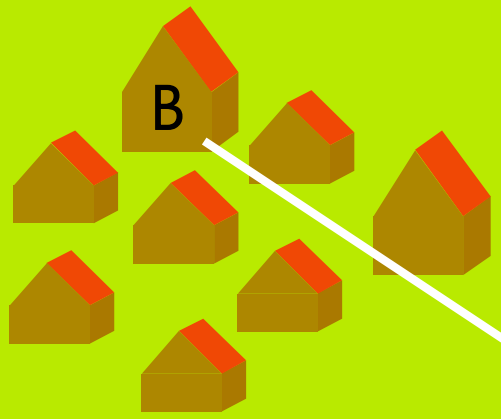


Bakery=

=

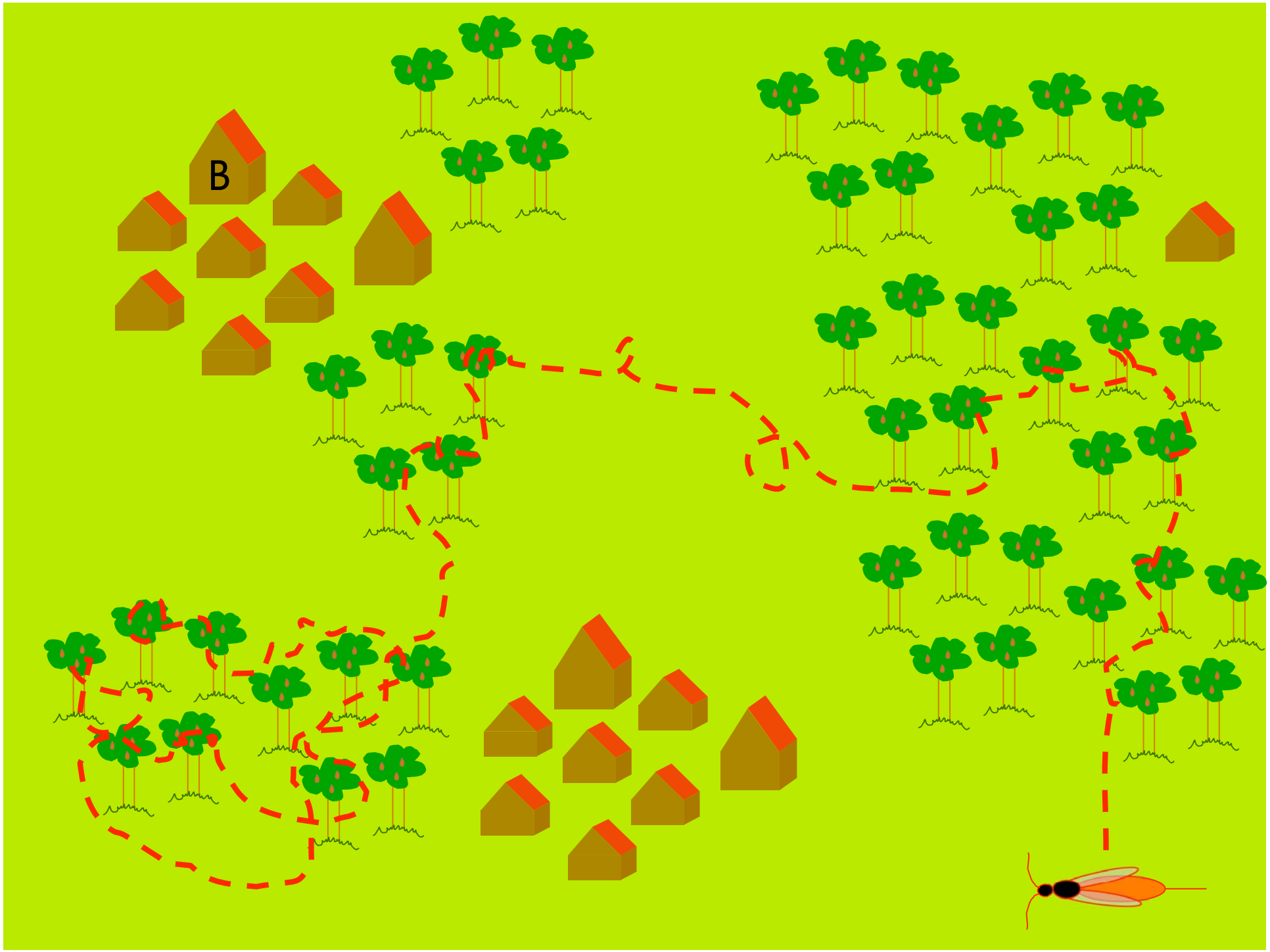
+

Flour moth


grain

=

=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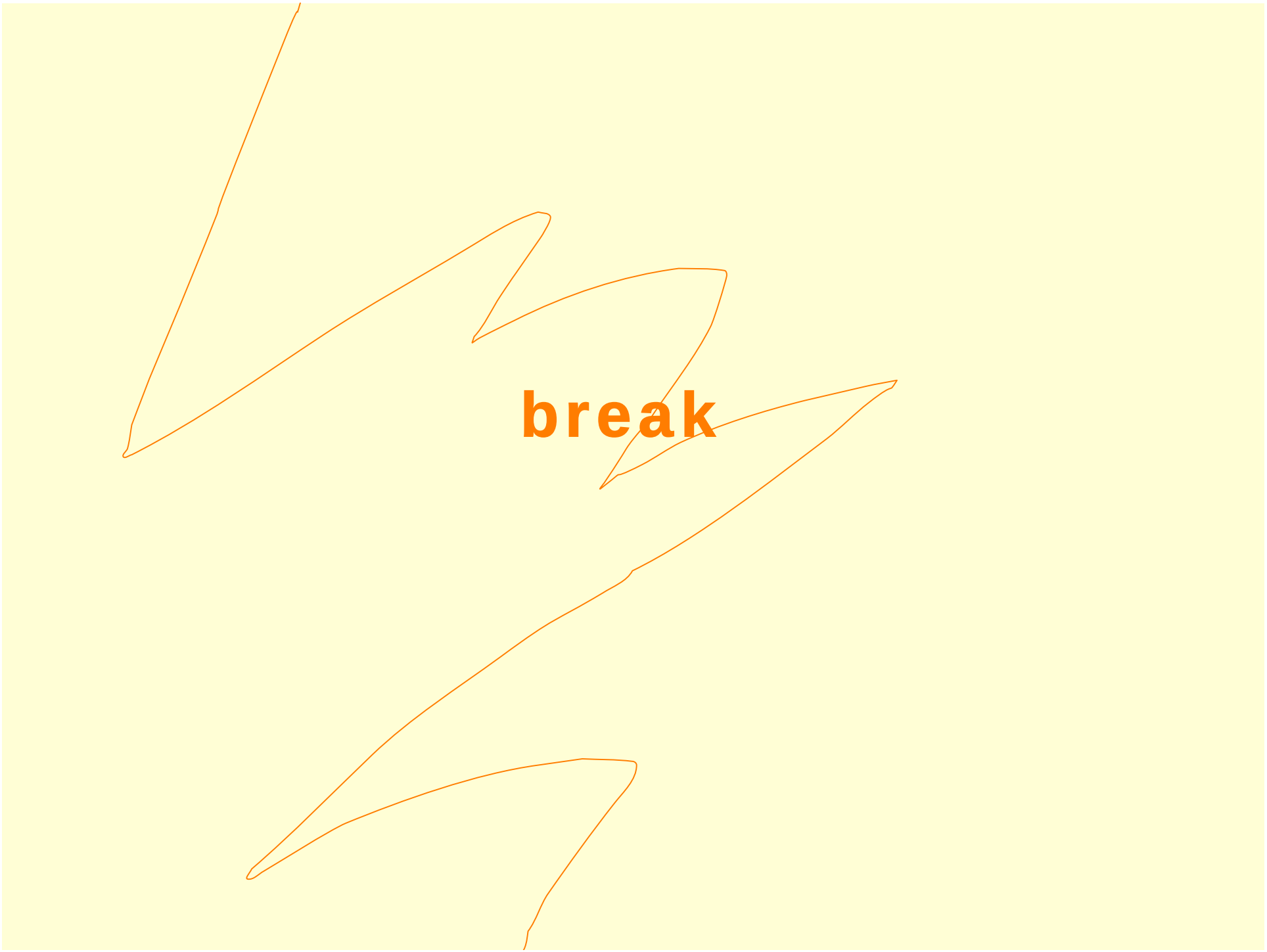
Meanwhile in the bakery...


break

competition

predation

herbivory

symbiosis
(parasitism, mutualism, and commensalism)

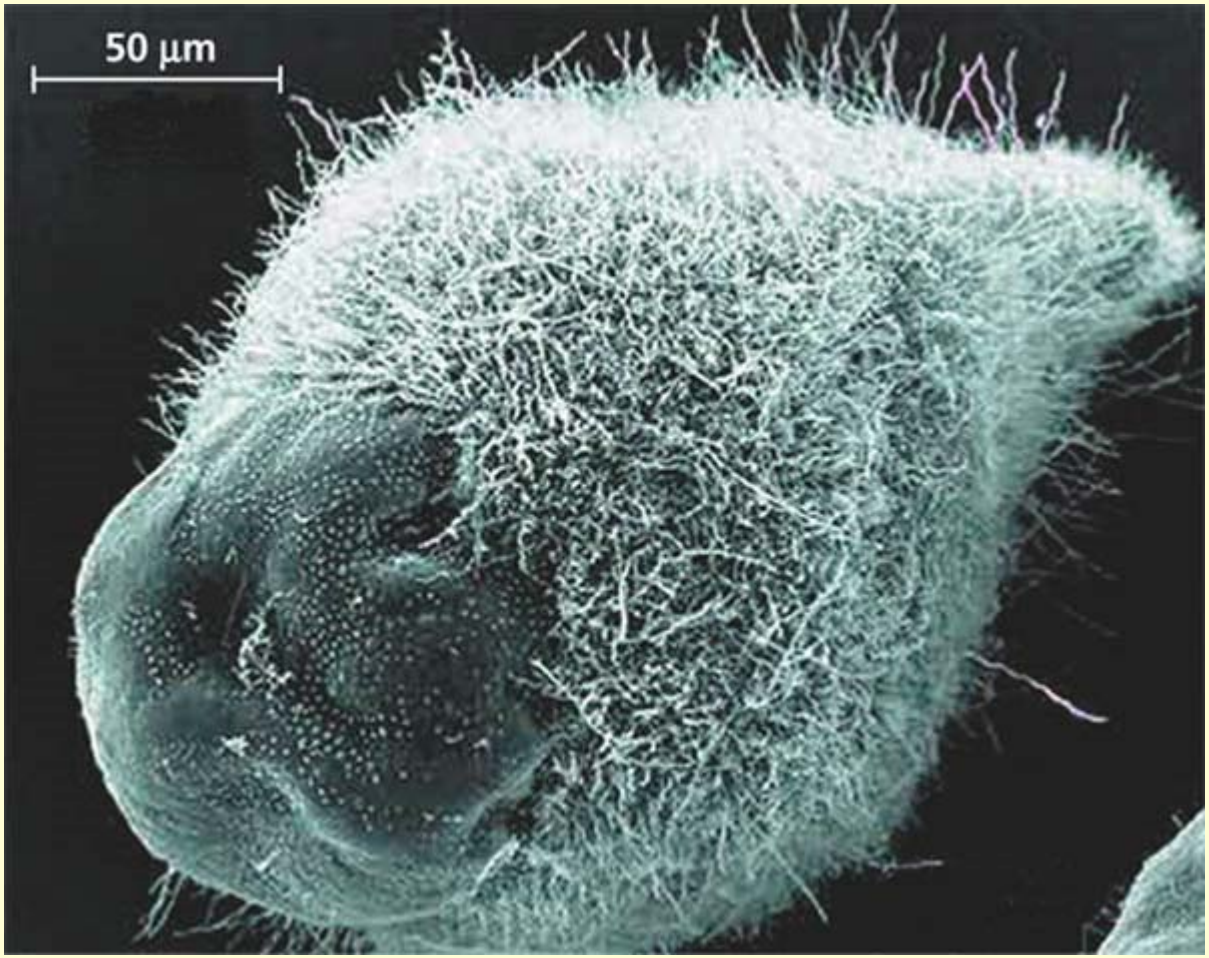
disease

interspecific interaction that benefits both species

Mutualism

The ants feed on sugar produced by nectaries on the tree and on protein–rich swellings (orange in the photograph) at the tips of leaflets. The acacia benefits because the pugnacious ants, which attack anything that touches the tree, remove fungal spores and other debris and clip vegetation that grows close to the acacia.

The protist *Mixotricha paradoxa*,



-lives in the gut of termites
-has three types of bacteria attached to its surface that provide it with motility
-A fourth type of bacterium lives inside Mixotricha and digests wood fragments eaten by the termite.

interaction between species that benefits one of the species but neither harms nor helps the other

Commensalism

Interaction	Effects on Interacting Species
Competition (−/−)	The interaction can be detrimental to both species.
Predation (+/−) Herbivory (+/−) Parasitism (+/−) Disease (+/−)	The interaction is beneficial to one species and detrimental to the other.
Mutualism (+/+)	The interaction is beneficial to both species.
Commensalism (+/0)	One species benefits from the interaction, and the other species is unaffected by it.

reciprocal evolutionary adaptations of two interacting species

When characters of one species change over generations, this exerts selective pressure on the other to counter-adapt to continue the interaction or not loose out

coevolution

→ predator-prey coevolution = “evolutionary arms race”

two fundamental features of community structure are:

i) feeding relationships

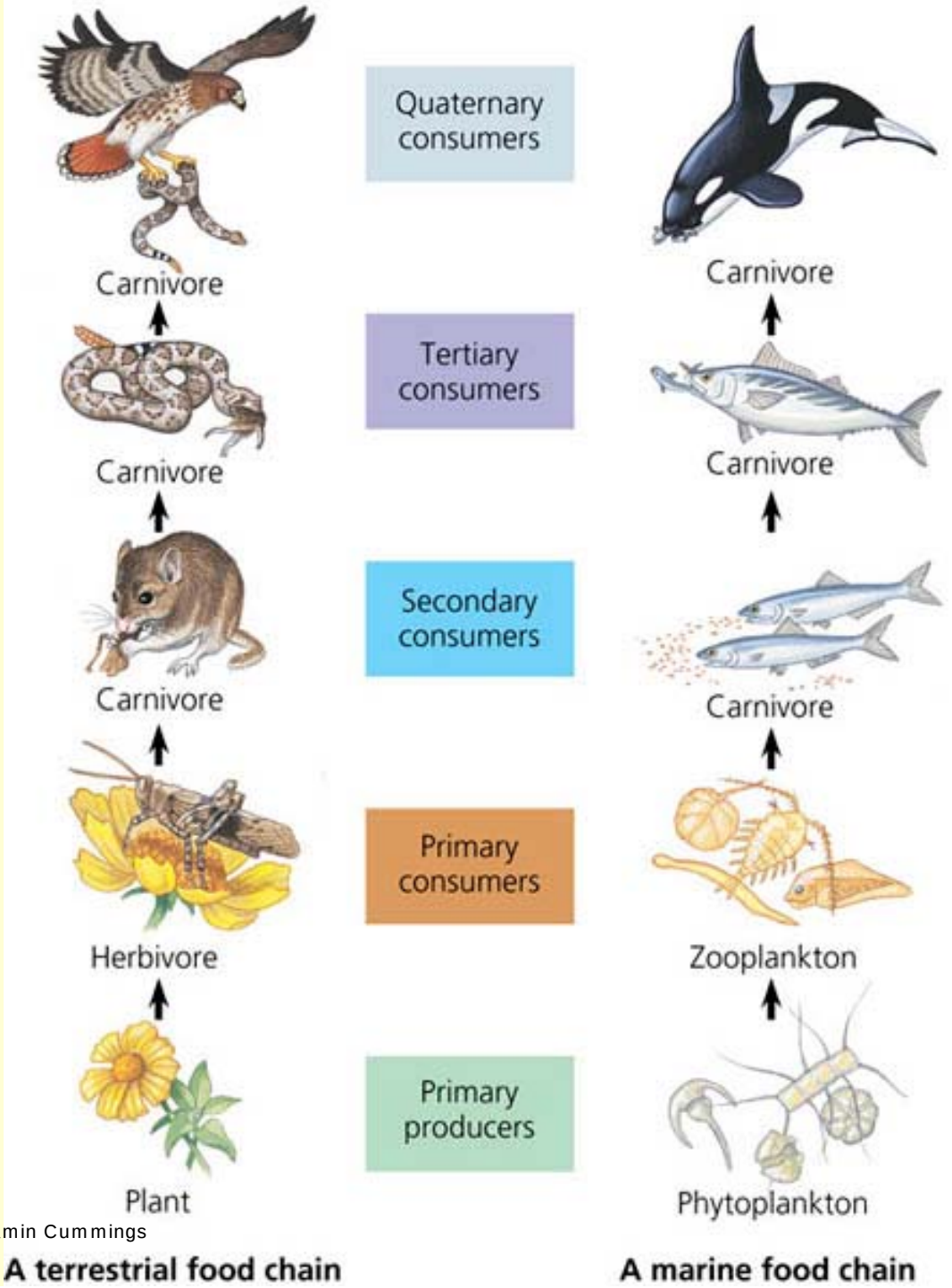
ii) species diversity

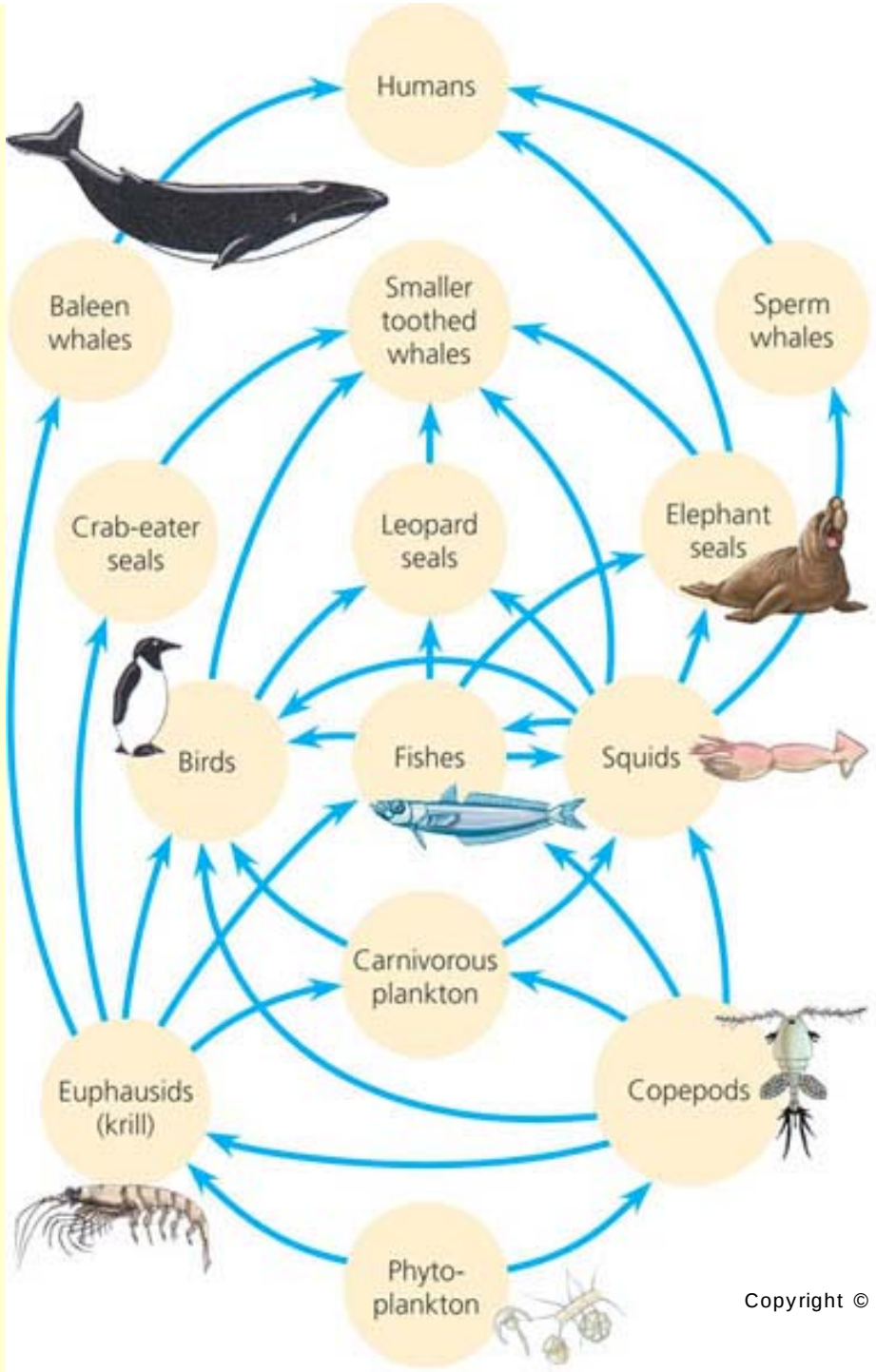
Trophic structure is a key factor in community dynamics

The **trophic structure** of a community is determined by the feeding relationships between organisms.

The transfer of food energy from its source in photosynthetic organisms through herbivores and carnivores is called the **food chain**.

Charles Elton first pointed out that the length of a food chain is usually four or five links, called **trophic levels**



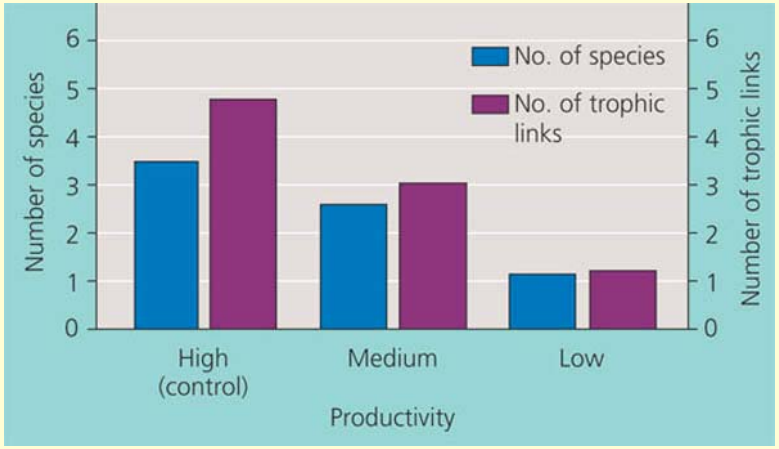


Elton recognized that food chains are not isolated units but are hooked together into **food webs**

Limits on Food Chain Length

The **energetic hypothesis** suggests that the length of a food chain is limited by the inefficiency of energy transfer along the chain.

~10% of the energy stored in the organic matter of any trophic level is converted to organic matter at the next trophic level: 100 kg plant material → 10kg herbivores → 1 kg of carnivores



Experimental test of hypothesis on tree communities in Australia

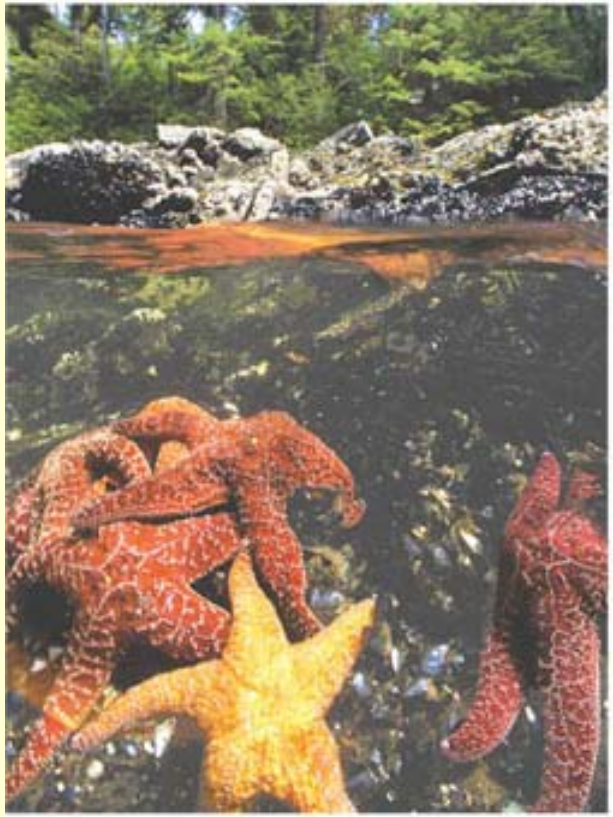
The **dynamic stability hypothesis** states that long food chains are less stable than short chains. Fluctuations at lower trophic levels are magnified at higher levels, potentially causing the extinction of top predators

Species with a Large Impact

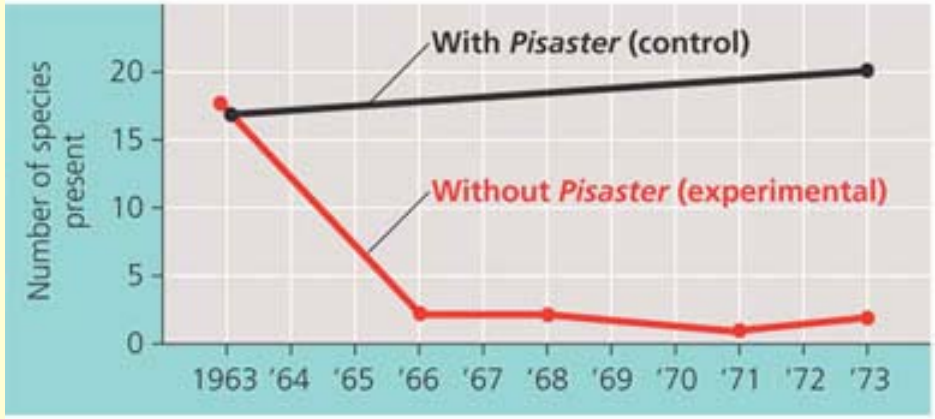
Dominant species are those species in a community that are the most abundant or that collectively have the highest **biomass** (the total mass of all individuals in a population).

If a dominant species is removed from a community, it can change much of the remaining community structure

contrast to dominant species, **keystone species** are not necessarily abundant in a community

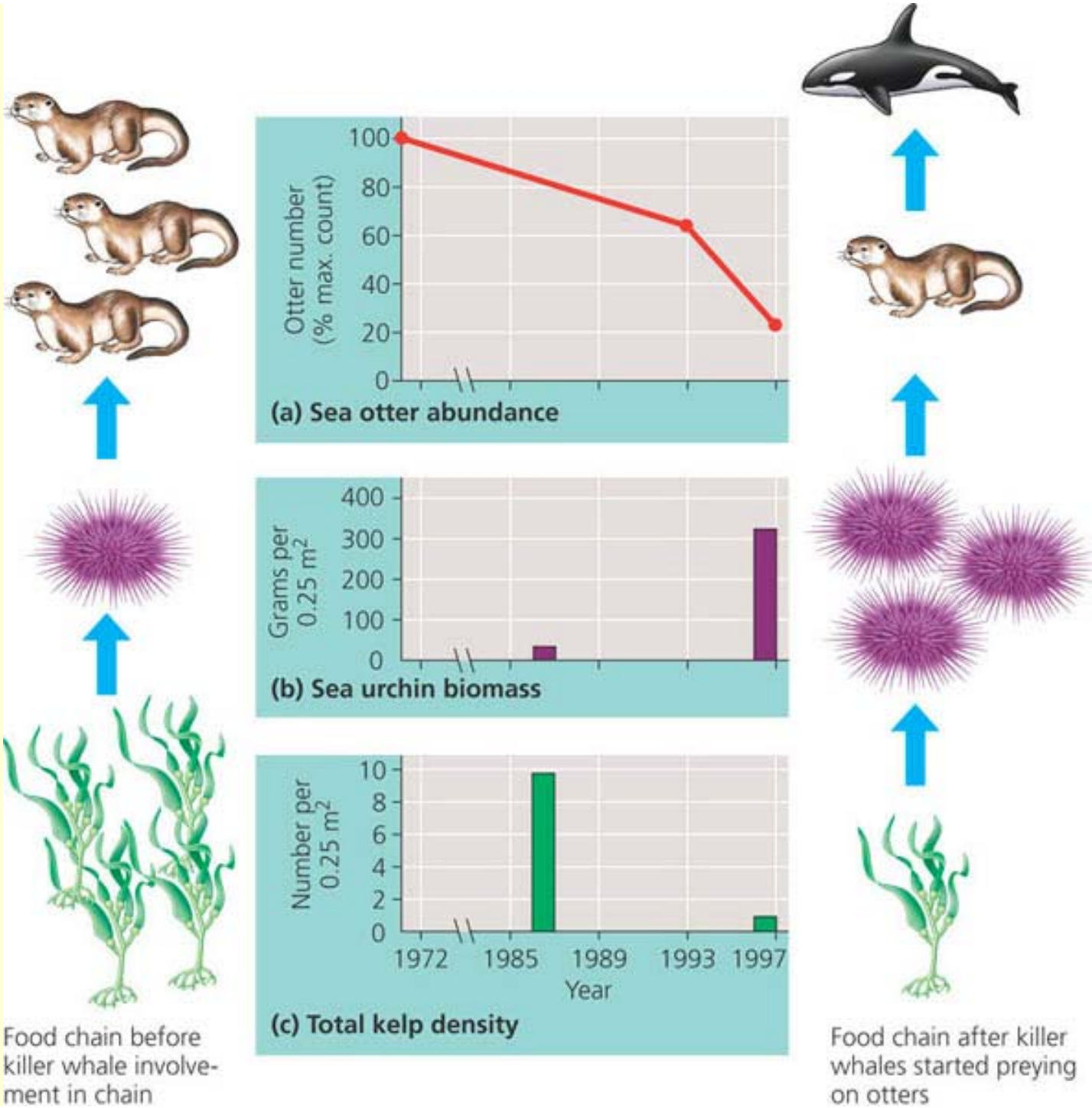


(a) The sea star *Pisaster ochraceous* feeds preferentially on mussels but will consume other invertebrates.



(b) When *Pisaster* was removed from an intertidal zone, mussels eventually took over the rock face and eliminated most other invertebrates and algae. In a control area from which *Pisaster* was not removed, there was little change in species diversity.

Sea otters as keystone predators in the North Pacific



Bottom–Up and Top–Down Controls

Consider three possible relationships between plants (V for vegetation) and herbivores (H).

V → H V ← H V ↔ H

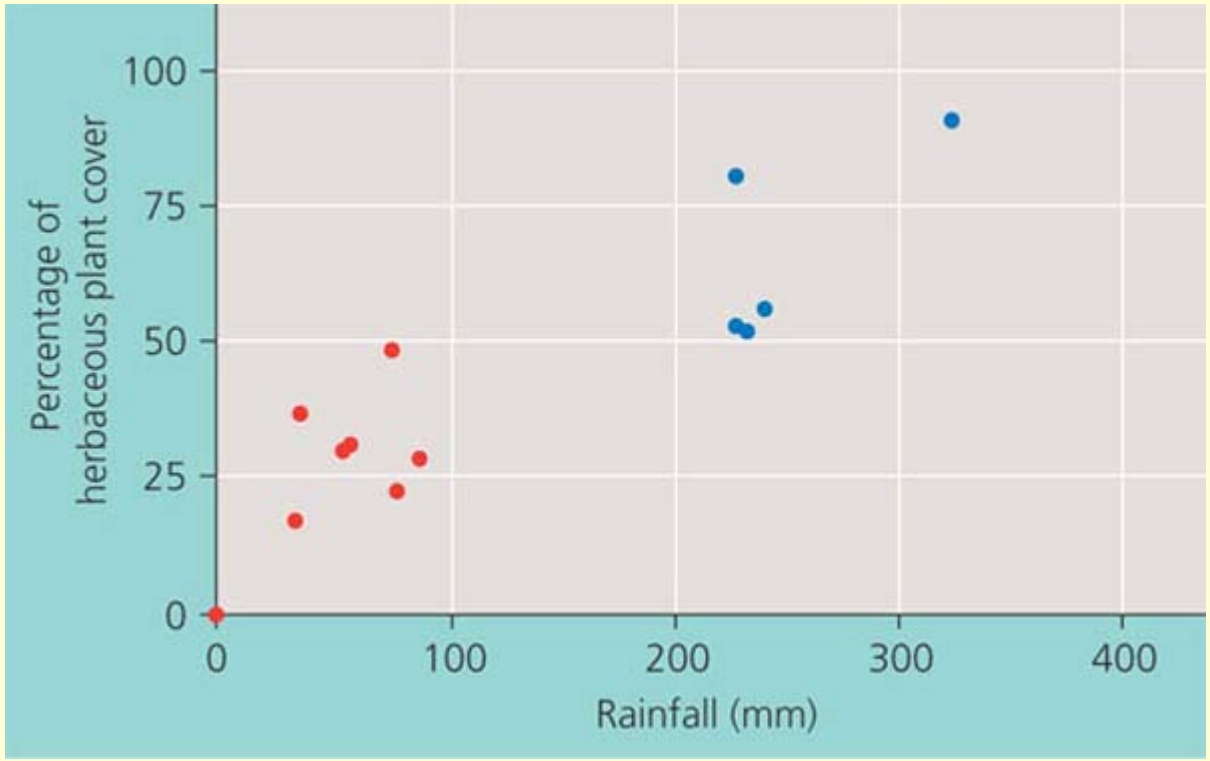
Arrows indicate that a change in biomass of one trophic level causes a change in the other trophic level.

The **bottom-up model** postulates V → H linkages, where nutrients and vegetation control community organization.

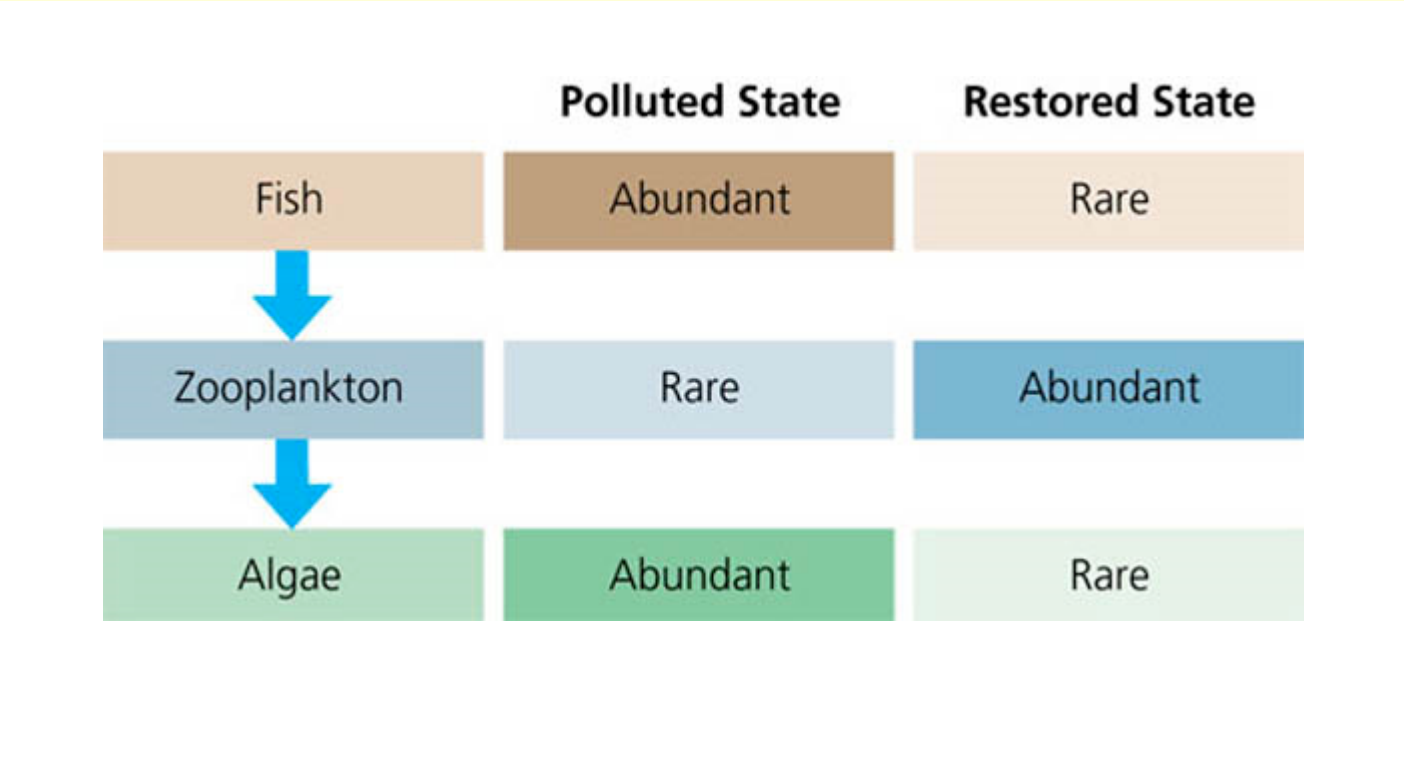
The **top-down model** postulates that it is mainly predation that controls community organization V ← H.

Other models go between the bottom-up and top-down extreme models but value of simplified models is that they provide a starting point for the analysis of communities.

one long–term experimental study of a desert shrub community in Chile showed that controls on primary producer biomass shift periodically from bottom–up to top–down, depending on the amount of rainfall



Biomanipulation: A technique for restoring eutrophic lakes that reduces populations of algae by manipulating the higher–level consumers in the community rather than by changing nutrient levels or adding chemical treatments. This is possible because freshwater lake communities seem to be structured according to the **top–down model**



Stable communities are in an equilibrium state of abundance of their member species

Disturbance influences species diversity and composition

A disturbance is an event, such as a storm, fire, flood, drought, overgrazing, or human activity, that changes a community, removes organisms from it, and alters resource availability.

(a) Before a controlled burn. A prairie that has not burned for several years has a high proportion of detritus (dead grass).

(b) During the burn. The detritus serves as fuel for fires.

(c) After the burn. Approximately one month after the controlled burn, virtually all of the biomass in this prairie is living.

Marine communities are subject to disturbance by tropical storms.

Disturbances are in many cases necessary for coexistence of pioneer and equilibrium species and hence for diversity

intermediate disturbance hypothesis

The concept that moderate levels of disturbance can foster greater species diversity than low or high levels of disturbance.

(a) Soon after fire. As this photo taken soon after the fire shows, the burn left a patchy landscape. Note the unburned trees in the distance.

(b) One year after fire. This photo of the same general area taken the following year indicates how rapidly the community began to recover. A variety of herbaceous plants, different from those in the former forest, cover the ground.

Human activities cause more disturbance than natural events but usually reduce species diversity in communities because they do not allow recovery after disturbance but keep communities constantly disturbed, and hence in an early colonization

Transition in the species composition of a biological community, often following ecological disturbance of the community; the establishment of a biological community in an area virtually barren of life.

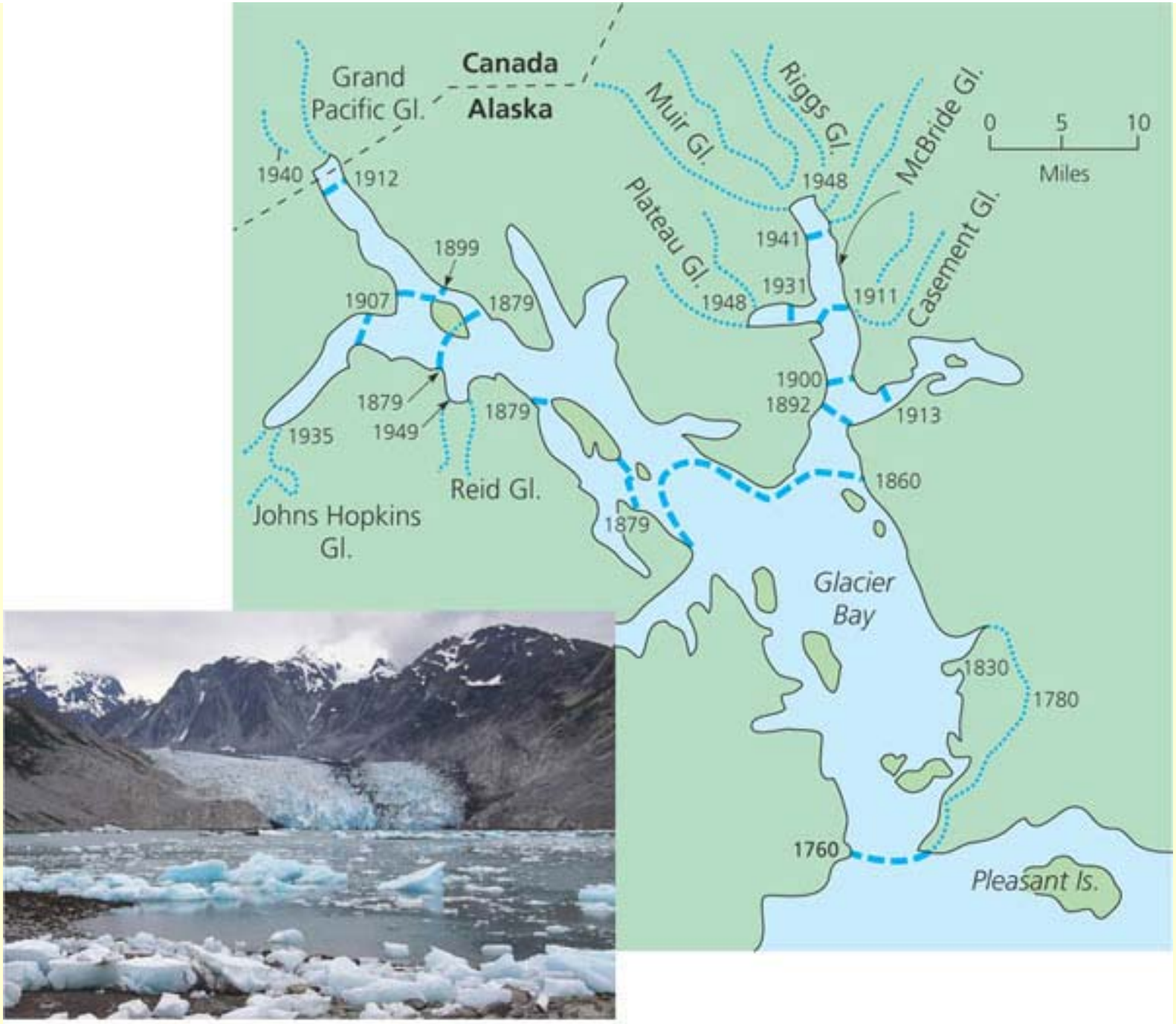
ecological succession

primary succession

A type of ecological succession that occurs in a virtually lifeless area, where there were originally no organisms and where soil has not yet formed.

secondary succession

A type of succession that occurs where an existing community has been cleared by some disturbance that leaves the soil intact.

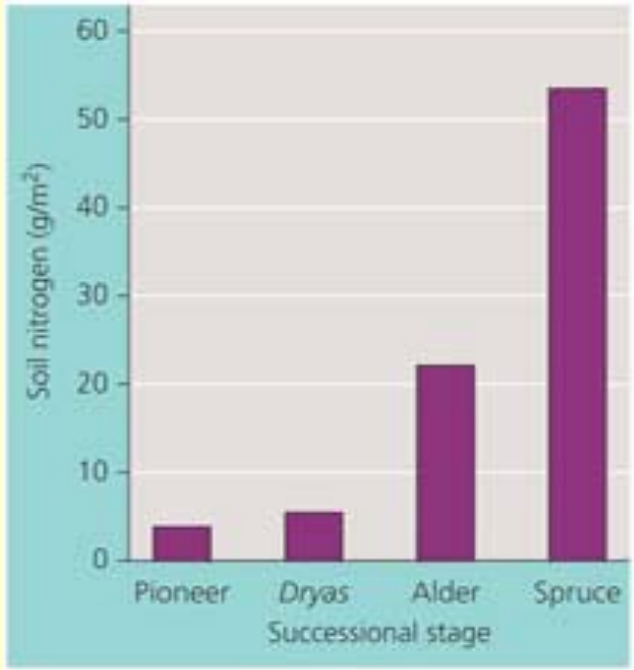


McBride glacier retreating

(a) Pioneer stage, with fireweed dominant

(b) *Dryas* stage

(c) Spruce stage



(d) Nitrogen fixation by *Dryas* and alder increases the soil nitrogen content.

Grasses grow first, then trees and other organisms. Secondary succession starts out with much higher diversity

Biogeographic factors affect community biodiversity

Three key factors correlated with a community's **biodiversity** (species diversity) are:

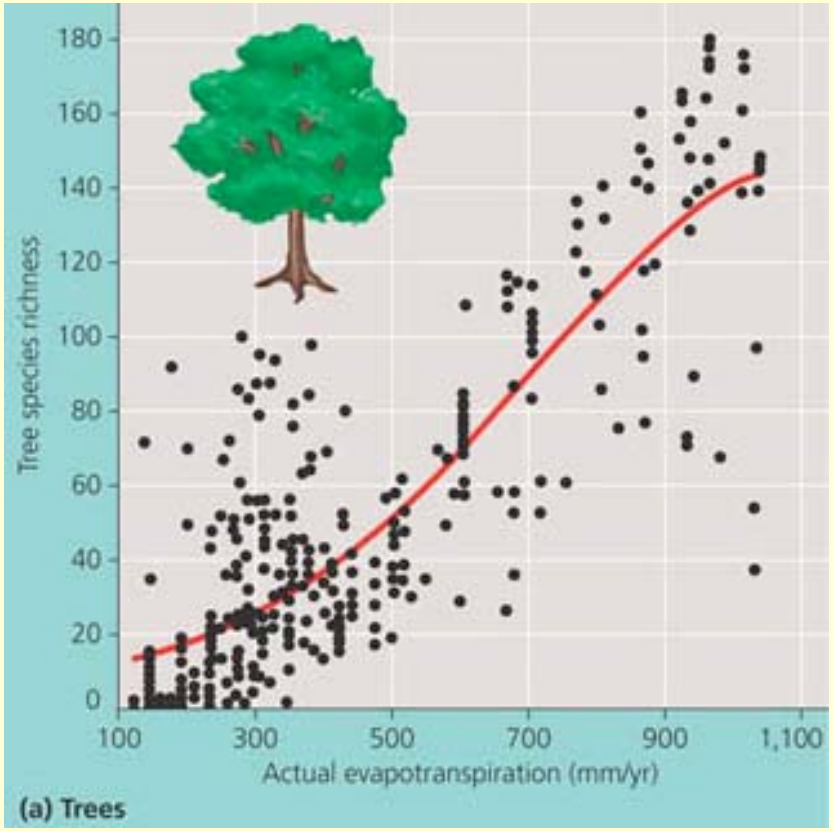
its size

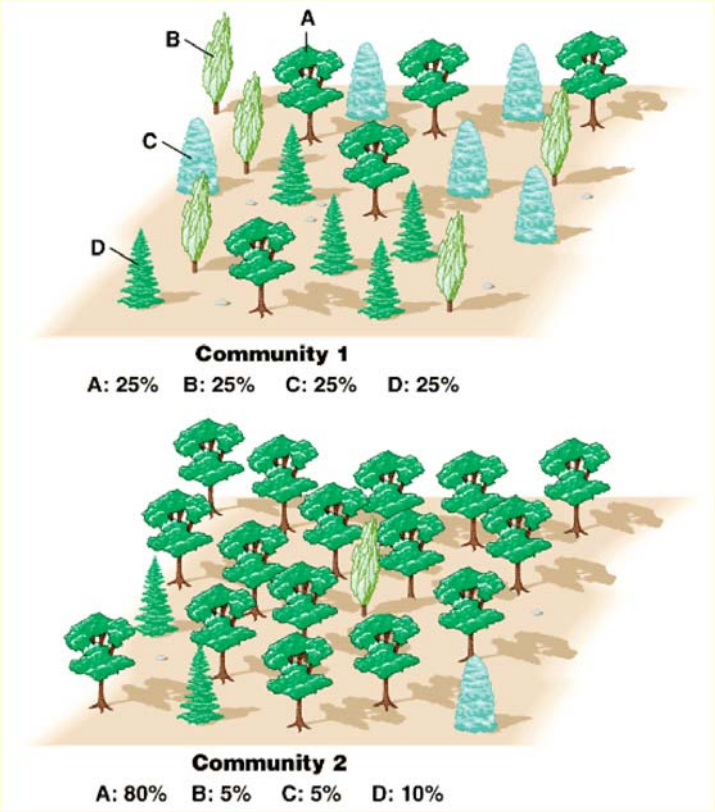
its biogeographical connectivity

its geographical (latitudinal) position

Species richness, the total number of species in the community.

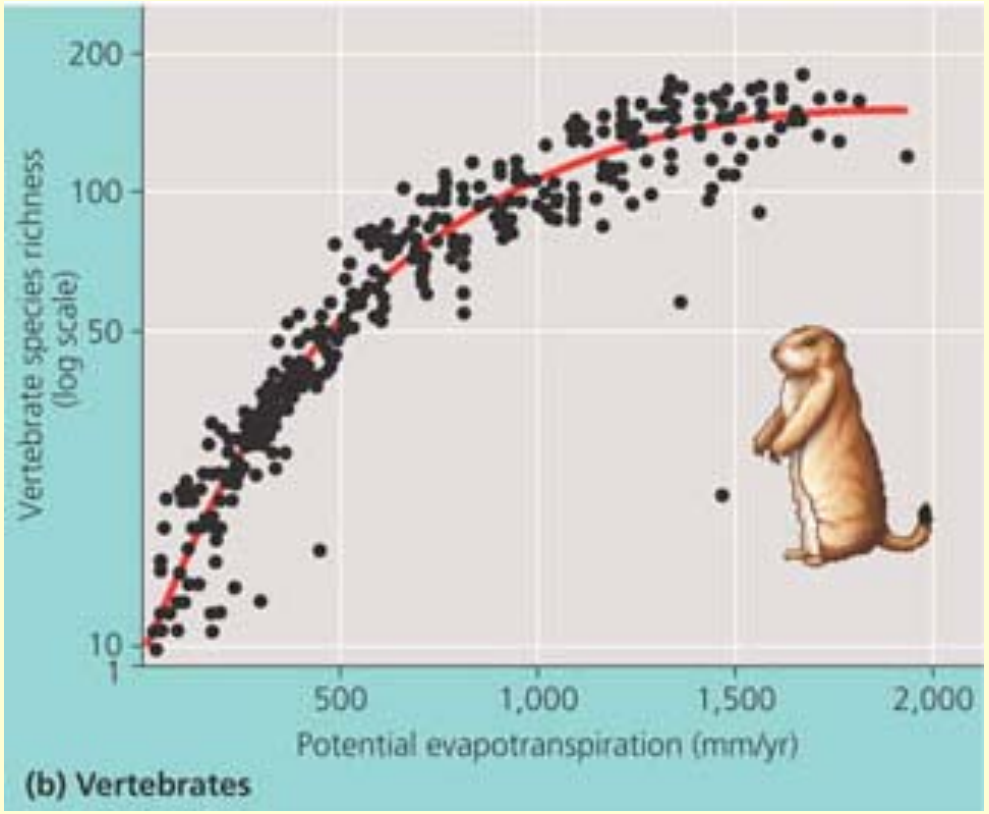
Relative abundance of the different species.



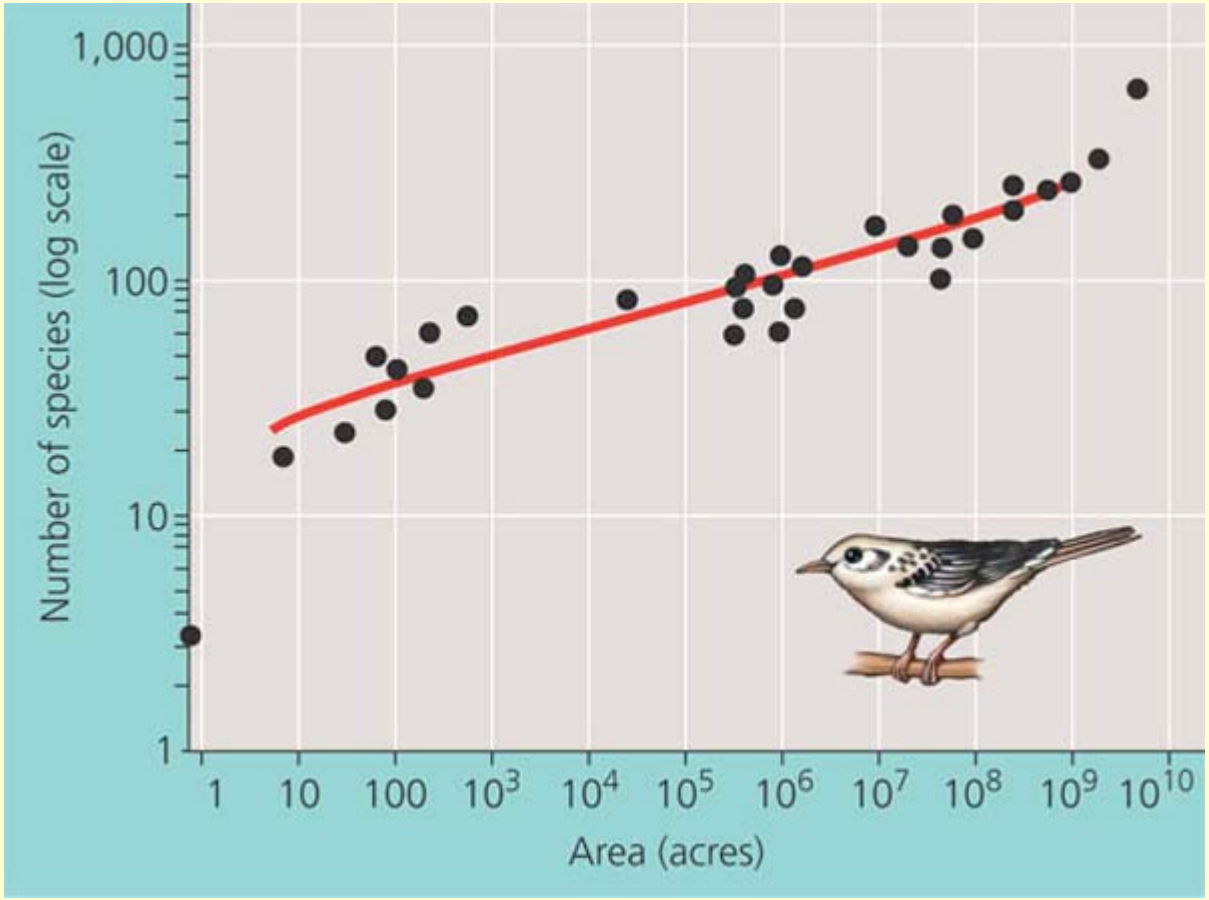


vertebrate species richness in North America increases most predictably with potential **evapotranspiration**.

The evaporation of water from soil plus the transpiration of water from plants.



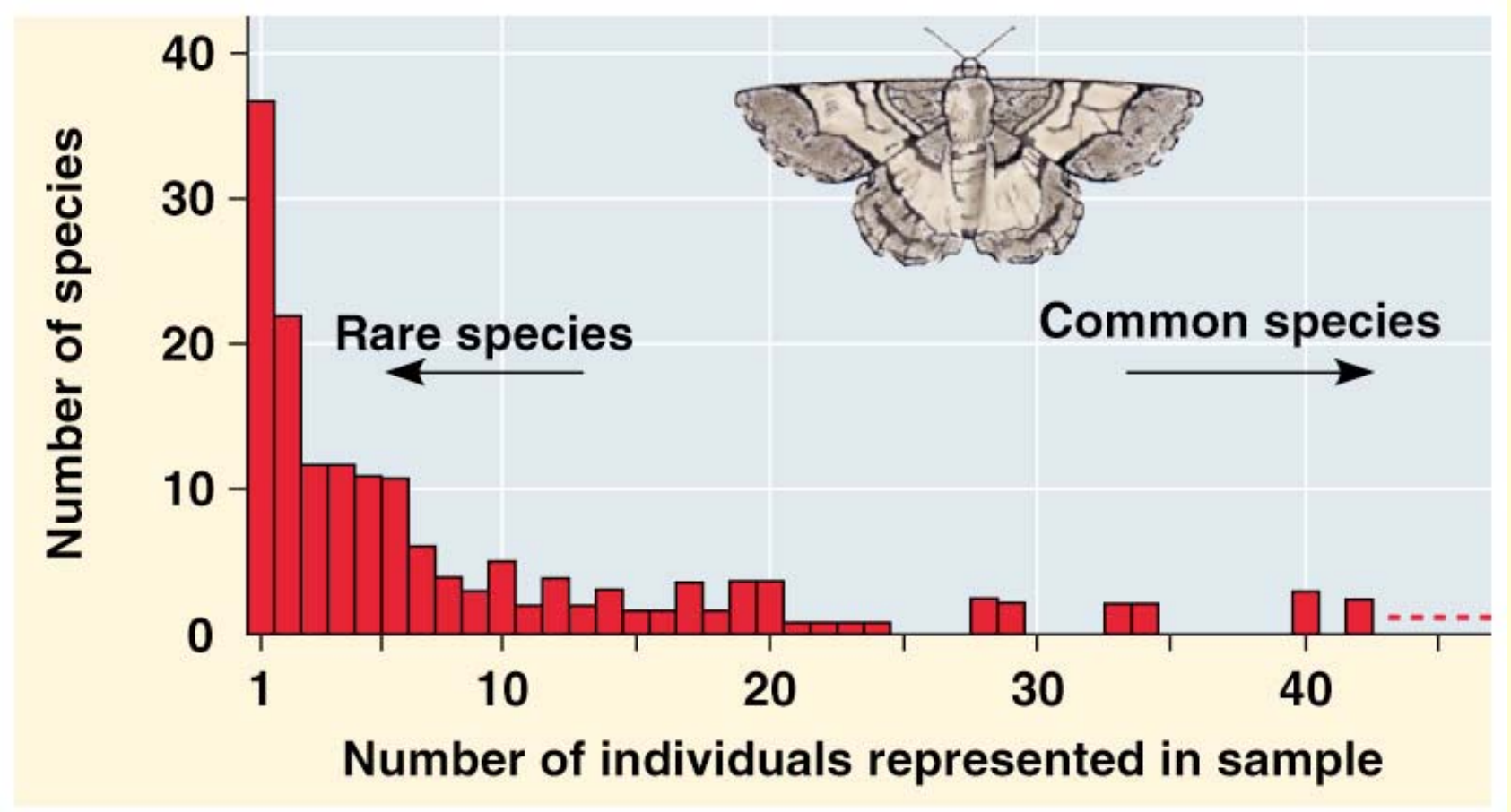
Alexander von Humboldt (1807) described one of the first patterns of biodiversity to be recognized, the **species–area curve**



All other factors being equal, the larger the geographic area of a community, the greater the number of species!!

To quantify and compare diversity between communities, species diversity indices are used that combine species numbers and the distribution of abundances over species.

Species-abundance curve (“hollow curve”)



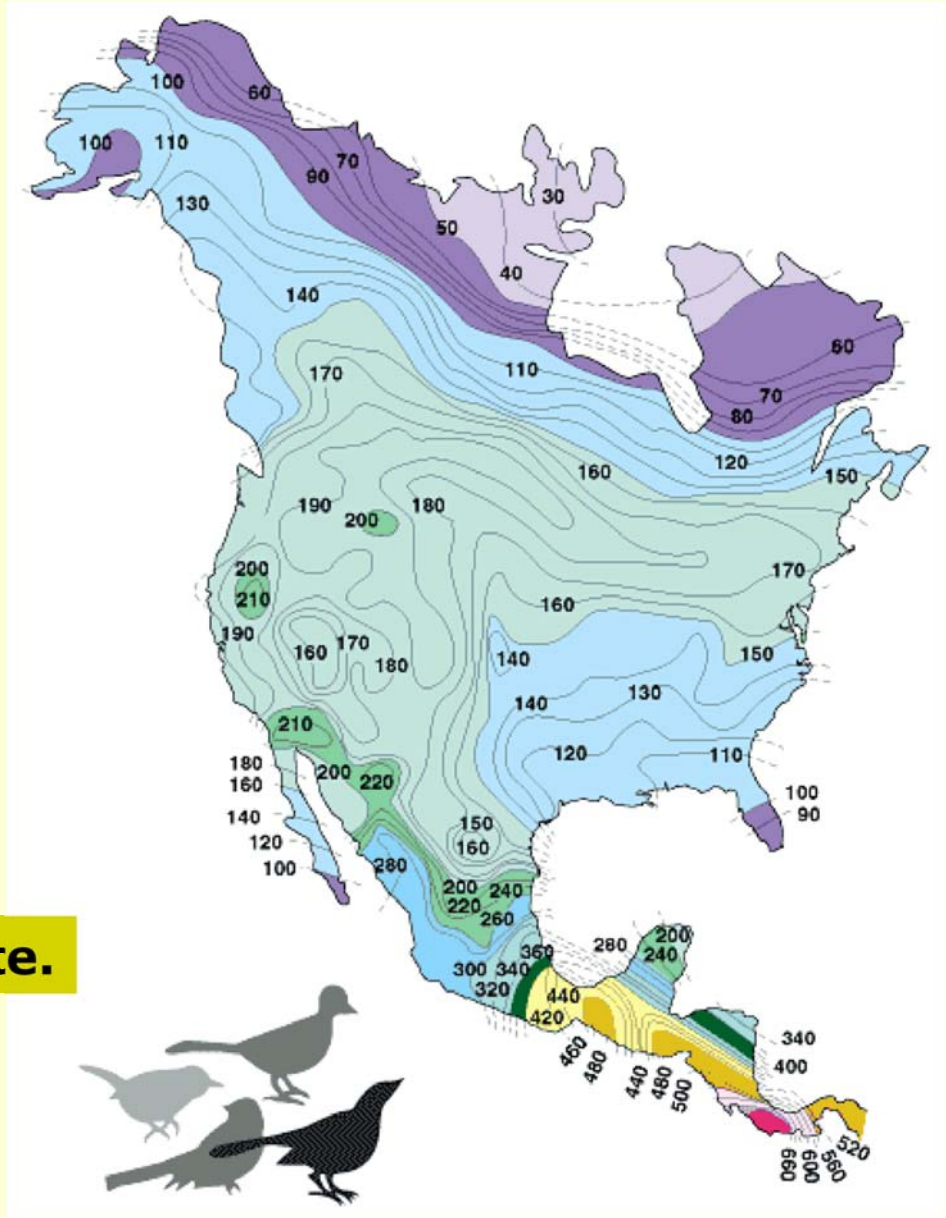
How to explain the predominance of “hollow” species-abundance curves?

Niche preemption hypothesis

Tropical habitats support much larger numbers of species than do temperate and polar regions.

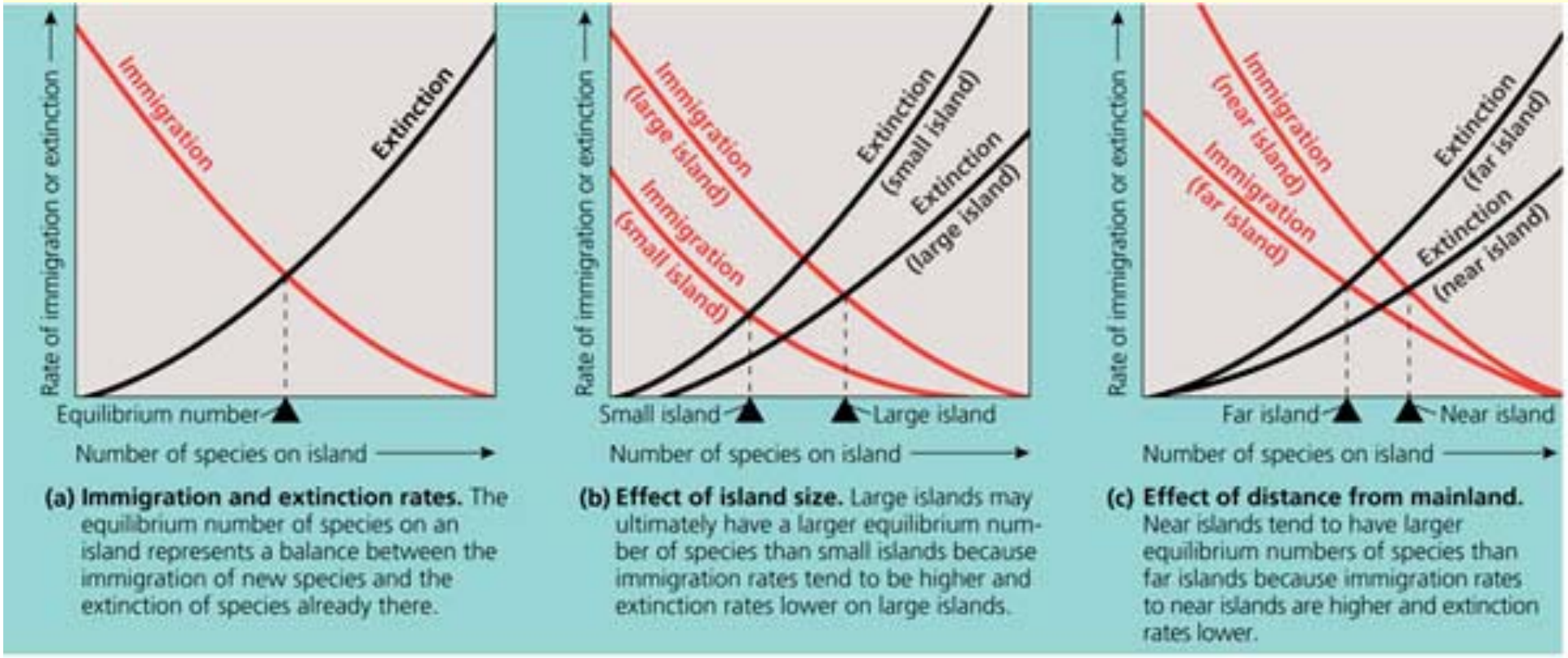
Although this general latitudinal diversity gradient is overlaid and locally sometimes overruled by regional patterns

Geographical pattern of species richness of land birds of North and Central America



evolutionary history and climate.

The equilibrium model of island biogeography.



Black triangles represent equilibrium numbers of species.

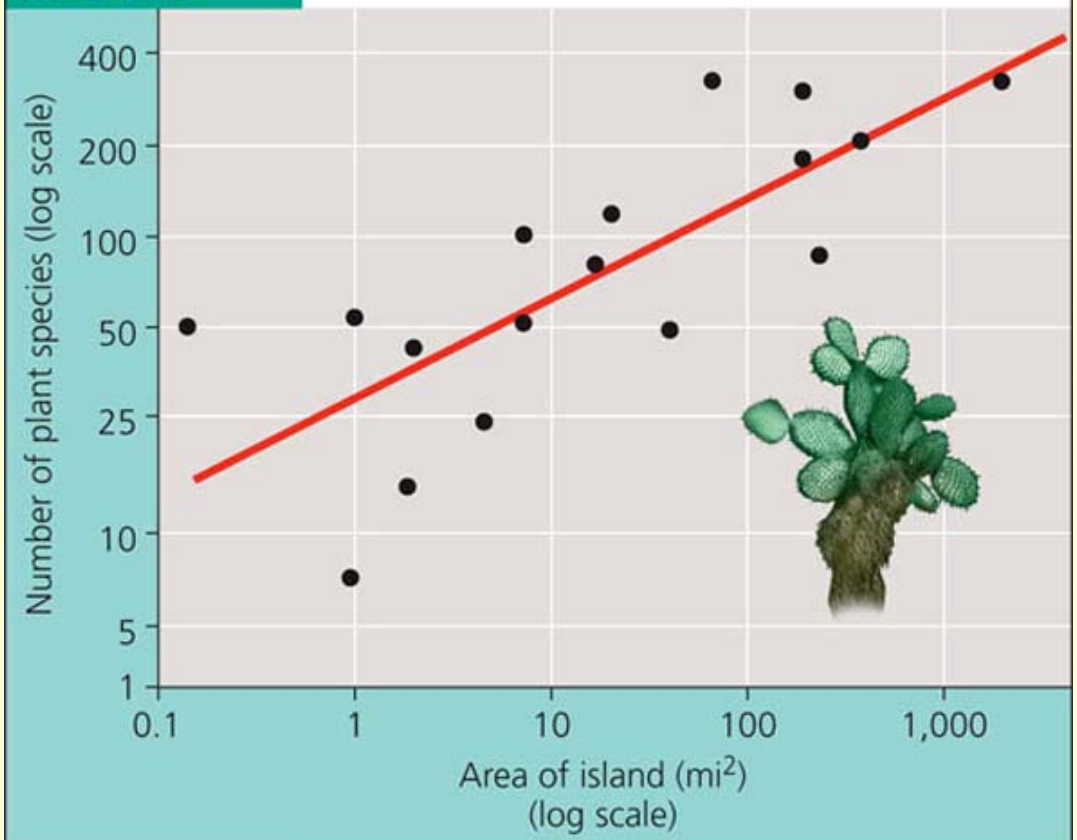
Figure 53.28

Inquiry How does species richness relate to area?

FIELD STUDY

Ecologists Robert MacArthur and E. O. Wilson studied the number of plant species on the Galápagos Islands, which vary greatly in size, in relation to the area of each island.

RESULTS

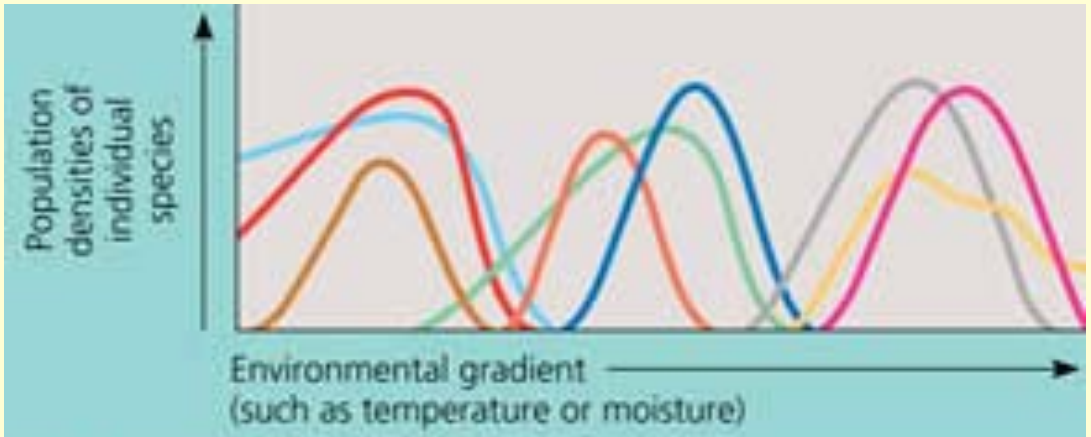


CONCLUSION

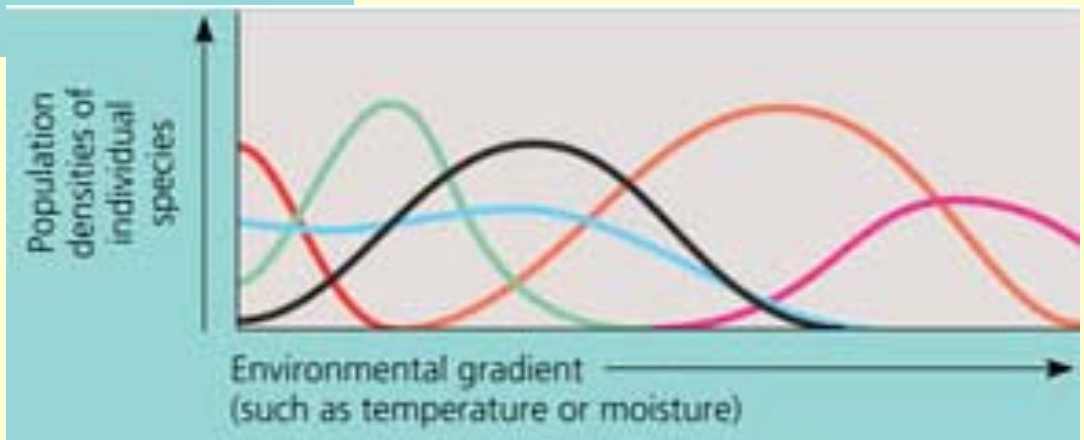
The results of the study showed that plant species richness increased with island size, supporting the species-area theory.

And finally…

views of community structure



(a) Integrated hypothesis. Communities are discrete groupings of particular species that are closely interdependent and nearly always occur together.



(b) Individualistic hypothesis. Species are independently distributed along gradients and a community is simply the assemblage of species that occupy the same area because of similar abiotic needs.

The **rivet model** (Paul and Anne Ehrlich): many or most of the species in a community are associated tightly with other species in a web of life. According to this model, an increase or decrease in one species in a community affects many other species. It is a reincarnation of the integrated model

The **redundancy model** states that most species in a community are not closely associated with one another.

On balance, there is strong evidence that ecological species interactions are a very important factor in determining community composition, although the different types of interactions may not be species-by-species specific but rather specific for interactions between and within ecological groups.

i) One can argue whether the apparent redundancy of species within the same ecological group is real redundancy. Competition among ecologically similar but not identical species may have important effects on the community.
ii) Competition is frequency-dependent which leads to larger total population density through more effective resource utilization

the end