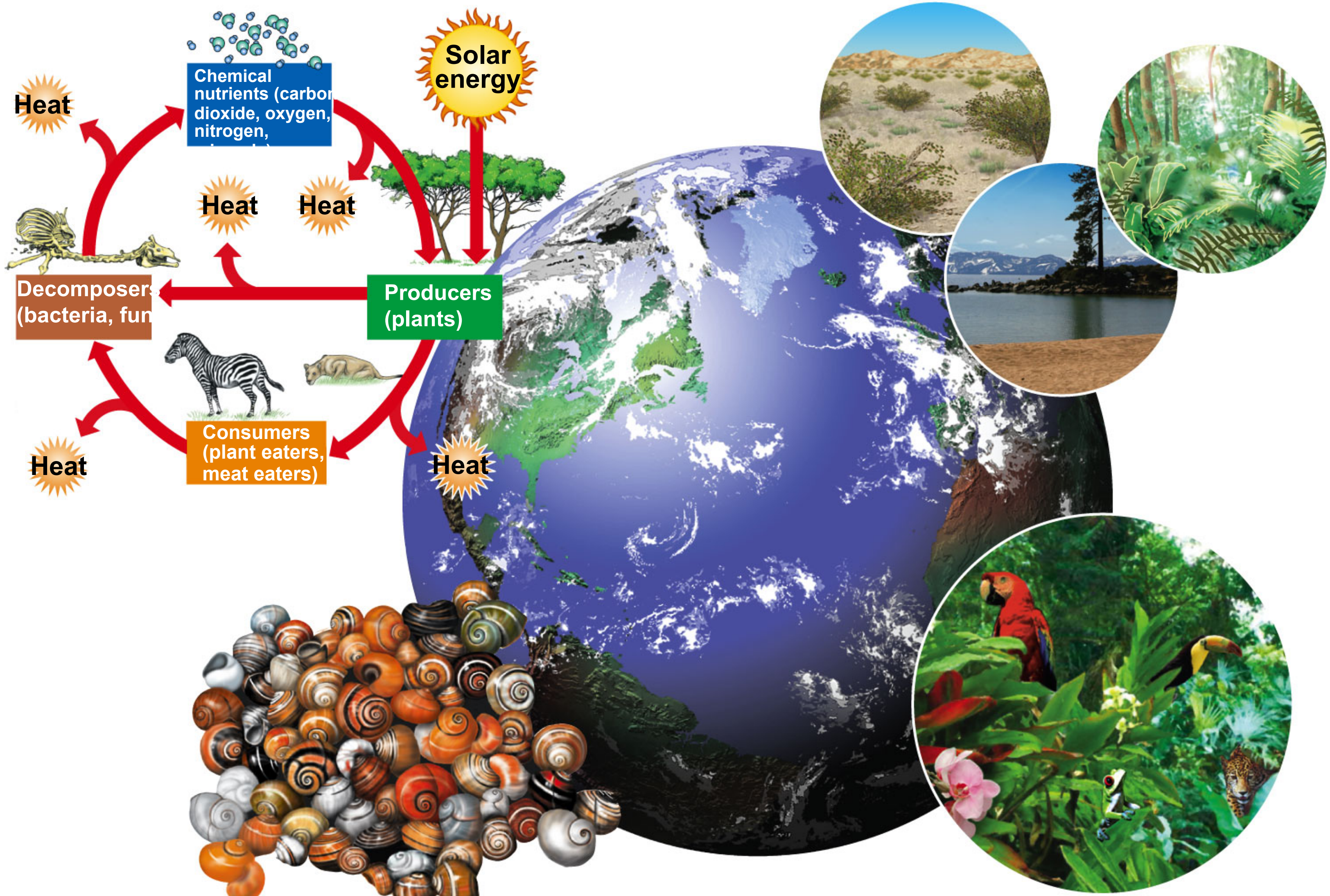
CHAPTER 4 & 5

Biodiversity: Evolution, Species Interactions, and Population Control

Functional Diversity The biological and chemical processes such as energy flow and matter recycling needed for the survival of species, communities, and ecosystems.

Ecological Diversity The variety of terrestrial and aquatic ecosystems found in an area or on the earth.



Genetic Diversity The variety of genetic material within a species or a population.

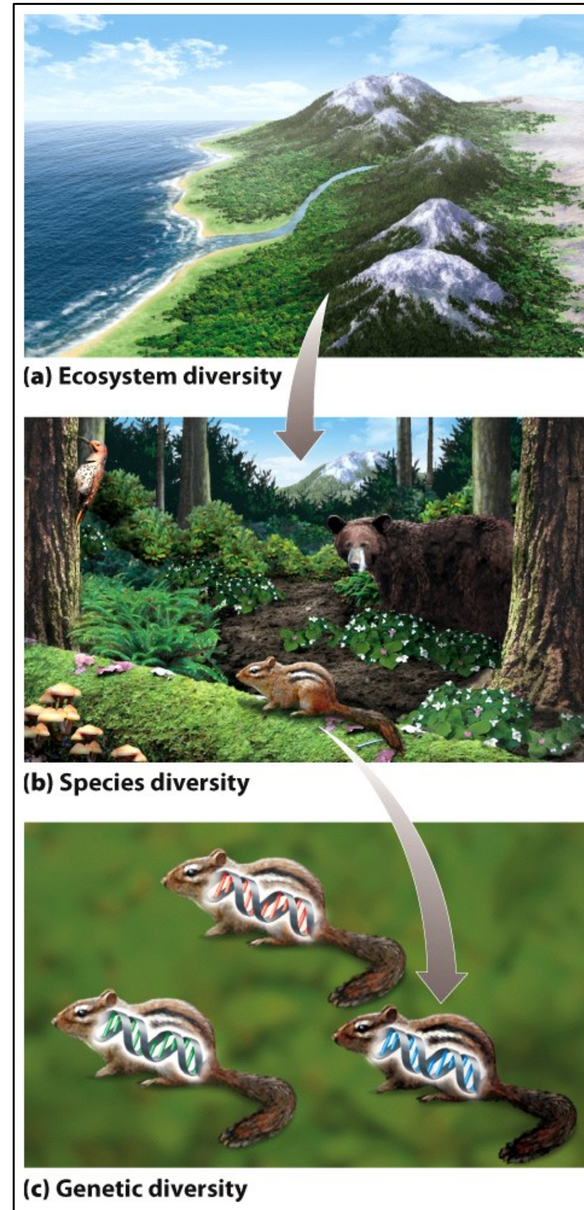
Species Diversity The number and abundance of species present in different communities.

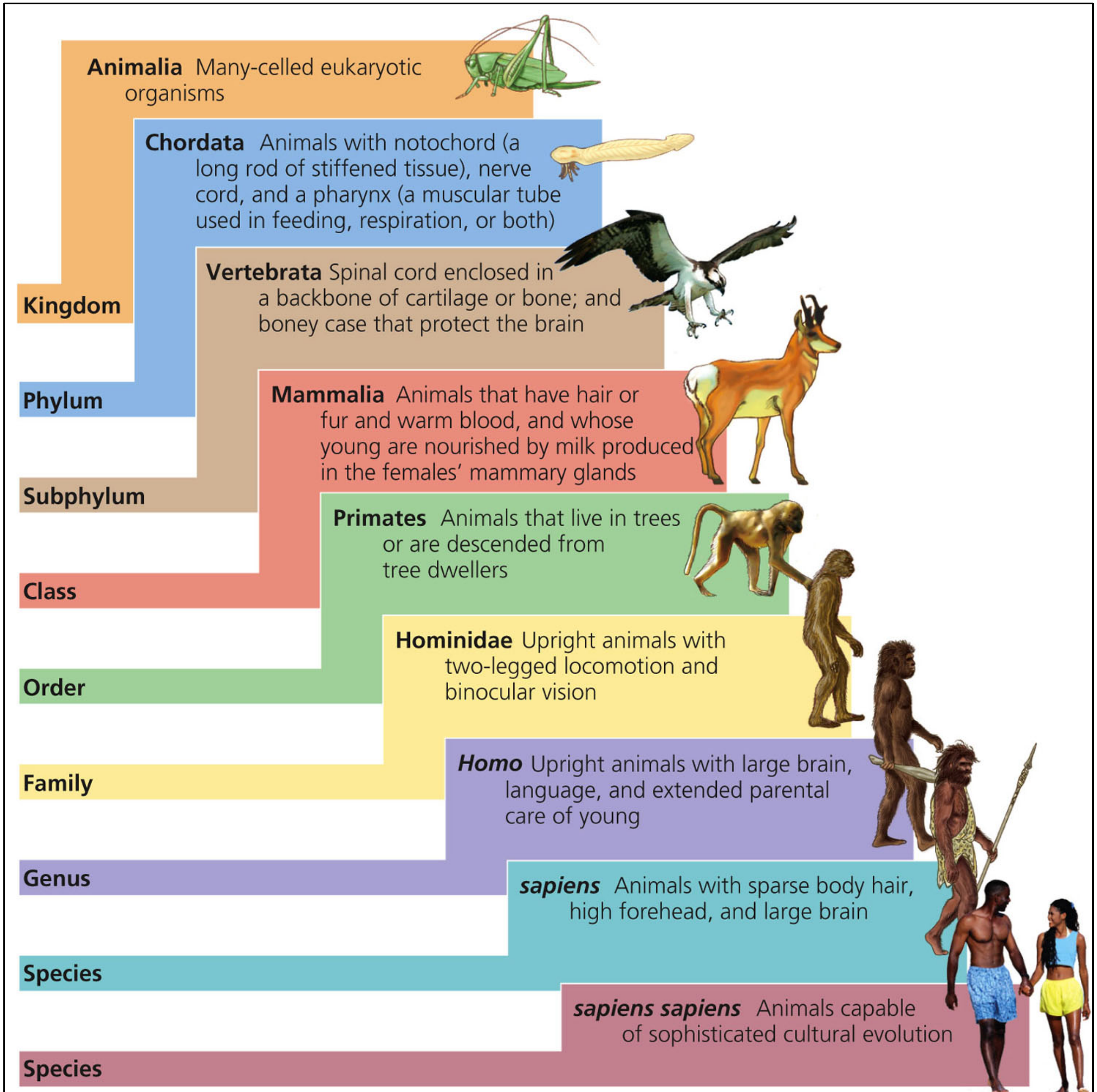
Biodiversity Is a Crucial Part of the Earth's Natural Capital

Biodiversity: variety of earth's species, or varying life forms, the genes they contain, the ecosystems they live in and the ecosystem processes of energy flow and nutrient cycling that sustain life.

- Species diversity
- Genetic diversity
- Ecosystem diversity
- Functional diversity

Biodiversity is an important part of natural capital




Animalia Many-celled eukaryotic organisms
Chordata Animals with notochord (a long rod of stiffened tissue), nerve cord, and a pharynx (a muscular tube used in feeding, respiration, or both)
Vertebrata Spinal cord enclosed in a backbone of cartilage or bone; and boney case that protect the brain
Mammalia Animals that have hair or fur and warm blood, and whose young are nourished by milk produced in the females' mammary glands
Primates Animals that live in trees or are descended from tree dwellers
Hominidae Upright animals with two-legged locomotion and binocular vision
Homo Upright animals with large brain, language, and extended parental care of young
sapiens Animals with sparse body hair, high forehead, and large brain
sapiens sapiens Animals capable of sophisticated cultural evolution
Kingdom
Phylum
Subphylum
Class
Order
Family
Genus
Species
Species

Biodiversity Is a Crucial Part of the Earth's Natural Capital

Species: set of individuals who can mate and produce fertile offspring

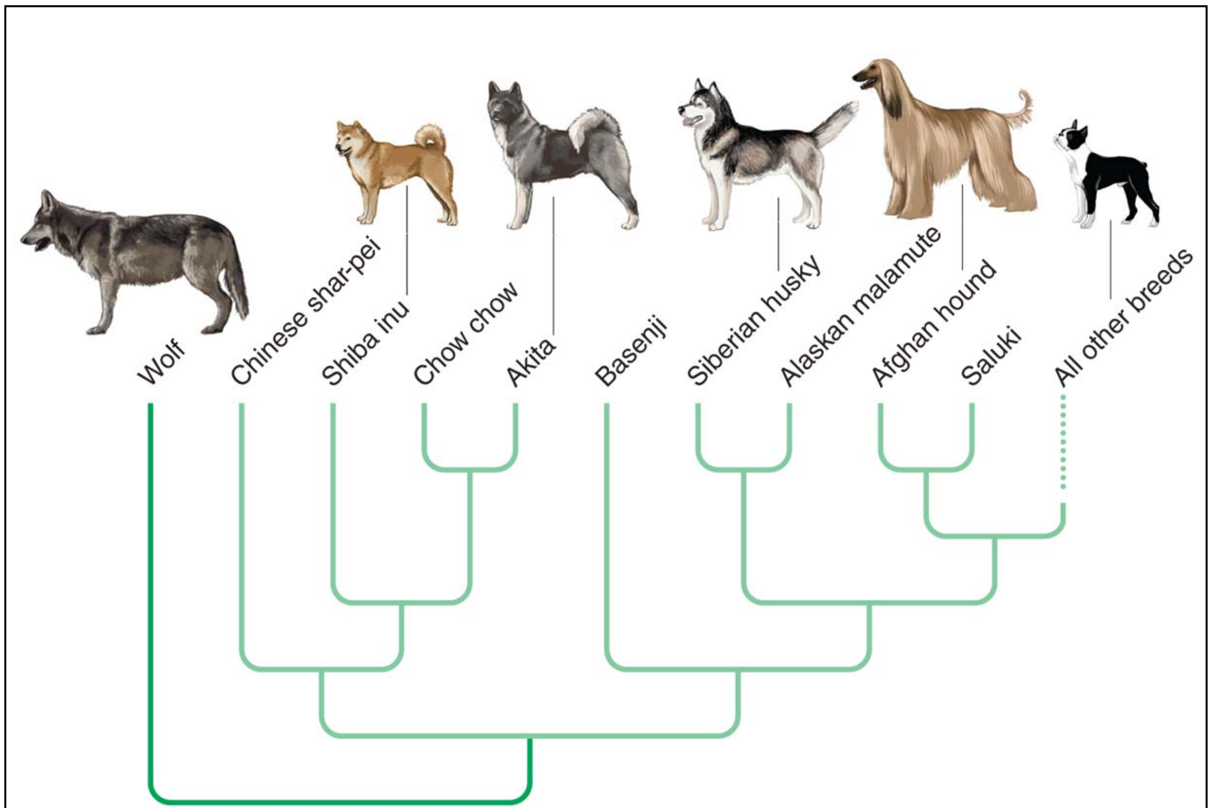
- Biologists have observed & identified 1.9 million species
- Estimated: 8 million to 100 million species
- Unidentified are mostly in rain forests and oceans

A dog and a cat: two different species

Changing the Genetic Traits of Populations

Artificial selection; i.e. Selective Breeding

All species belong to the same species as the gray wolf (*Canis lupus*), yet dogs exist in an amazing variety of shapes, sizes, and behavior types. Dogs remain a single species (*Canis lupus*) and can still mate and breed with on another and produce viable fertile offspring.

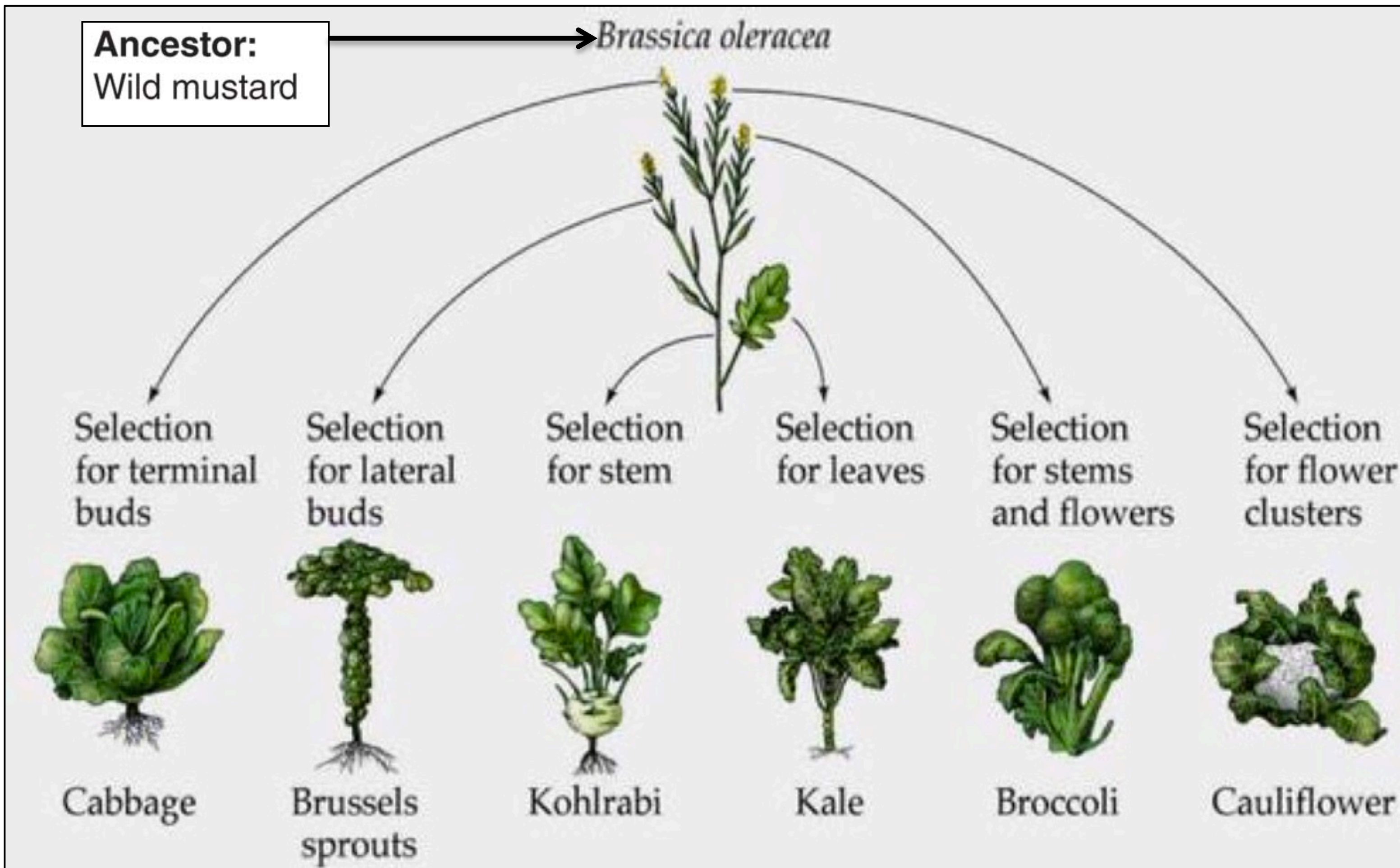


Changing the Genetic Traits of Populations

Artificial selection; i.e. Selective Breeding

- **Common Garden Experiments**

Use selective breeding/crossbreeding; e.g. wild mustard over thousands of years each has been selectively bred for a different trait.



Biological Evolution by Natural Selection Explains How Life Changes over Time

Biological evolution: how earth's life changes over time through changes in the genetic characteristics of populations.

Darwin*: Origin of Species*: Change in populations (not individuals) genetic makeup over successive generations.

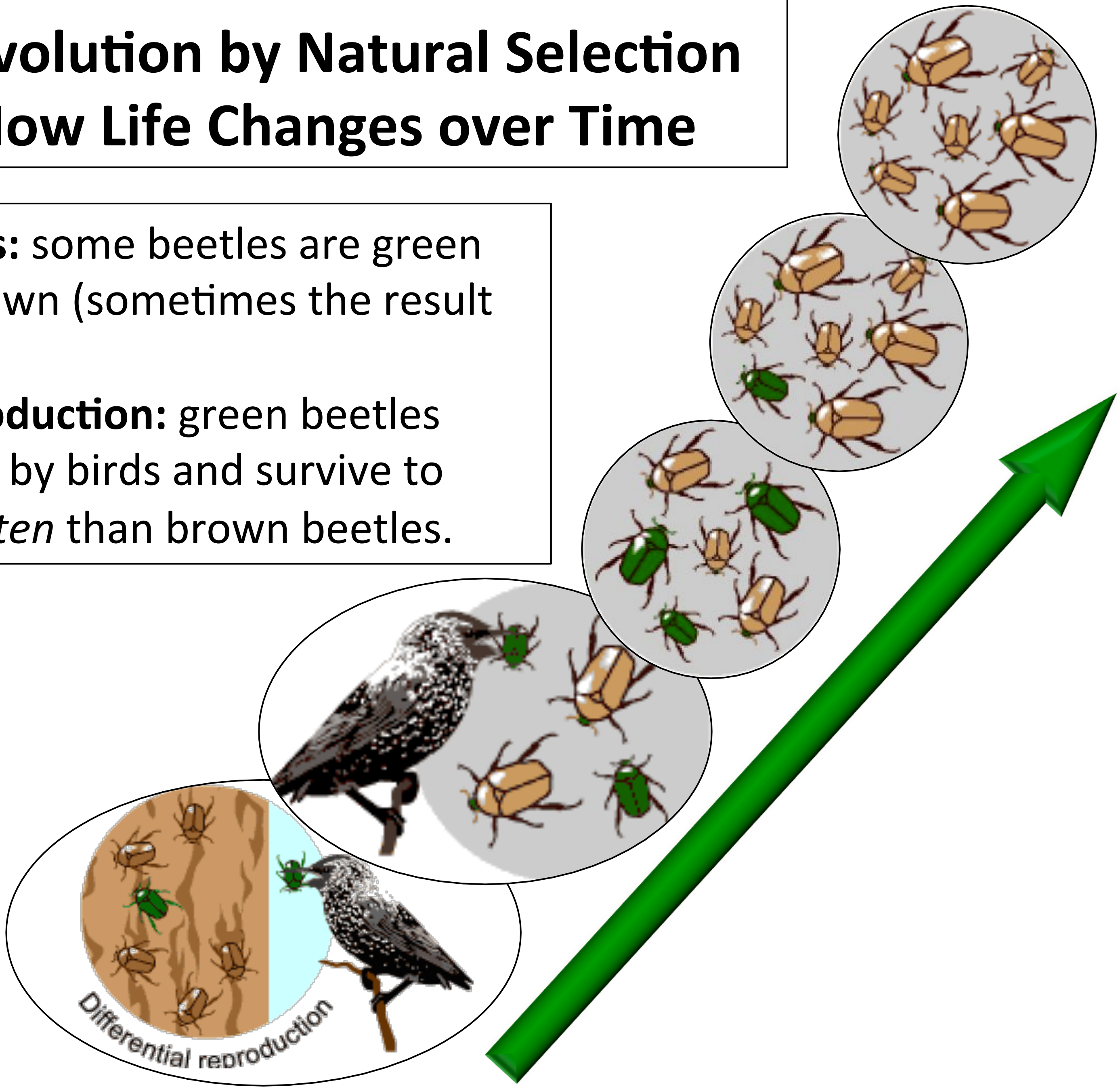
Natural selection: individuals with certain traits are more likely to survive and reproduce under a certain set of environmental conditions. Traits are passed to offspring. More advantageous traits allow some organisms to survive and thus have more offspring, then the trait becomes more common in the population.

Differential reproduction: organisms that are best adapted to a given environment will be most likely to survive to reproductive age and have offspring of their own and therefore the better-adapted organisms will reproduce at a greater rate than the less well-adapted organisms.

Biological Evolution by Natural Selection Explains How Life Changes over Time

Variation in traits: some beetles are green and some are brown (sometimes the result of a mutation).
Differential reproduction: green beetles tend to get eaten by birds and survive to reproduce *less often* than brown beetles.

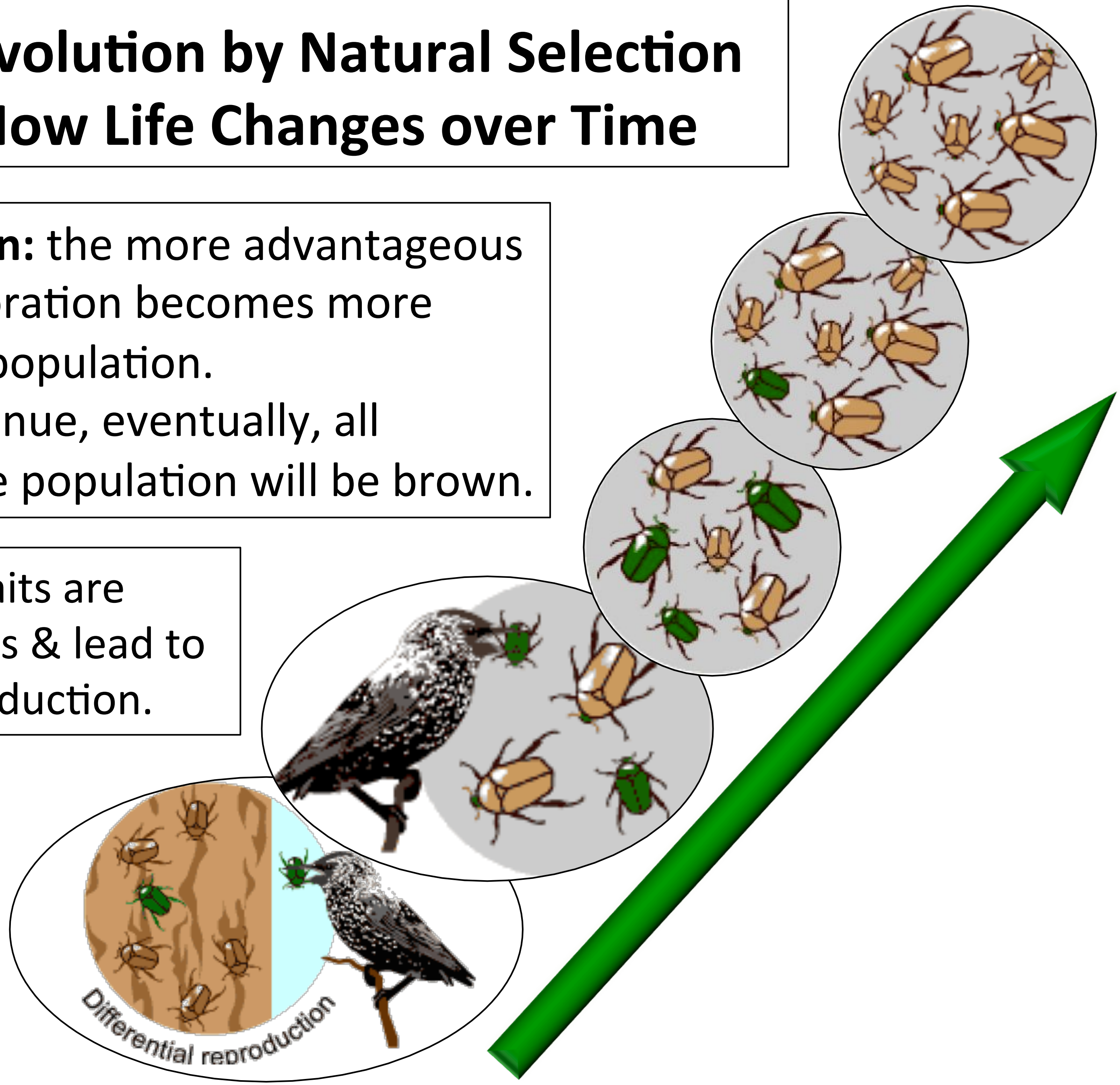
Heredity:
the surviving brown beetles have brown baby beetles because this trait has a genetic basis.



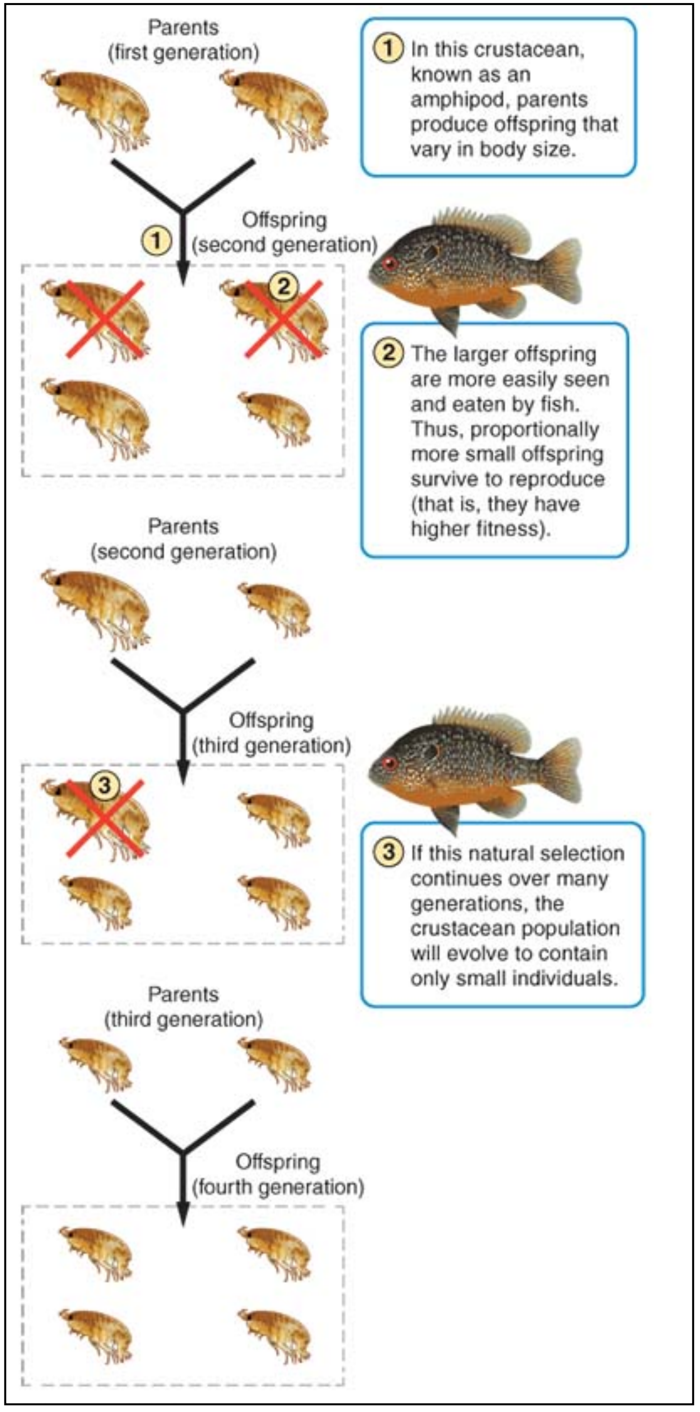
Biological Evolution by Natural Selection Explains How Life Changes over Time

Natural Selection: the more advantageous trait, brown coloration becomes more common in the population.
Should this continue, eventually, all individuals in the population will be brown.

Advantageous traits are called adaptations & lead to differential reproduction.

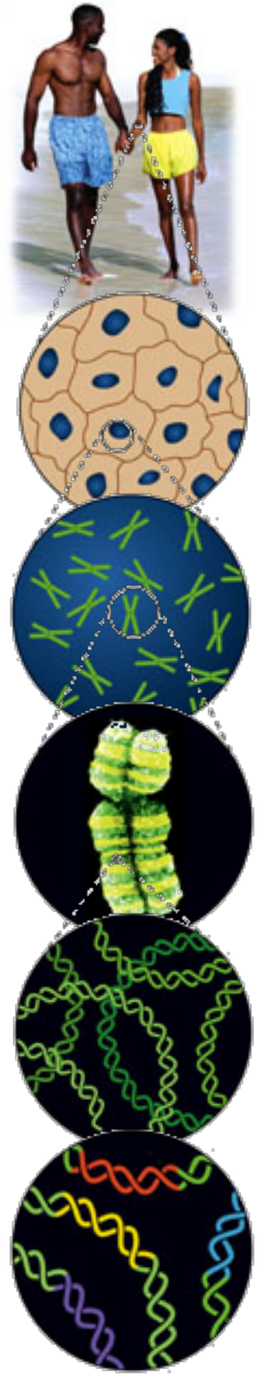


Do the strong survive?



Levels of Organization

- **Cells:** fundamental units of life; all organisms are composed of one or more cells
- **Genes**
  - Sequences of nucleotides within DNA
  - Instructions for proteins
  - Create inheritable **traits**
- **Chromosomes**: composed of many genes



A human body contains trillions of cells, each with an identical set of genes.

Each human cell (except for red blood cells) contains a nucleus.

Each cell nucleus has an identical set of chromosomes, which are found in pairs.

A specific pair of chromosomes contains one chromosome from each parent.

Each chromosome contains a long DNA molecule in the form of a coiled double helix.

Genes are segments of DNA on chromosomes that contain instructions to make proteins—the building blocks of life.

Genetics 101-Understanding How Populations Change

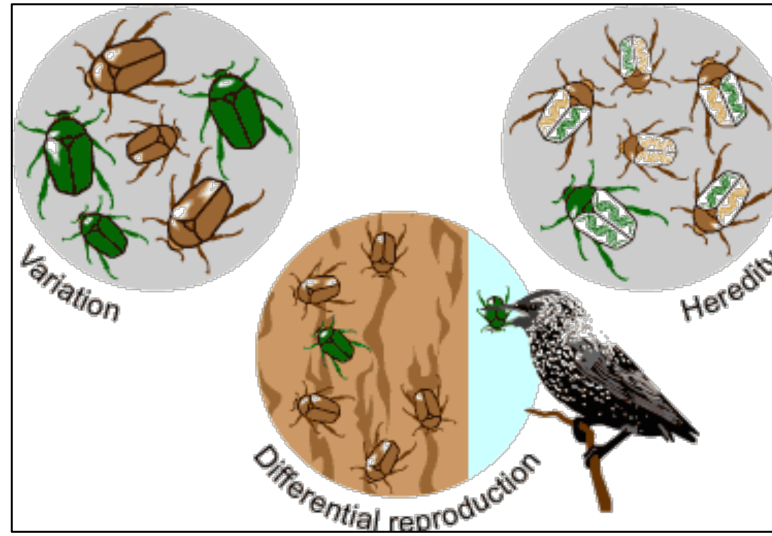
Gene: unit of heritable information located within a specific region of a chromosome (at the molecular/DNA level).

Allele: one of two or more slightly different forms of a given **gene.**

Genotype: a selection of the genes that make up an individual.

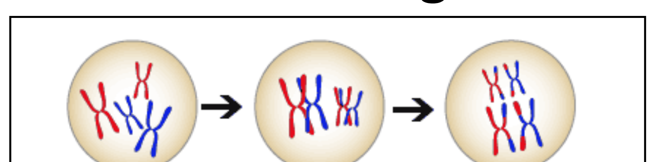
Phenotype: the expression of the genotype

Gene pool: all the **genotypes** within a **population**.



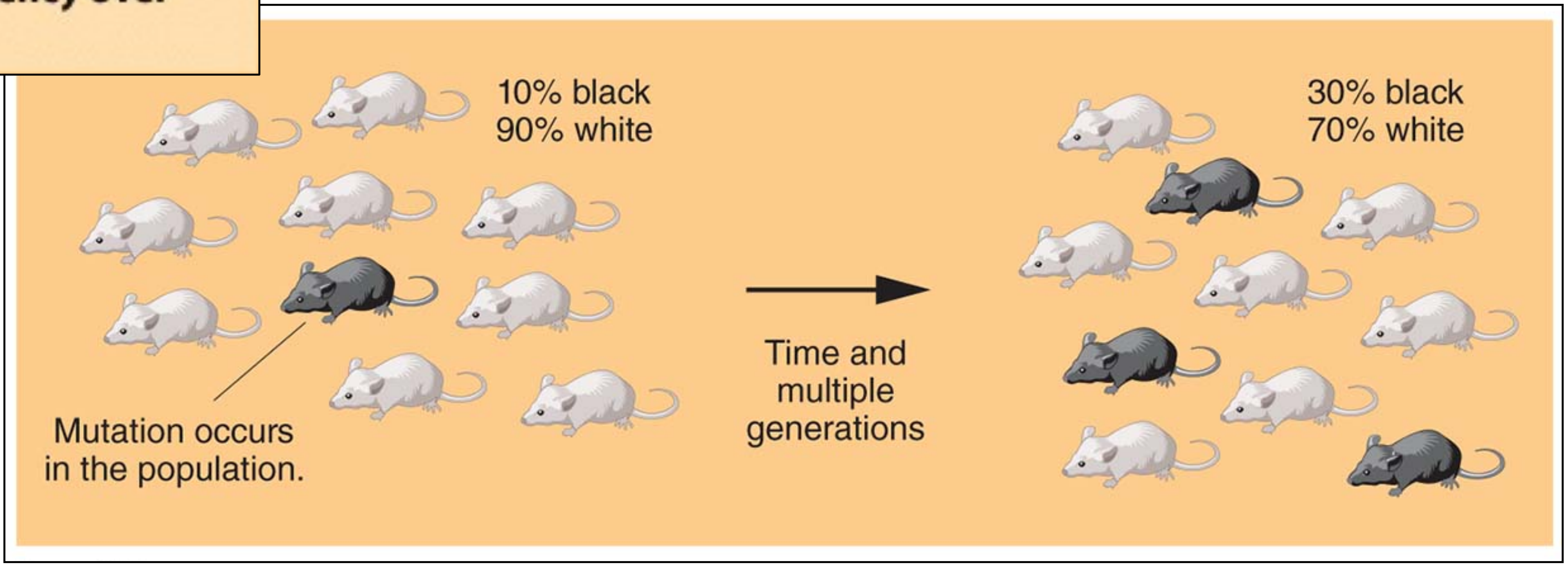
Mutation: mistake in copying of genetic code; if mutation in sex cells it is inherited.

Recombination: during cell division part of one chromosome breaks off and attaches to another, which leads to new gene combinations and thus genetic diversity



Evolution by Natural Selection

(a) Mutation
A mutation can arise in a population and, if it is not lost, may increase in frequency over time.

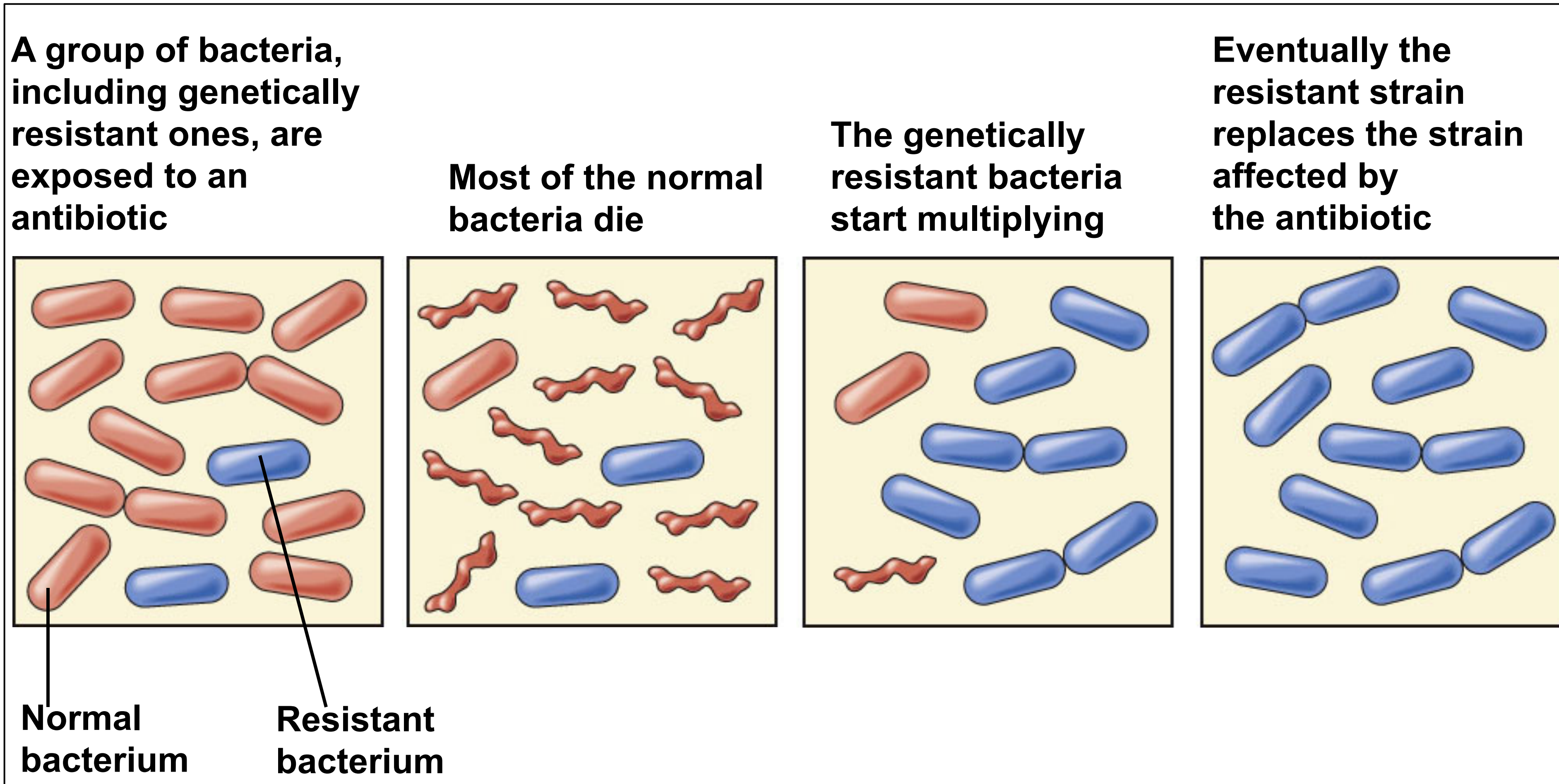


A mutation can arise in a population and if it's not lost may increase in frequency over time.

Evolution by Natural Selection

Genetic resistance: ability of one or more members of a population to resist a chemical designed to kill it

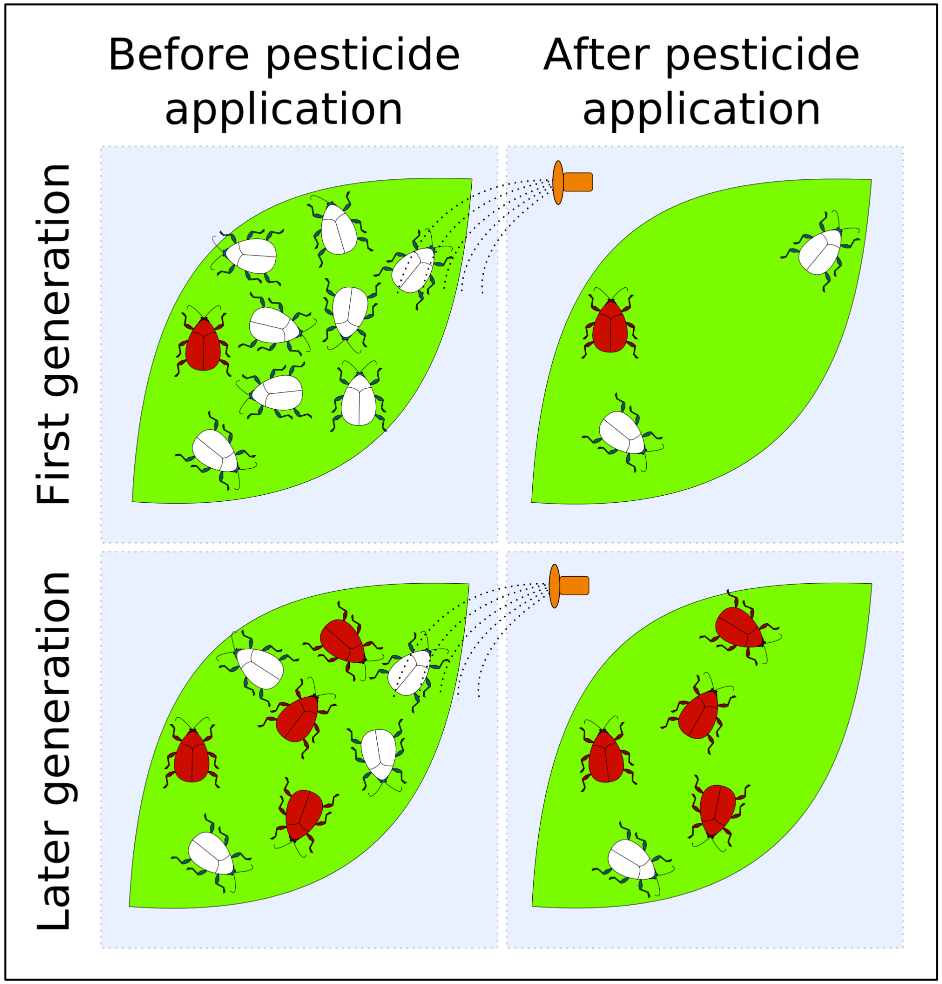
Unintended consequence: bacterial resistance to antibacterial drugs



Genetic Resistance: ability of one or more organisms in a population to tolerate a chemical designed to kill it.

Unintended consequence: agricultural pesticide/herbicide use often results in the pest population developing resistance pesticide/herbicide.

Pesticide Resistance



Evolution by Natural Selection

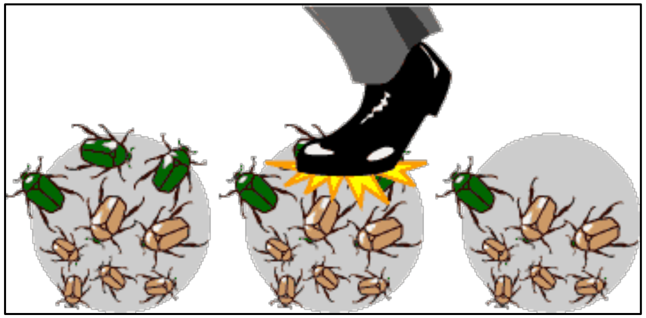
Genetic Drift: some individuals may, by chance, leave behind a few more descendants (genes) than other individuals.

The genes of the next generation will be the genes of the "lucky" individuals, not necessarily the healthier or "better" individuals.

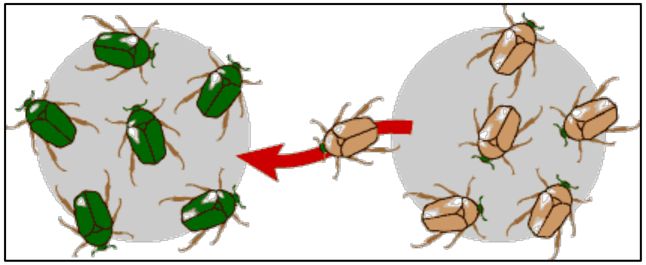
Gene Flow: also called migration, is any movement of individuals and their genetic material from one population to another.

If genes are carried to a population where those gene previously did not exist, gene flow can be a very important source of genetic variation and in-turn biodiversity.

Genetic Drift



Gene Flow

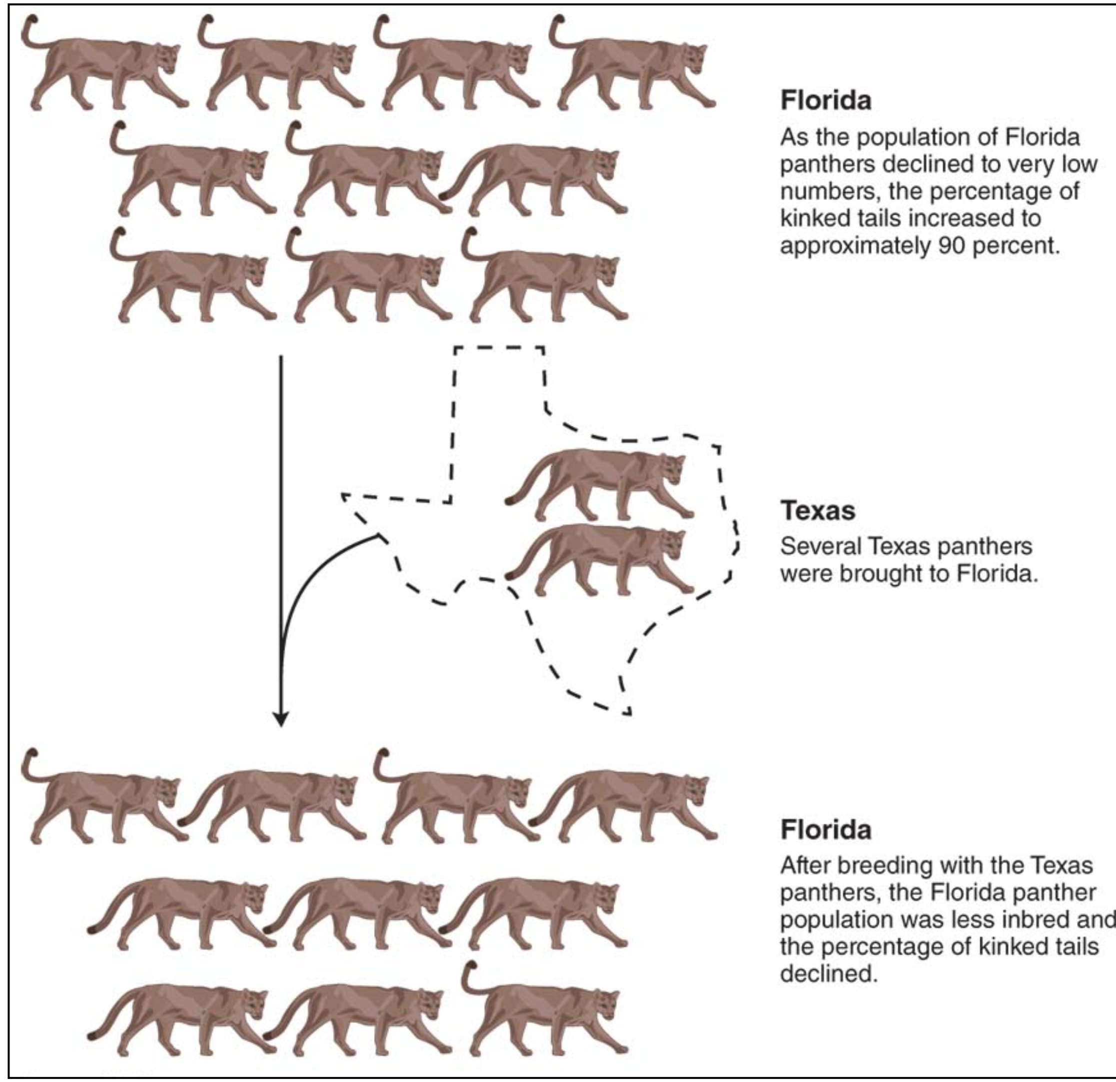


__Gene Flow__ can be helpful in bringing genetic variation to a population that lacks it.

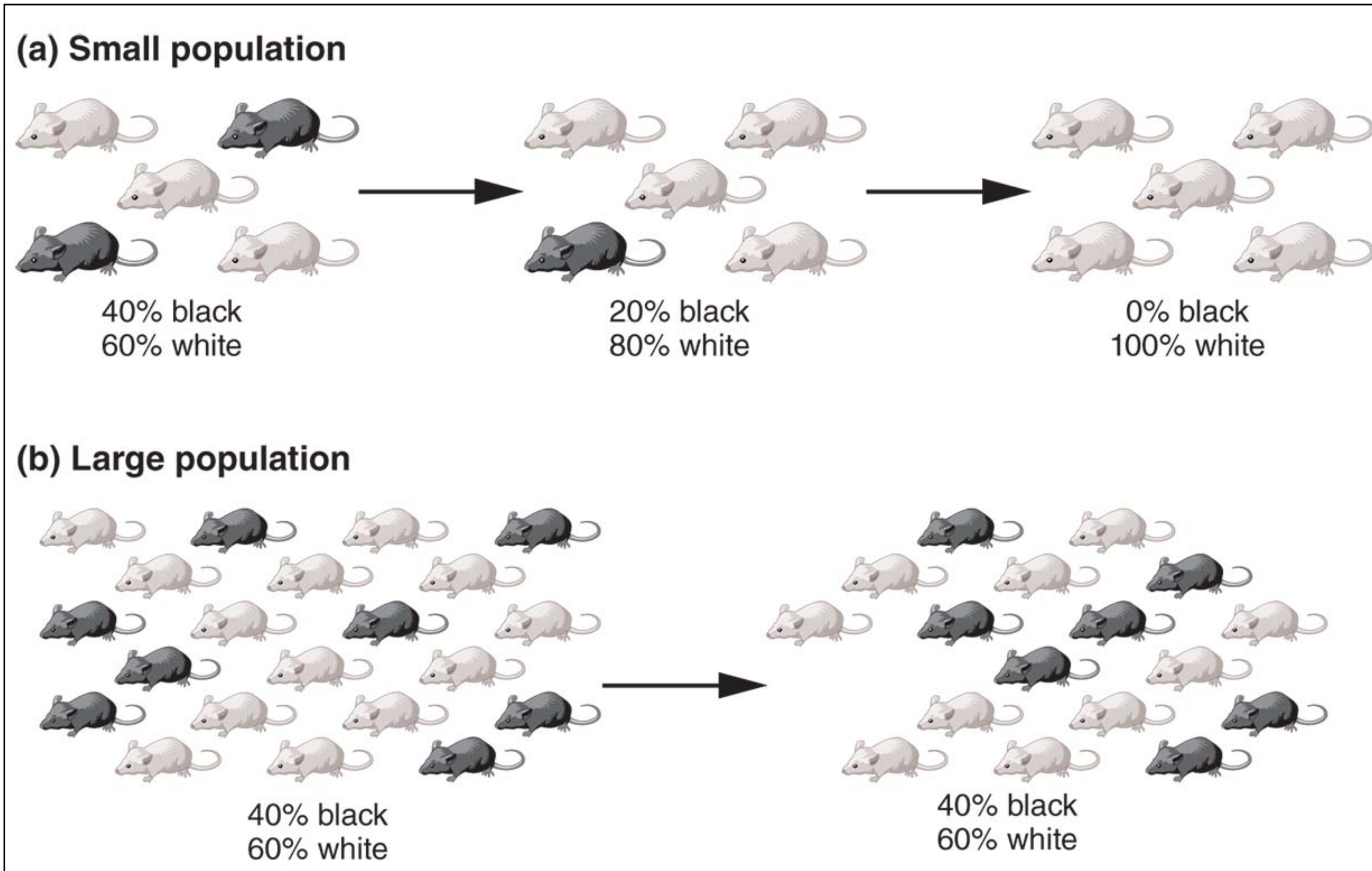
Florida Panther (*Puma concolor*) Agriculture, urban development, and interstates highways fragmented panther habitat by 1995 only 5% of original habitat remained; And only about 30 individuals.

Due to inbreeding, a high prevalence of kinked tails, heart defects, and low sperm count existed in the small population.

Eight Texas panthers (*Puma concolor*) were introduce to Florida population to increase genetic variation and by 2011 the prevalence of genetic defects have declined and the population has grown to 160 individuals.

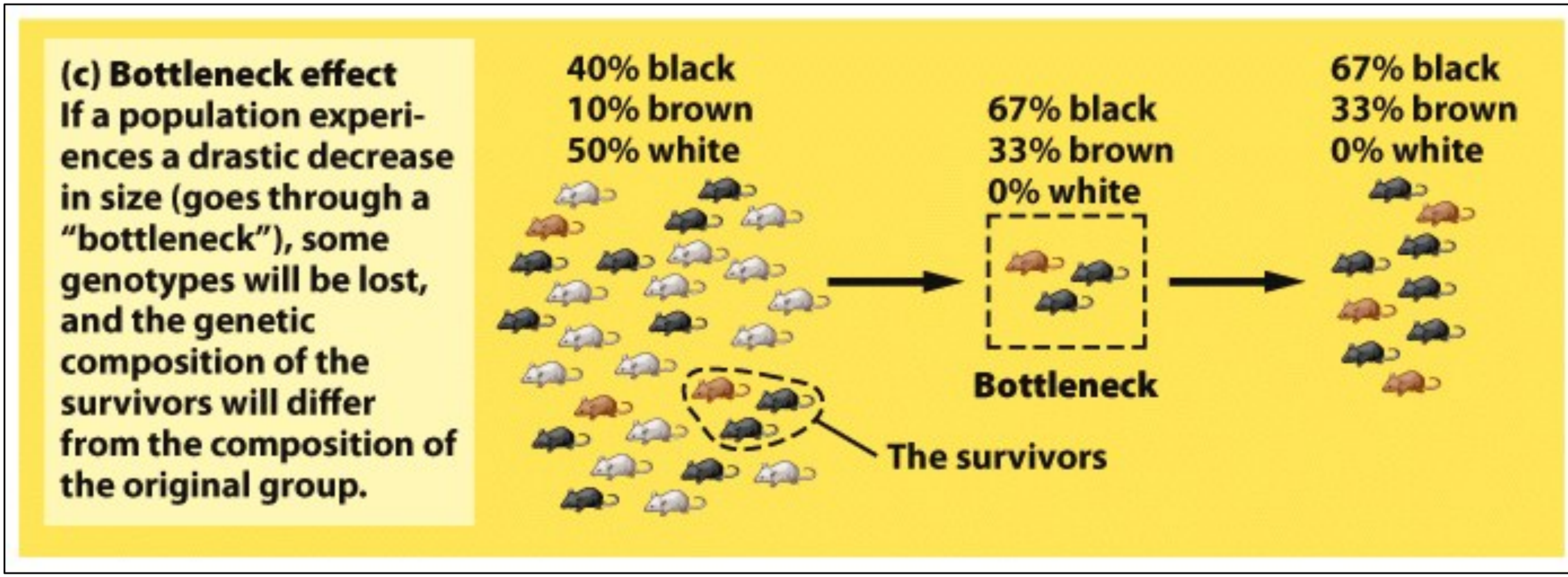


Genetic Drift: (a) In a small population, some less-common genotypes can be lost by chance as random mating among a small number of individuals can result in the less-common genotype not mating. As a result, the genetic composition can change over time. (b) In a large population it is more difficult for the less-common genotypes to be lost by chance because the absolute number of individuals is large. As a result, the genetic composition tends to remain the same over time in larger populations.

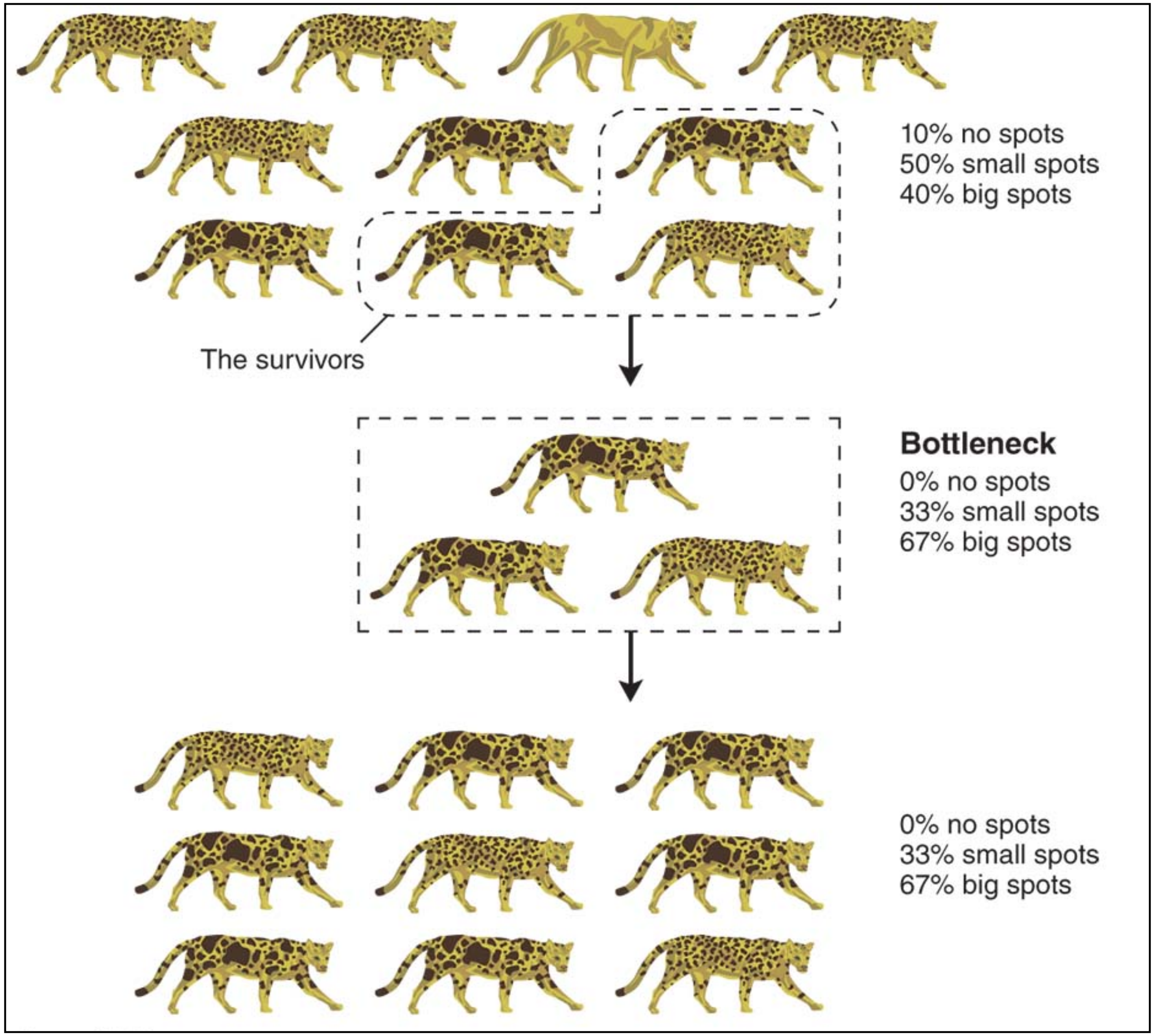


Evolution by Natural Selection

Population Bottleneck: an evolutionary event in which a significant percentage of a population or species is killed or otherwise prevented from reproducing; some genotypes will be lost and genetic composition of survivors will differ from original group.

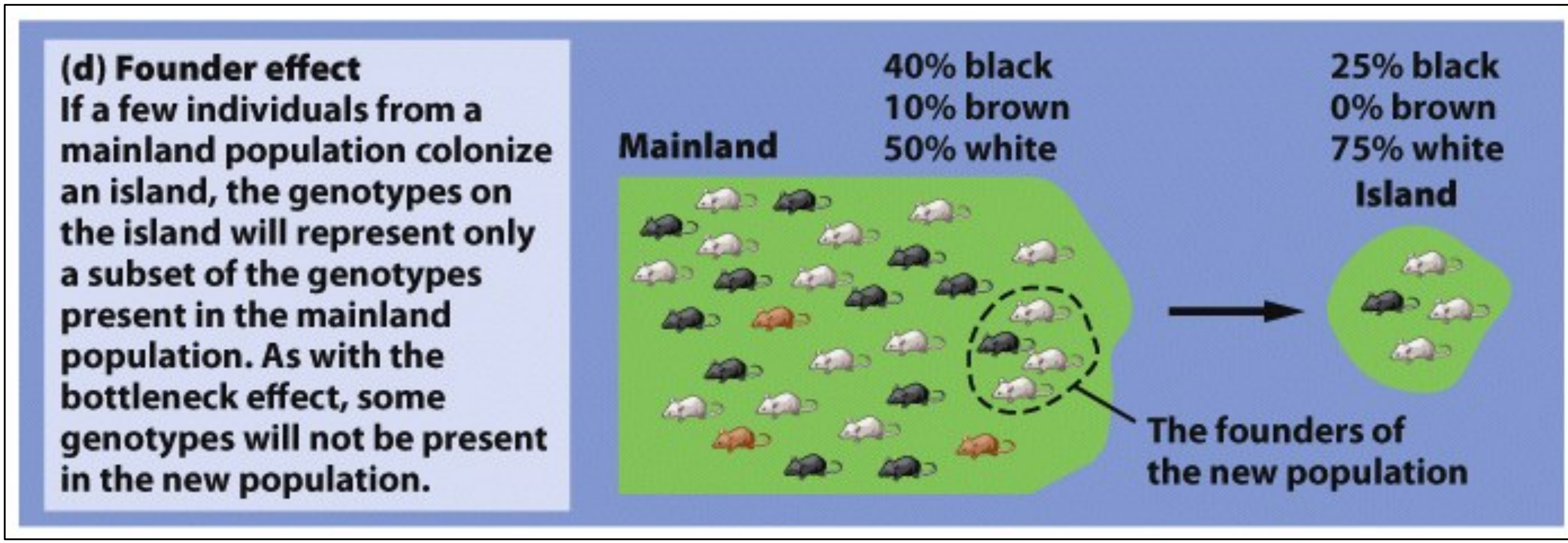


Population Bottleneck

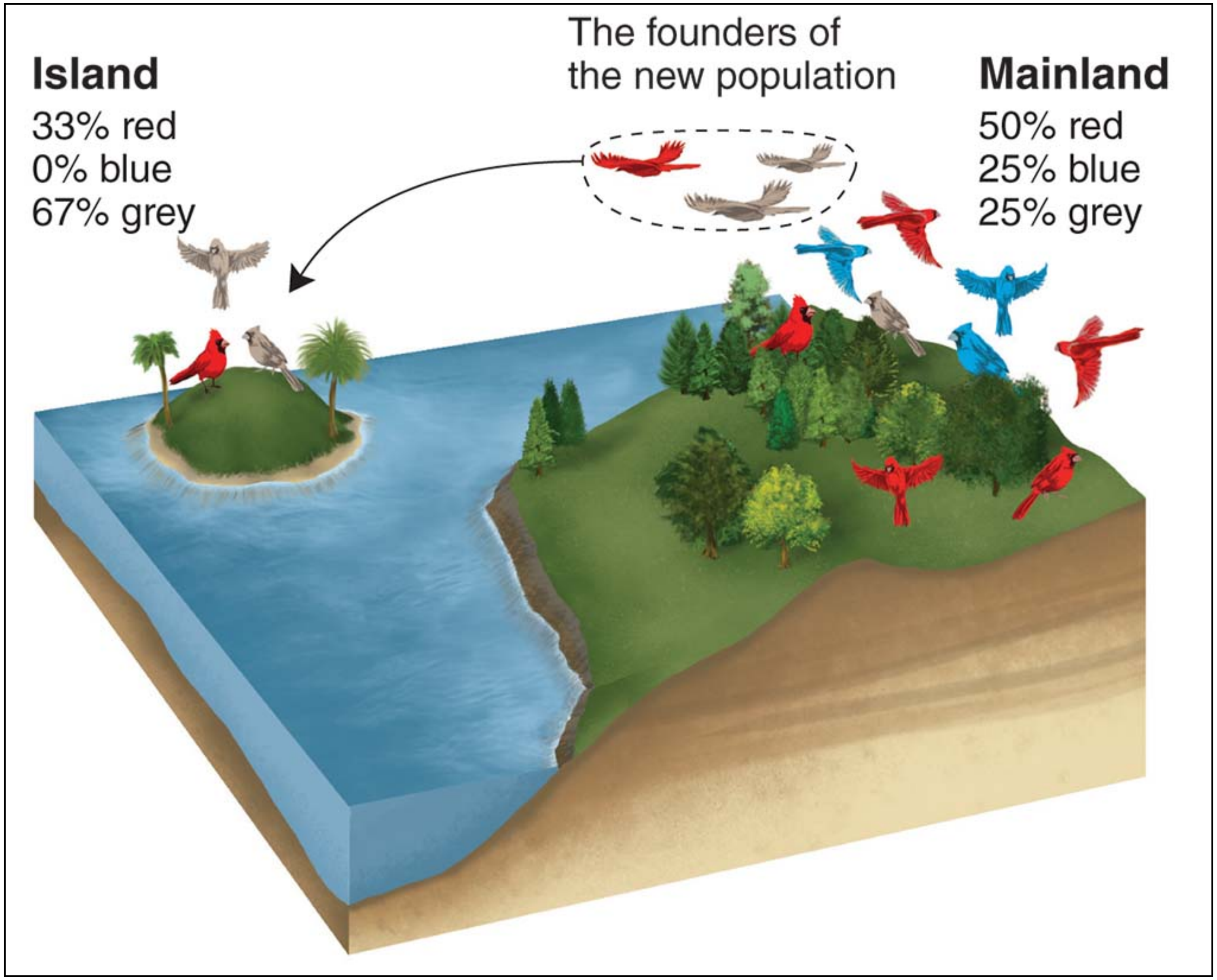


Evolution by Natural Selection

The founder effect is a special case of a population bottleneck, occurring when a small group in a population splinters off from the original population and forms a new one, taking with it only limited alleles from the original population.



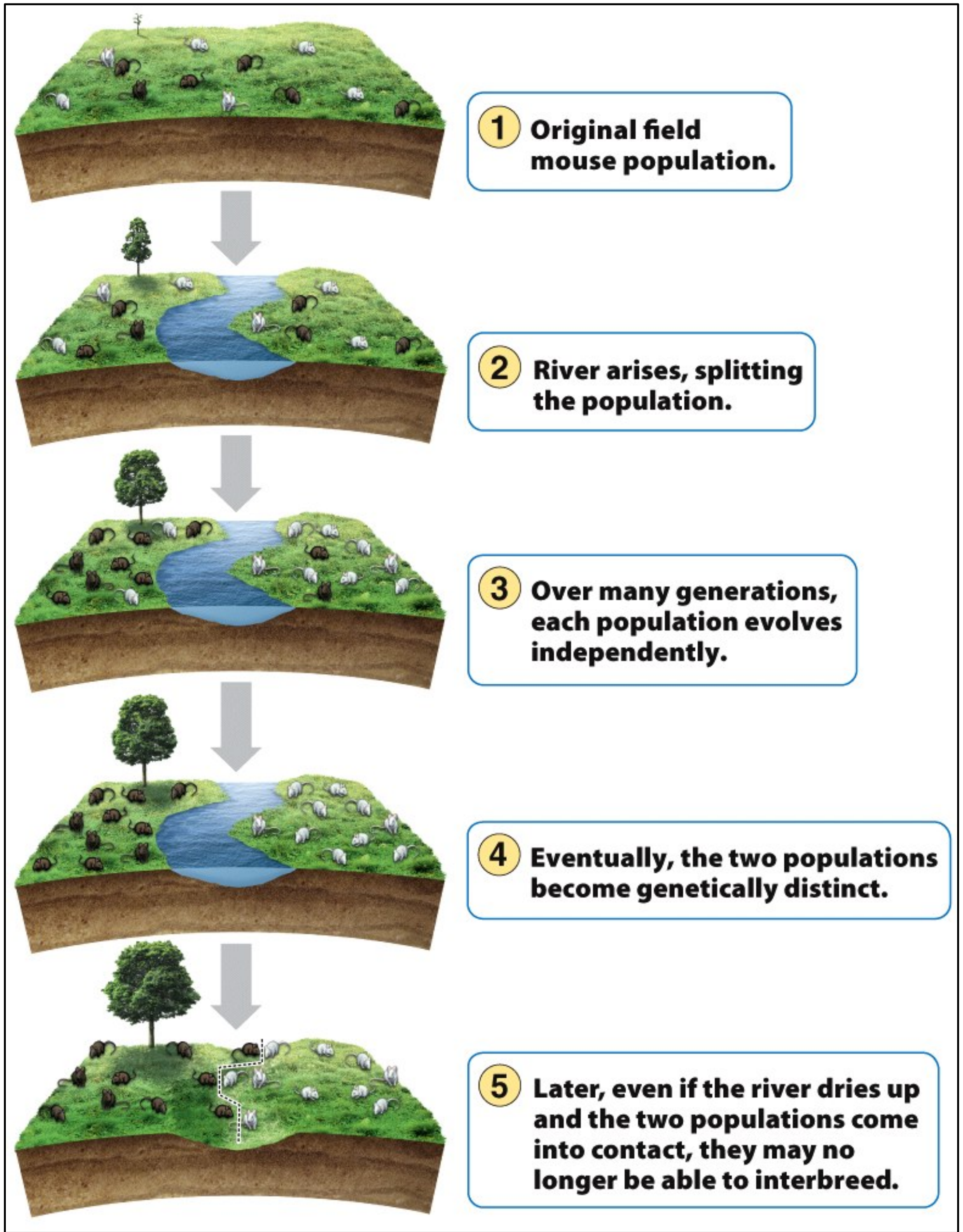
The Founder Effect



Note: *a limitation to adaptation through natural selection is that the ability to adapt is limited by reproductive capacity (rate)*

How Do New Species Evolve?

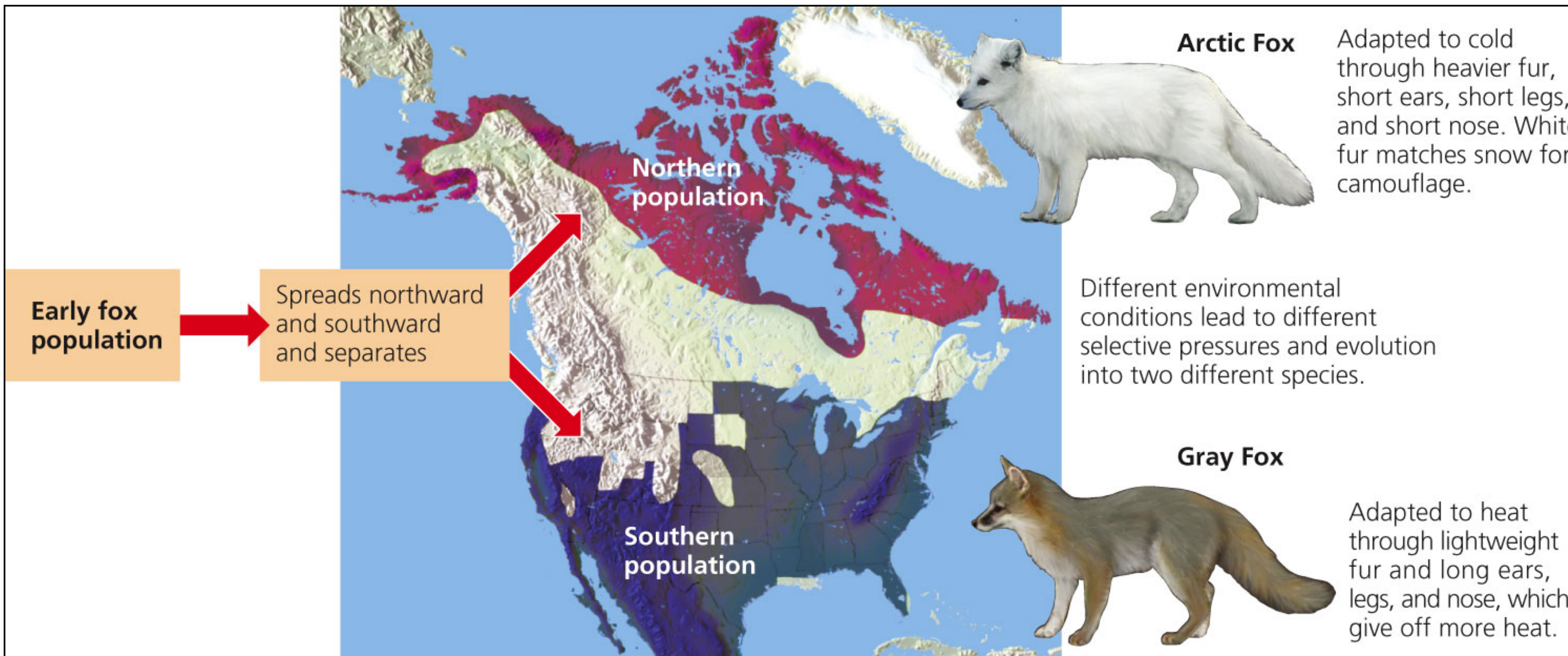
Speciation: one species splits into two or more species



Geographic Isolation Can Lead to Reproductive Isolation

Geographic isolation: happens first; groups from same population become physically isolated for a long period of time

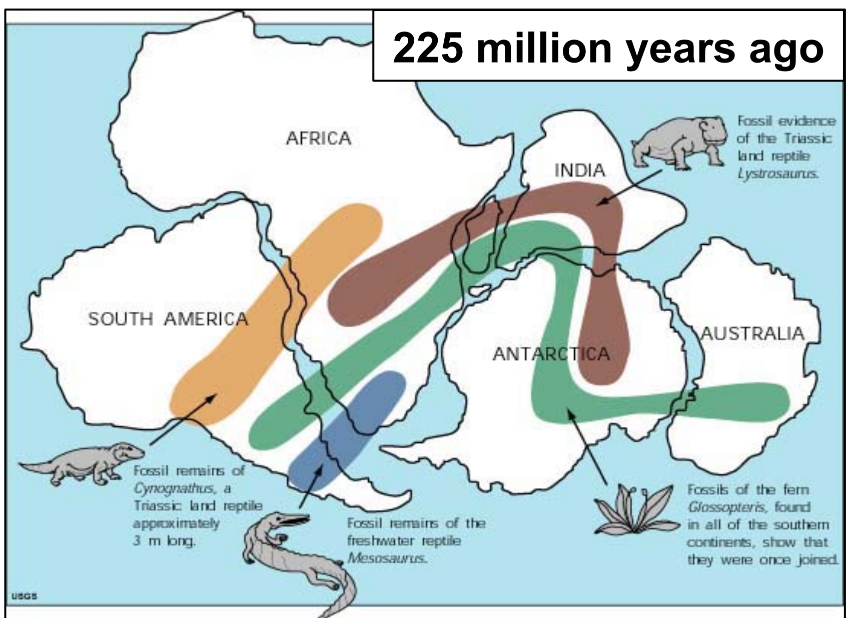
Reproductive isolation: populations of organisms become geographically isolated leading and become so genetically different they cannot mate

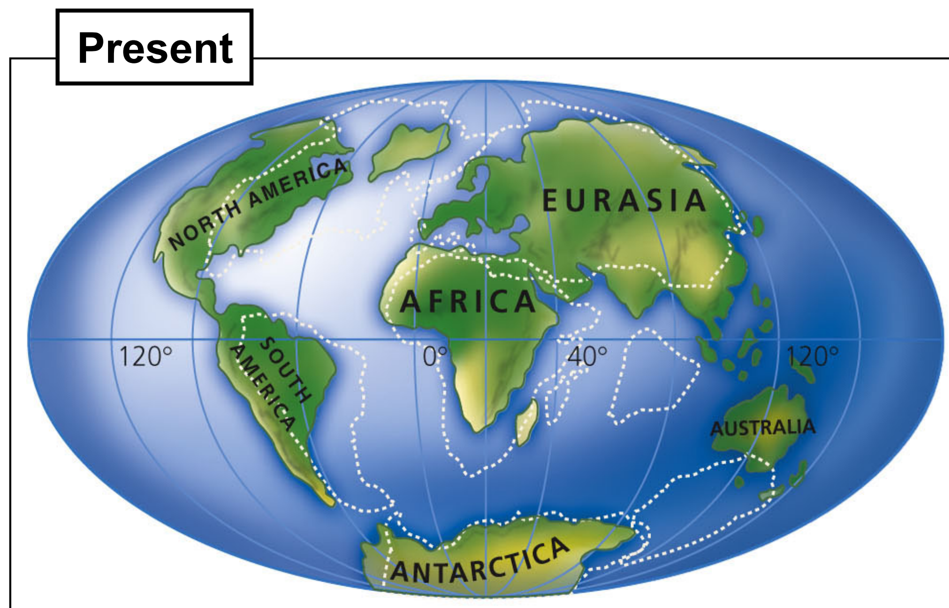


Geologic Processes, Climate Change, & Catastrophes Affect Natural Selection

Tectonic plates affect evolution and the location of life on earth by determining the location of continents and ocean basins.

- Location/latitude of continents determines climate and thus where plants and animals live
- Movement of continents has allowed species to move, adapt to new climates and form new species through natural selection



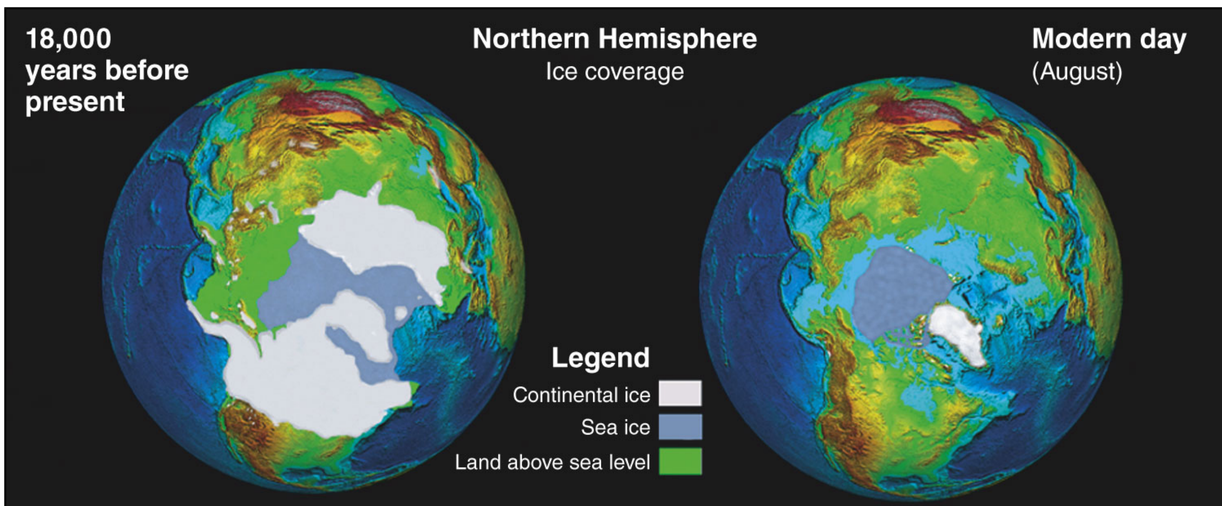


Geologic Processes, Climate Change, & Catastrophes Affect Natural Selection

Volcanic Eruptions: Mt. Saint Helens: Destroy habitat and wipe out populations

Earthquakes: create fissures that separate and isolate populations

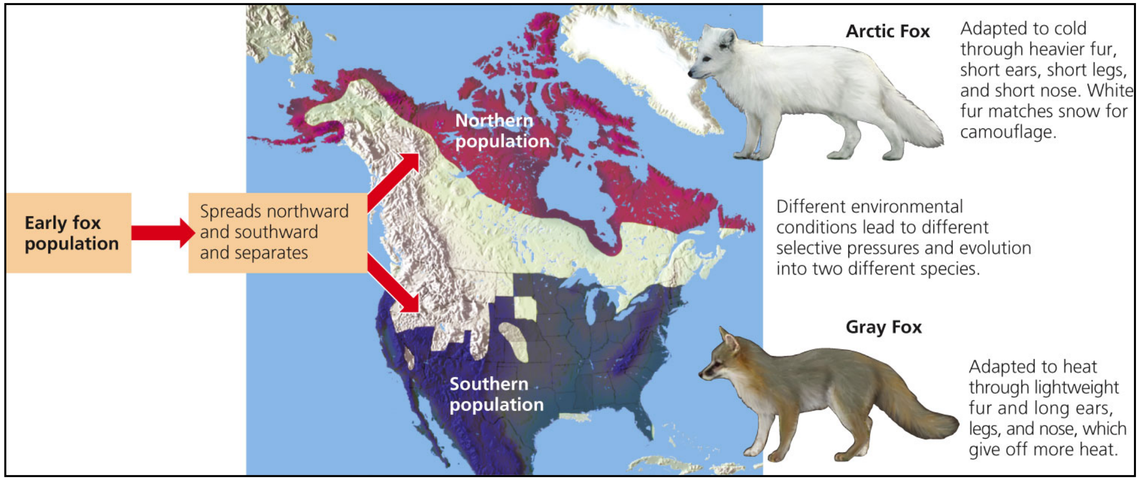
Climate Change and Natural Selection: Grizzly and Polar Bear



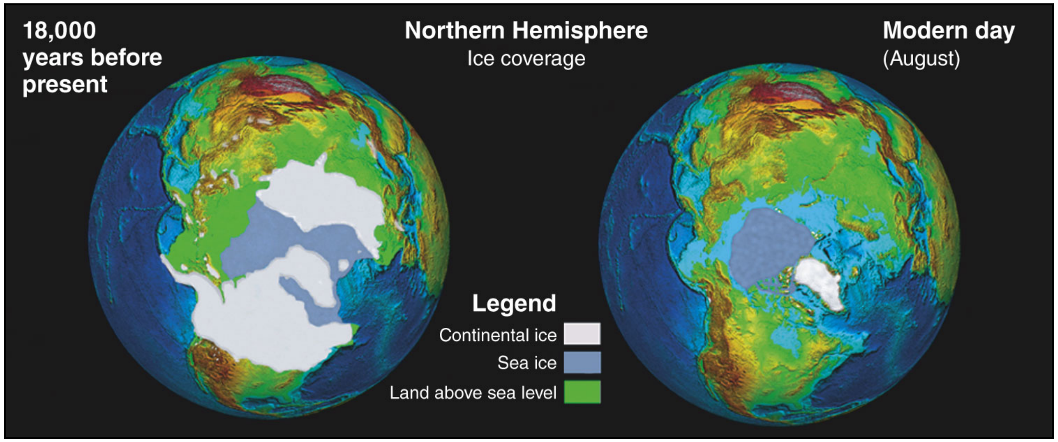
These hybrid cubs above are Pizzly bears, which are the product of a Polar bear dad, Grizzly mom. When hybrids such as these are capable of having fertile offspring, speciation will occur. →

Divergent vs. Convergent Evolution

Divergence: One species becomes two; e.g. Arctic Fox



Convergence: The evolution of species from different taxonomic groups toward a similar form; e.g. potentially grizzly & polar bear



Geologic Processes, Climate Change, & Catastrophes Affect Natural Selection

Collisions between the earth and large asteroids

- New species
- Extinctions

Extinction is Forever

Extinction

- Biological extinction
- Local extinction

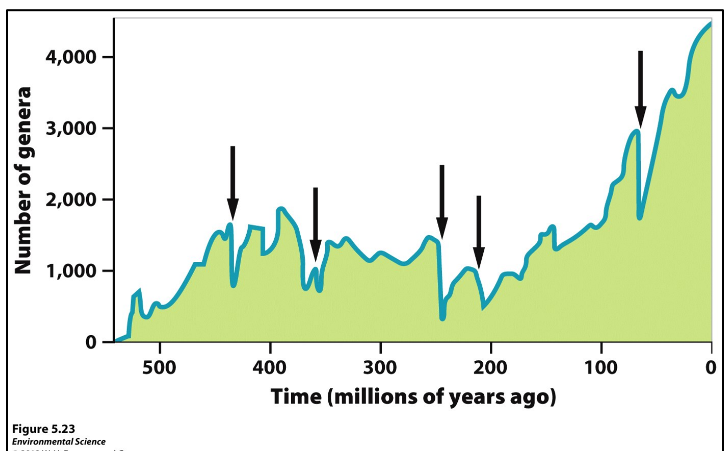
Endemic species

- Found only in one area
- Particularly vulnerable

Golden Toad of Costa Rica, Extinct

Background extinction: typical low rate of extinction

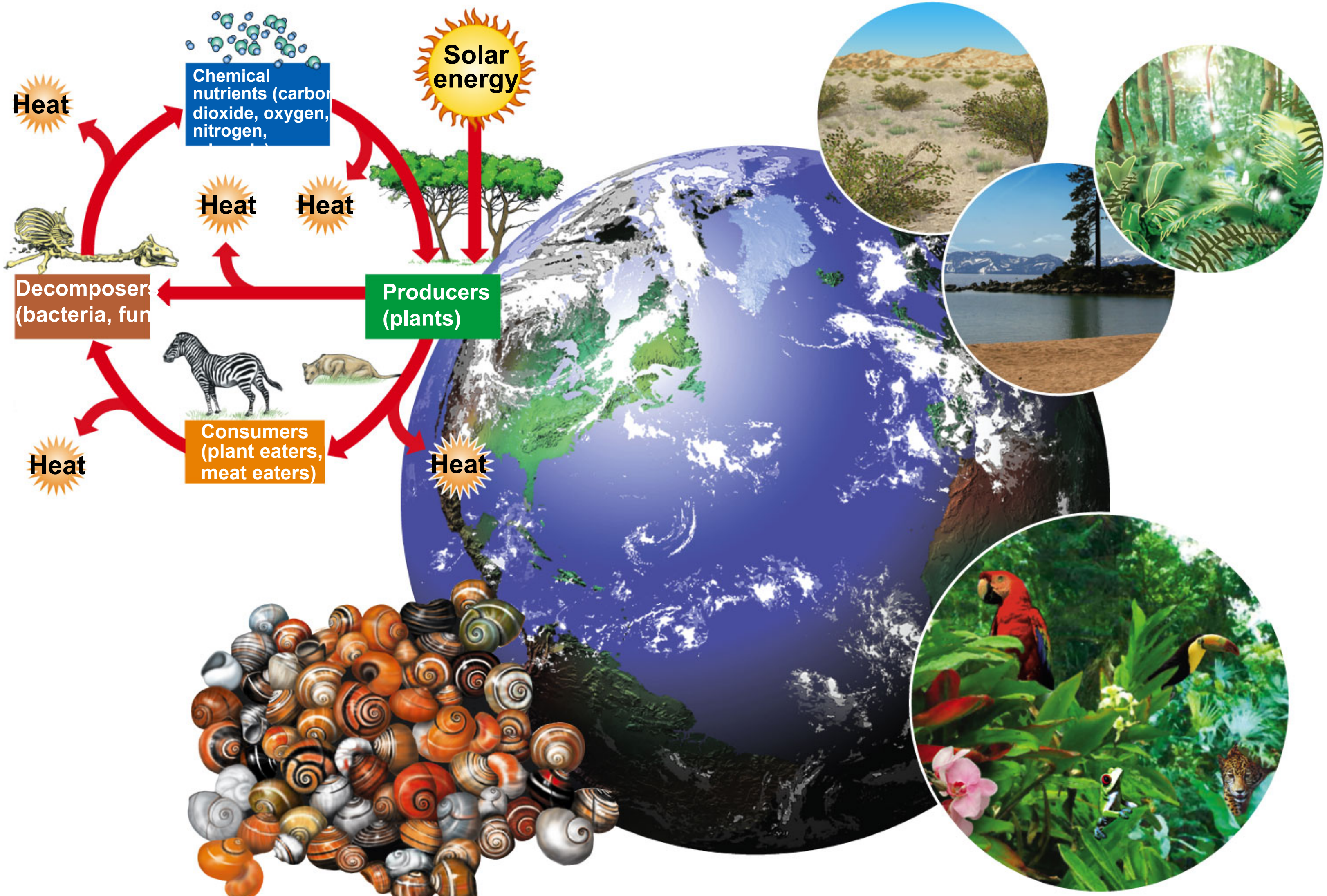
Mass extinction: 3-5 over 500 million years



Extinction and speciation are mechanisms of biodiversity

Functional Diversity The biological and chemical processes such as energy flow and matter recycling needed for the survival of species, communities, and ecosystems.

Ecological Diversity The variety of terrestrial and aquatic ecosystems found in an area or on the earth.

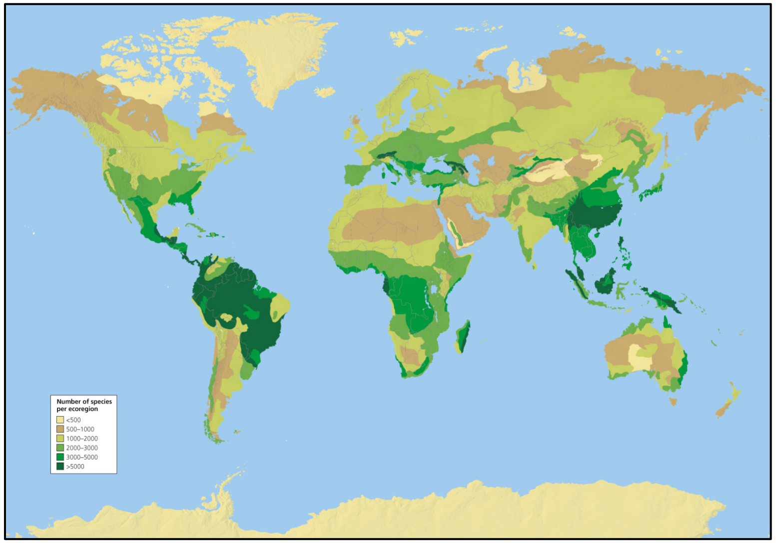


Genetic Diversity The variety of genetic material within a species or a population.

Species Diversity The number and abundance of species present in different communities.

Species Diversity

Diversity varies with geographical location



The most species-rich communities

- Tropical rain forests
- Coral reefs
- Ocean bottom zone
- Large tropical lakes

Species richness seems to increase productivity and stability or sustainability, and provide insurance against catastrophe

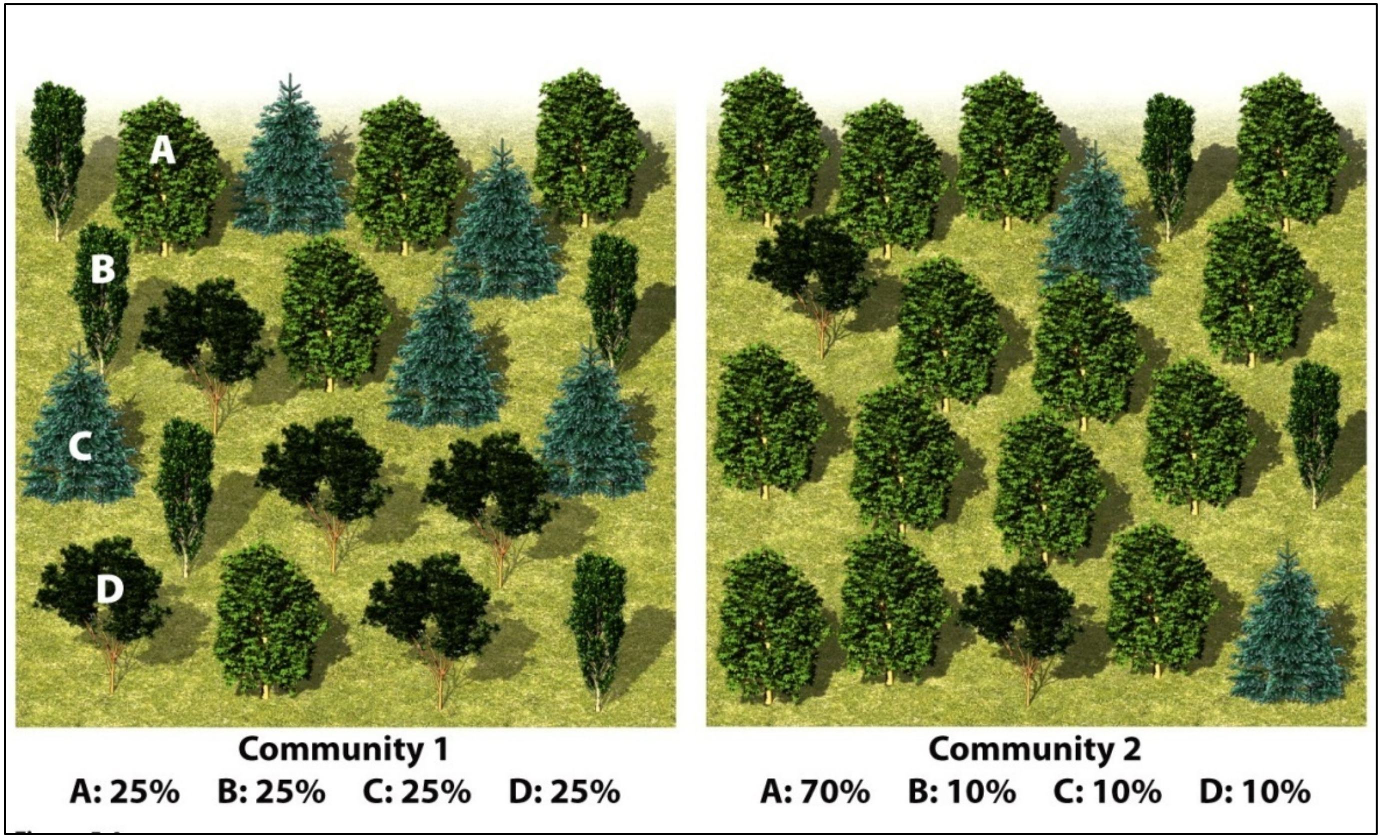
Species Diversity

Species richness:

- The number of different species in a given area

Species evenness:

- The relative proportion of individuals within the different species in a given area



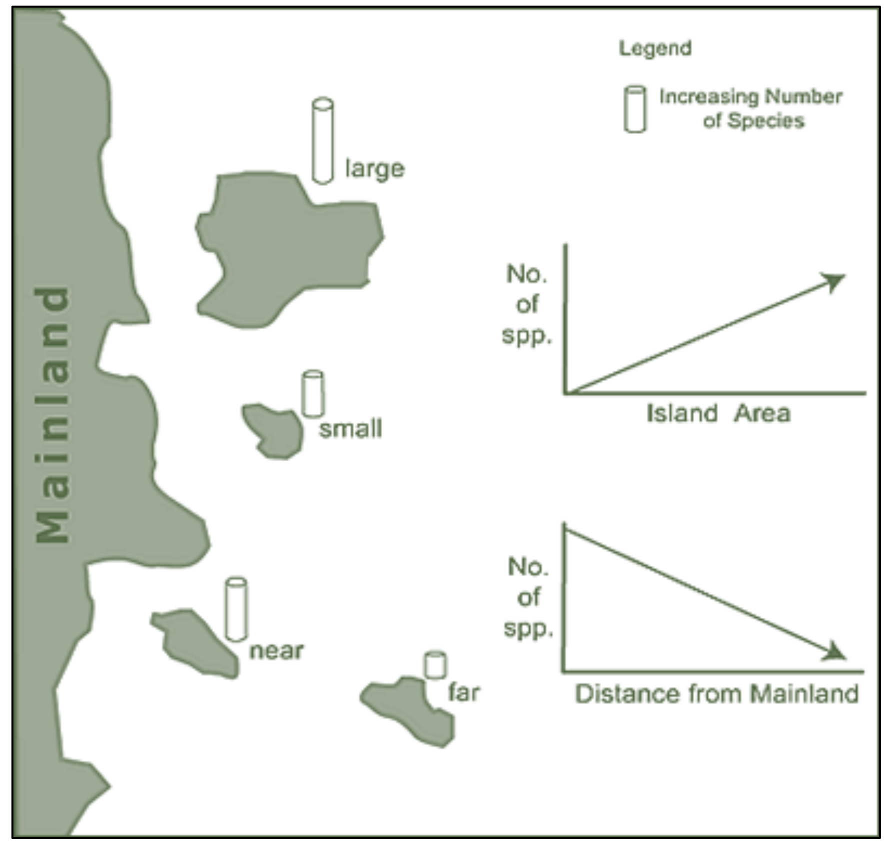
Theory of Island Biogeography

Diversity varies with geographical location

Number of types of species influenced by size & distance from mainland

- **Size**: larger habitats have more species
- **Distance**: Closer to mainland and or other habitat = more species
- First observed & reported by Edward O. Wilson
- Theory of island biogeography;

  a.k.a. Species equilibrium model: rate of new species immigrating should balance with the rate of species extinction



Species Interactions

Five Types of Species Interaction

- **Interspecific Competition**
- **Predation**
- **Parasitism**
- **Mutualism**
- **Commensalism**

Most Consumer Species Feed on Live Organisms of Other Species

Predators may capture prey by

1. Walking
2. Swimming
3. Flying
4. Pursuit and ambush
5. Camouflage
6. Chemical warfare

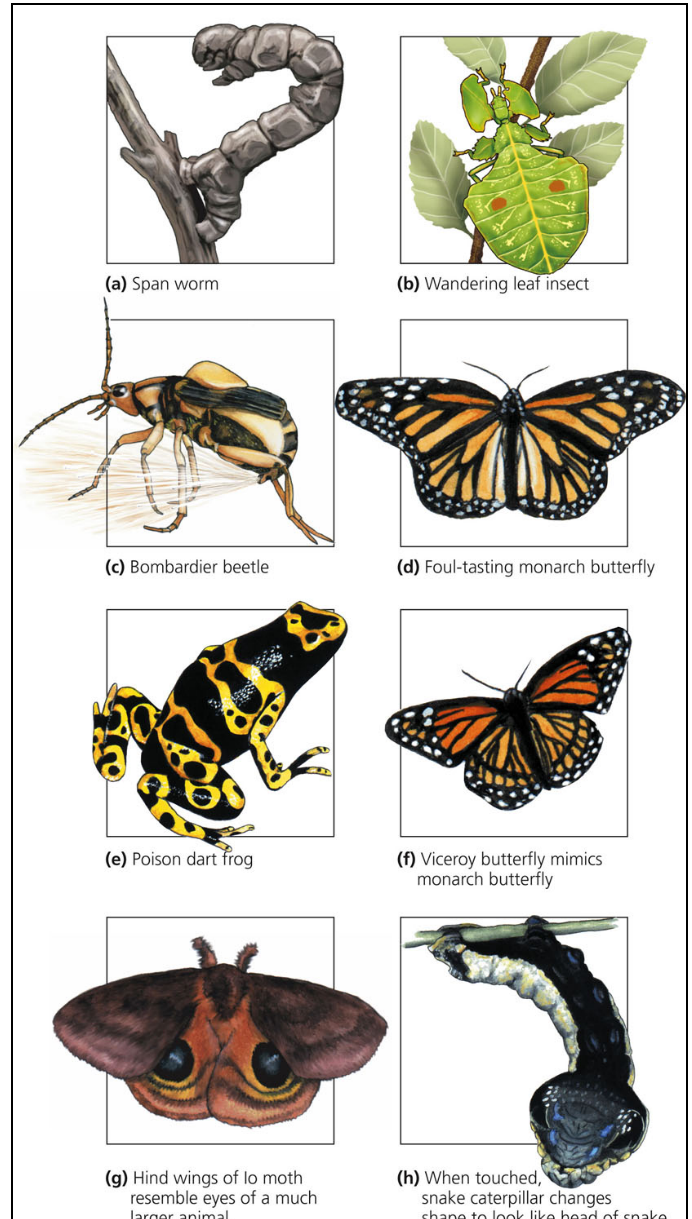
Predator-Prey Relationships

Most Consumer Species Feed on Live Organisms of Other Species

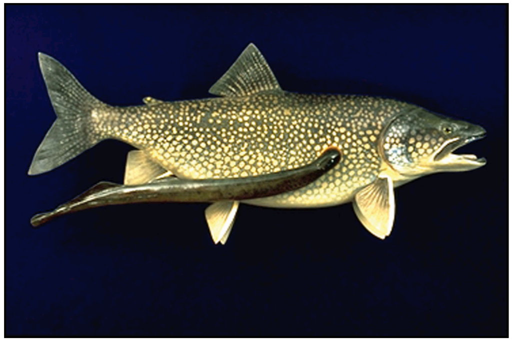
Prey may avoid capture by

1. Run, swim, fly
2. Protection: shells, bark, thorns
3. Camouflage
4. Chemical warfare
5. Warning coloration
6. Mimicry
7. Deceptive looks
8. Deceptive behavior

Some ways prey species avoid their predators →



Parasitism



Some species feed off other species by living on or in them

- Parasite is usually much smaller than the host
- Parasite rarely kills the host
- Parasite-host interaction may lead to coevolution
- Ex. Sea lampreys prey on most species of large Great Lakes fish.

Mutualism

In some interactions, both species benefit

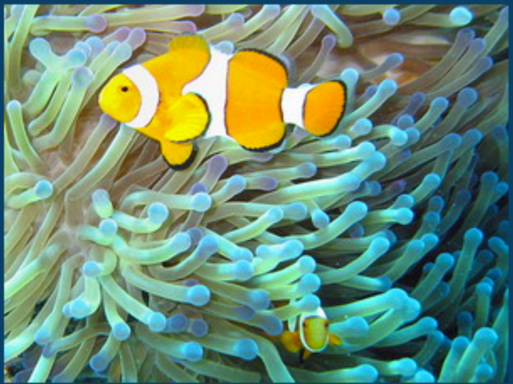
- Nutrition and protection relationship
- Ex. Plant pollinator relationships
- Ex. Gut inhabitant mutualism
- Ex. Coral reefs (algae & polyps)
- Ex. Lichen (algae & fungus)
- Not cooperation: it's mutual exploitation

Commensalism

In some interactions, one species benefits and not harmed

- Epiphytes: Bromeliads
- Birds nesting in trees

Anemone & Clownfish



Sea Anemones are predators that attach themselves to rocks or coral. There, they sit and wait until a fish swims close enough to attack with its tentacles. When a fish swims by the anemone, its tentacles will shoot out a long poisonous thread. The toxins in this thread paralyze the prey.

Clownfish are one of the only species that can survive the deadly sting of the Sea Anemone. By making the anemone their home, clownfish become immune to its sting. These fish will gently touch every part of their bodies to the anemone's tentacles until it no longer affects them. A layer of mucus then forms on the clownfish's body to prevent it from getting stung again.

"A sea anemone makes an ideal home for a clownfish. Its poisonous tentacles provide protection from predators and a clownfish makes its meals from the anemone's leftovers."

"A clownfish can help an anemone catch its prey by luring other fish toward over so that the anemone can catch them. Clownfish also eat any dead tentacles keeping the anemone and the area around it clean. "

Predator and Prey Interactions Can Drive Each Other's Evolution

Intense natural selection pressures between predator & prey populations can facilitate coevolution.

Coevolution

Interact over a long period of time

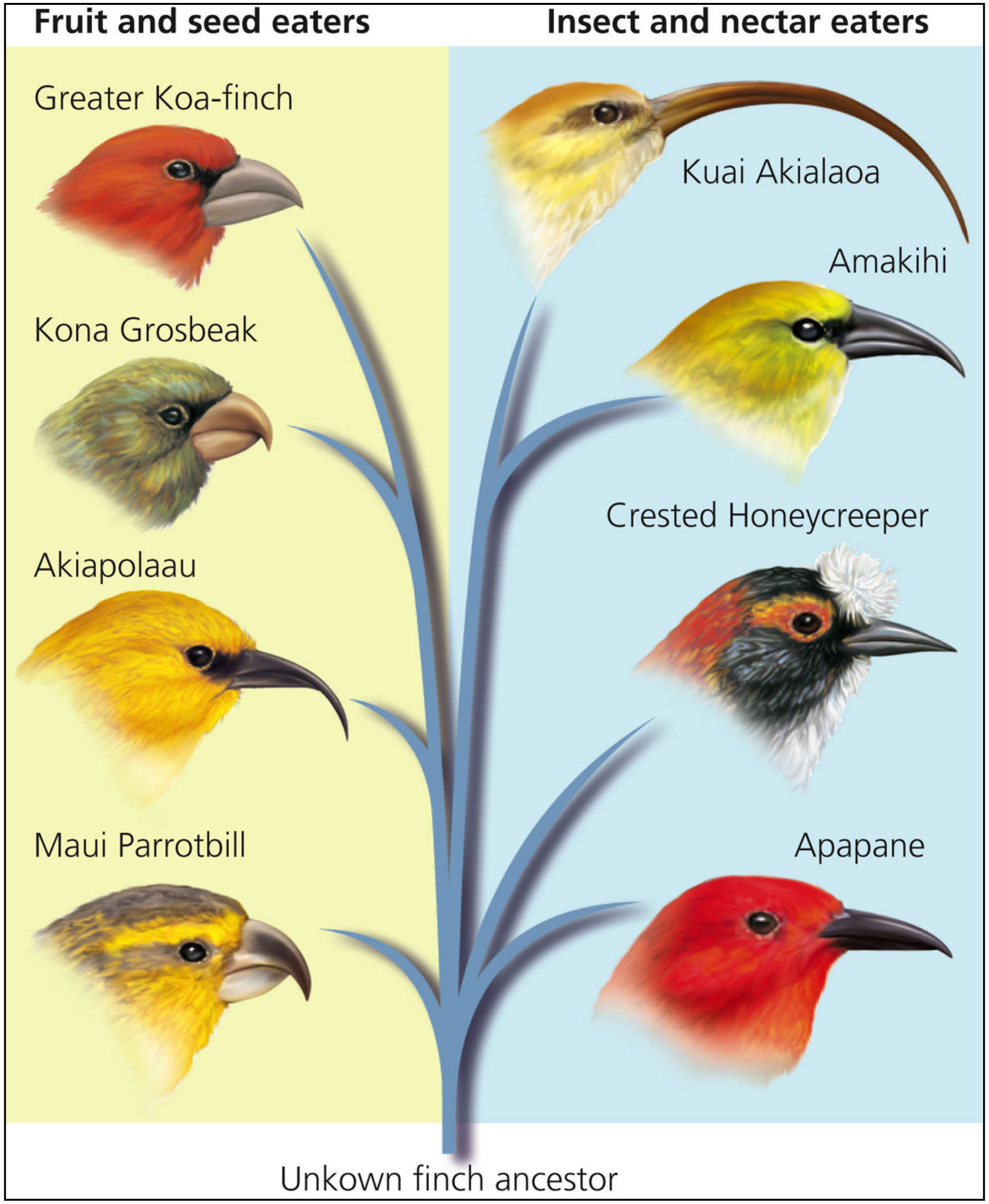
- Plants and their pollinators
- Bats and moths: echolocation of bats and sensitive hearing of moths

Central American Acacia species:

- hollow thorns and pores at the bases of their leaves secrete nectar
- hollow thorns are exclusive nest-site of some species of ant that drink the nectar
- Ants drink nectar and in turn defend the acacia plant against herbivores

Coevolution: plants would not have evolved hollow thorns or nectar pores unless their evolution had been affected by the ants, and the ants would not have evolved herbivore defense behaviors unless their evolution had been affected by the plants. →

Specialist Species of Honeycreepers



Species Can Play Five Major Roles within Ecosystems

- **Native species**
- **Nonnative species**
- **Indicator species**
- **Keystone species**
- **Foundation species**

Species Can Play Five Major Roles within Ecosystems

Keystone species: plant or animal that plays a unique and crucial role in the way an ecosystem functions; Alter habitat or have a niche that supports other populations. There disappearance would start a domino effect. Ex. pollinators & top predators

<u>**Examples**</u>

Pollinators: keystone species in most terrestrial ecosystems.

- Provide essential ecological services.
- Necessary for the reproduction of over 2/3 of the world's crop species.

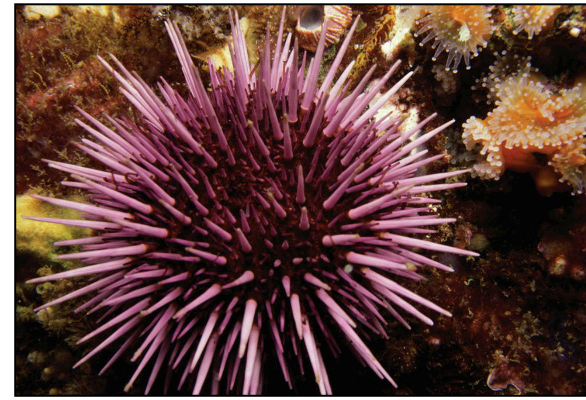
Top Predators: American alligator are a keystone species in wetland ecosystems.

- digs holes that hold freshwater during dry spells
- serve as refuges for aquatic life and provide fresh water

Southern Sea Otters & Marine Ecosystems

Keystone species

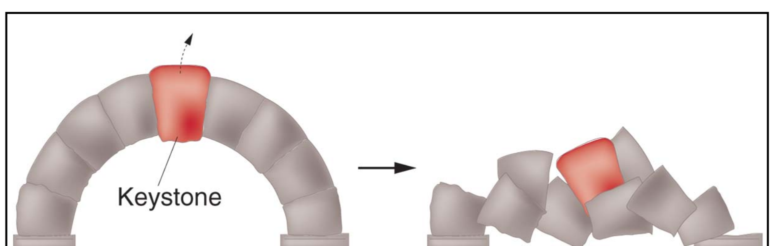
Southern sea otters eat sea urchins that eat kelp; there regulating sea urchin populations and maintaining kelp forests



- Habitat- California coast between Santa Cruz & Santa Barbara
- Hunted: early 1900s; then partial recovery
  - Protected: Endangered Species Act 1977

Woodpeckers: Keystone Species Complex

Species in a Colorado subalpine ecosystem show subtle interdependences. Red-naped sapsuckers play two distinct keystone roles. They excavate nest cavities in fungus infected aspens that are required as nest sites by two species of swallows, and they drill sap wells into willows that provide abundant nourishment for themselves, humming birds, orange crowned warblers, chipmunks, and an array of other sap robbers. The swallows thus depend on, and the sap robbers benefit from, a keystone species complex comprised of sapsuckers, willows, aspens, and a heartwood fungus. Disappearance of any element of the complex could cause an unanticipated unraveling of the community.



Species Can Play Five Major Roles within Ecosystems

Foundation Species Help to Form the Bases of Ecosystems

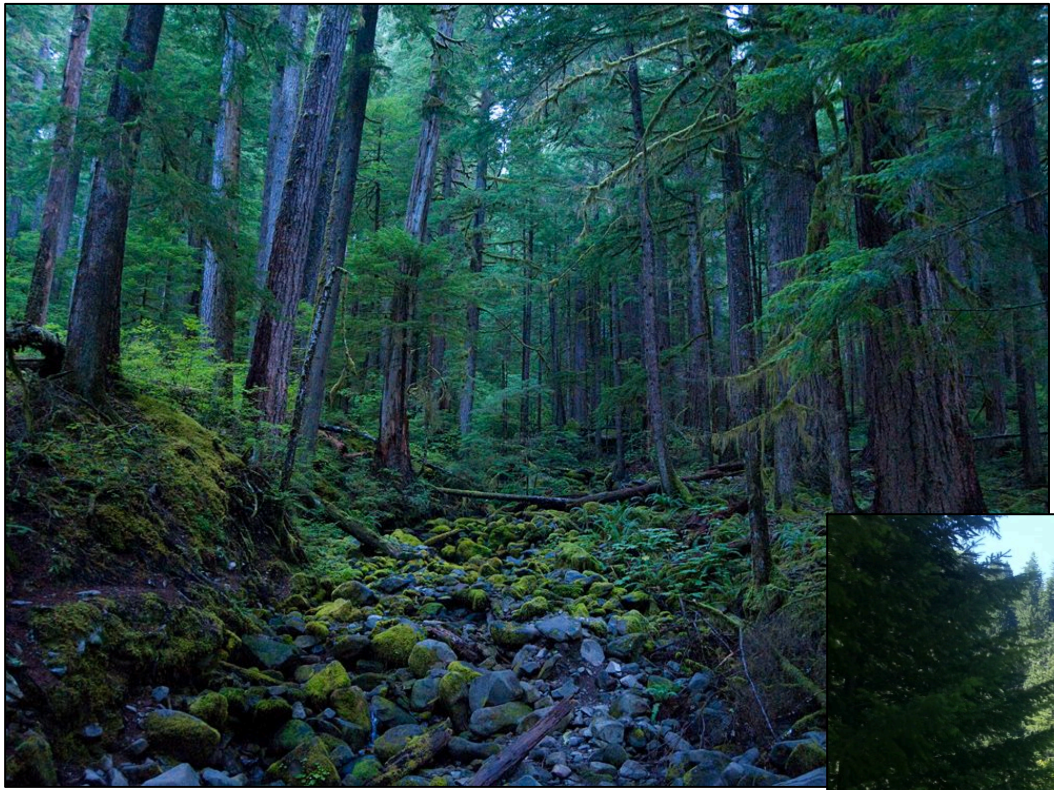
Create or enhance their habitats, which benefit others

Beaver: build a dam that creates a pond where other organisms live.

Bat and bird species: regenerate deforested areas and spread fruit plants in their droppings.

Wolves: Predators that keep herbivore population in check so as not to destroy grazing land.

Dominant Trees Can Be Foundation Species



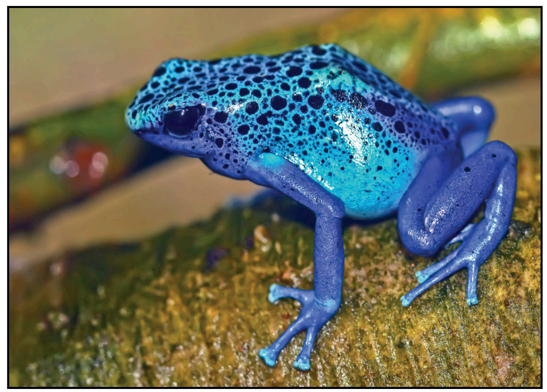
Eastern Hemlock

Douglas Fir

Species Can Play Five Major Roles within Ecosystems

Indicator species

- Provide early warning of damage to a community
- Indicator species serve as biological smoke alarms
- Can be used monitor environmental quality
    - Trout
    - Birds
    - Butterflies
    - Frogs



Sensitive to habitat Loss, increases in UV, parasites, pollution (pesticides), climate change, overhunting, etc...

Population Abundance and Distribution

Most Populations Live Together in Clumps or Patches

Population distribution

1. Clumping
2. Uniform dispersion
3. Random dispersion

(a) Clumped (elephants) **(b)** Uniform (creosote bush) **(c)** Random (dandelions)

Generalized Dispersion Patterns

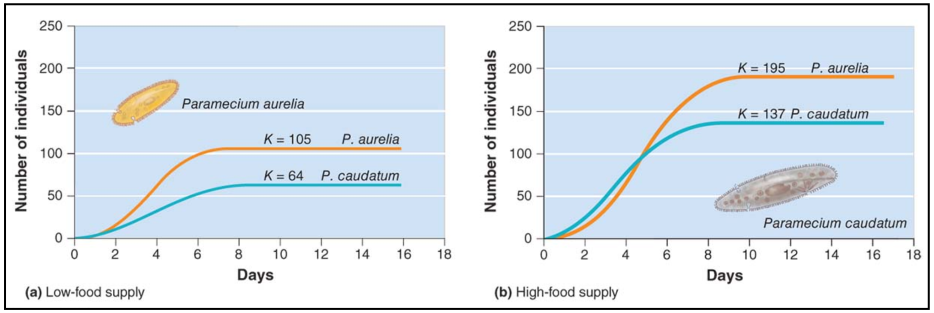
Some Factors Can Limit Population Size

Limiting factor principle

Too much or too little of any physical or chemical factor can limit or prevent growth of a population, even if all other factors are at or near the optimal range of tolerance.

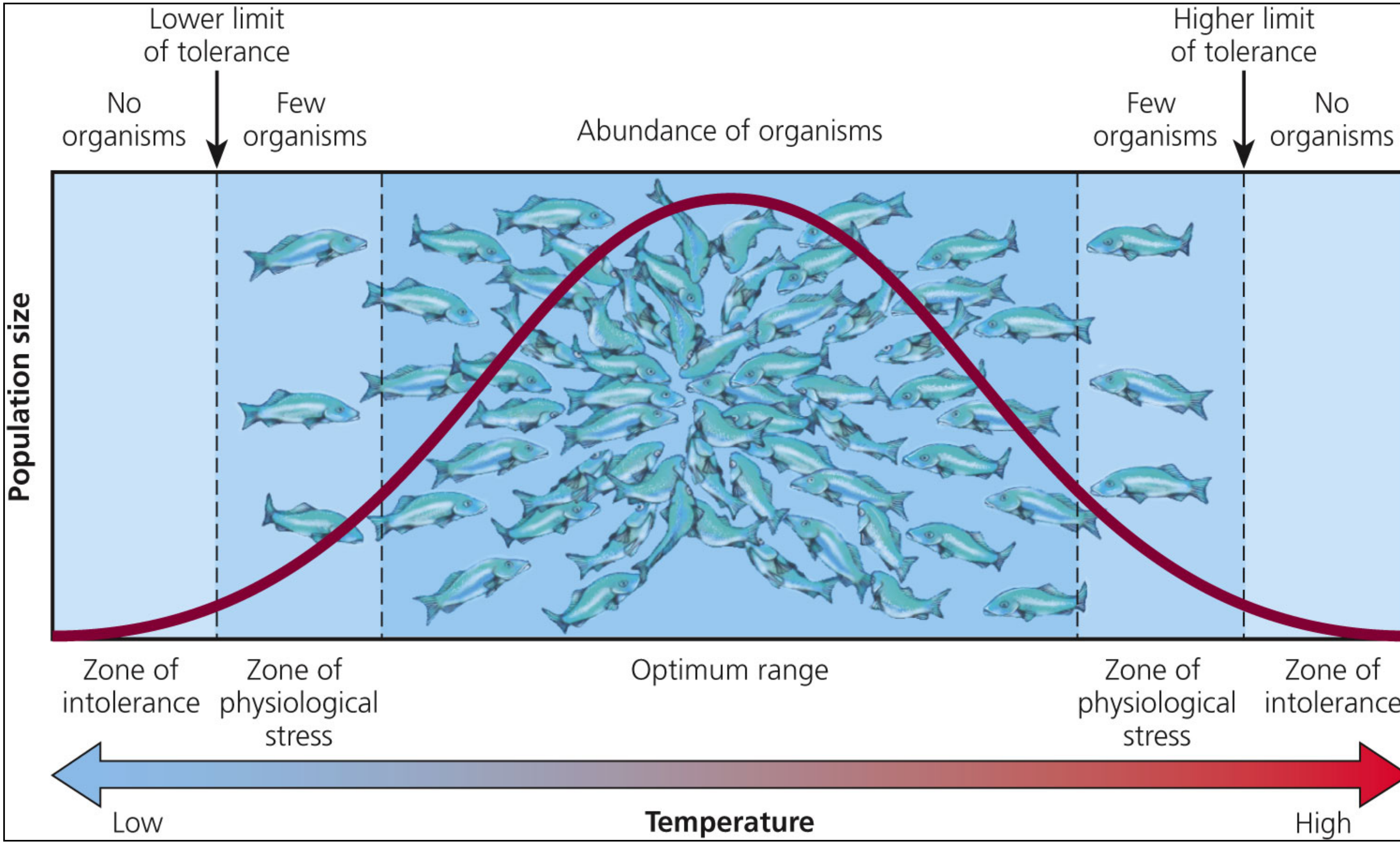
Size of populations controlled by ***limiting factors****:*

- Light (sunlight)
- Water (precipitation)
- Space
- Nutrients
- Exposure to too many competitors, predators or infectious diseases



Some Factors Can Limit Population Size

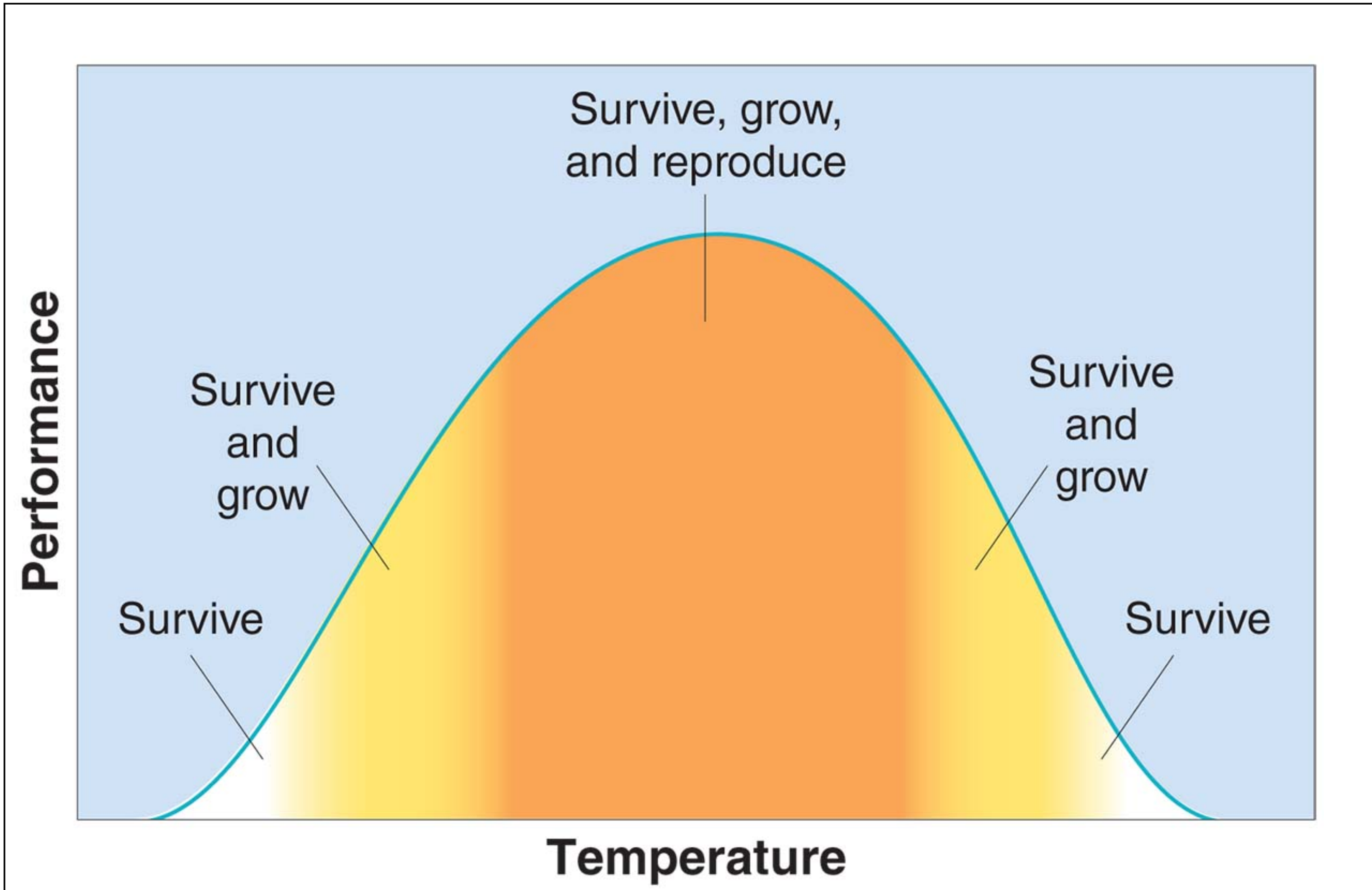
Range of tolerance: Variations in physical and chemical environment



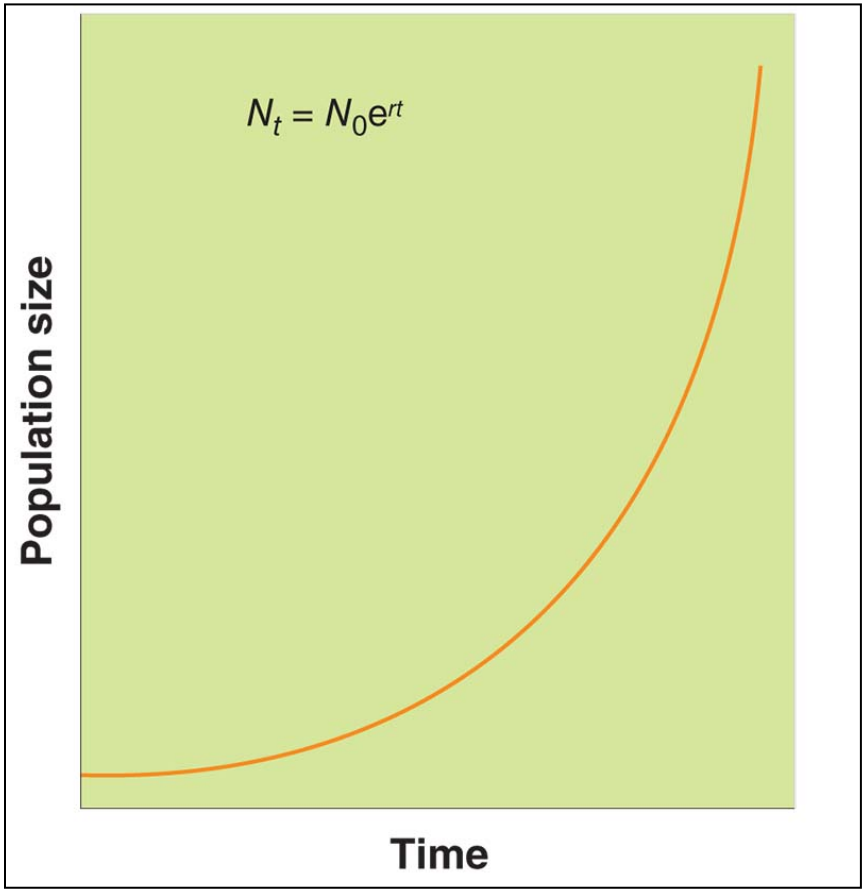
Trout Tolerance of Temperature

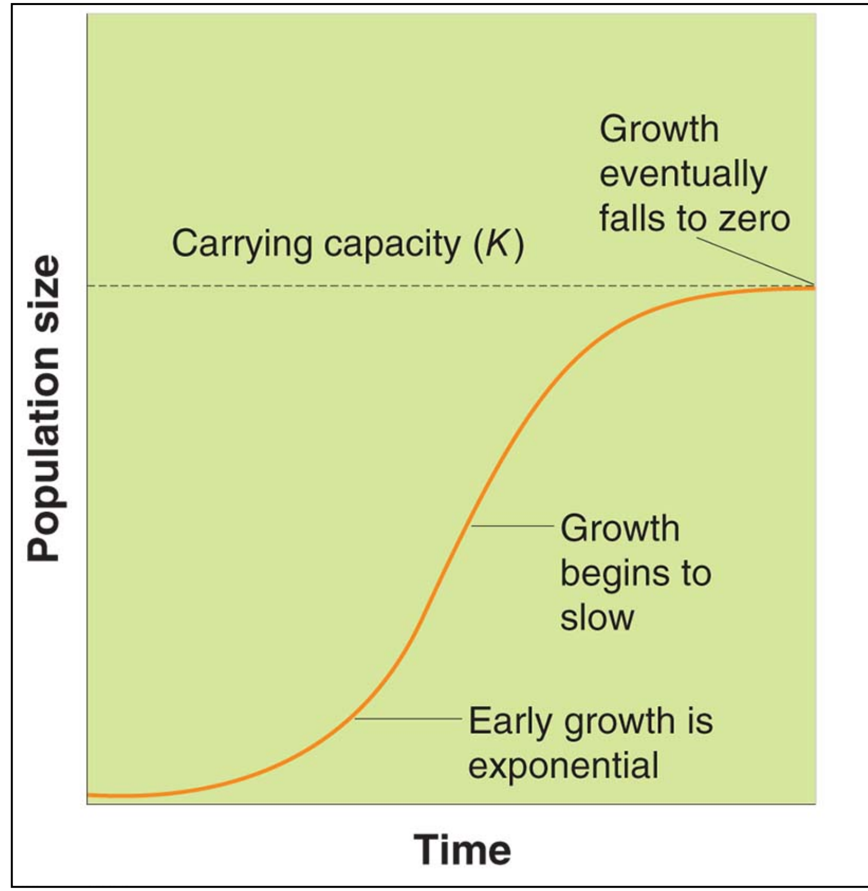
Some Factors Can Limit Population Size

All species has an optimal environment in which it performs particularly well-a **range of tolerance** or limit to abiotic conditions they can tolerate.



No Population Can Grow Indefinitely: J-Curves and S-Curves





Population growth is affected by biotic or ***intrinsic*** *factors that are built into the genetic basis of each species.*

Biotic potential (i.e. intrinsic growth): the maximum size a population would get it there were nothing holding it back.

No Population Can Grow Indefinitely: J-Curves and S-Curves

Environmental resistance

- All factors that act to limit the growth of a population

Carrying capacity (K)

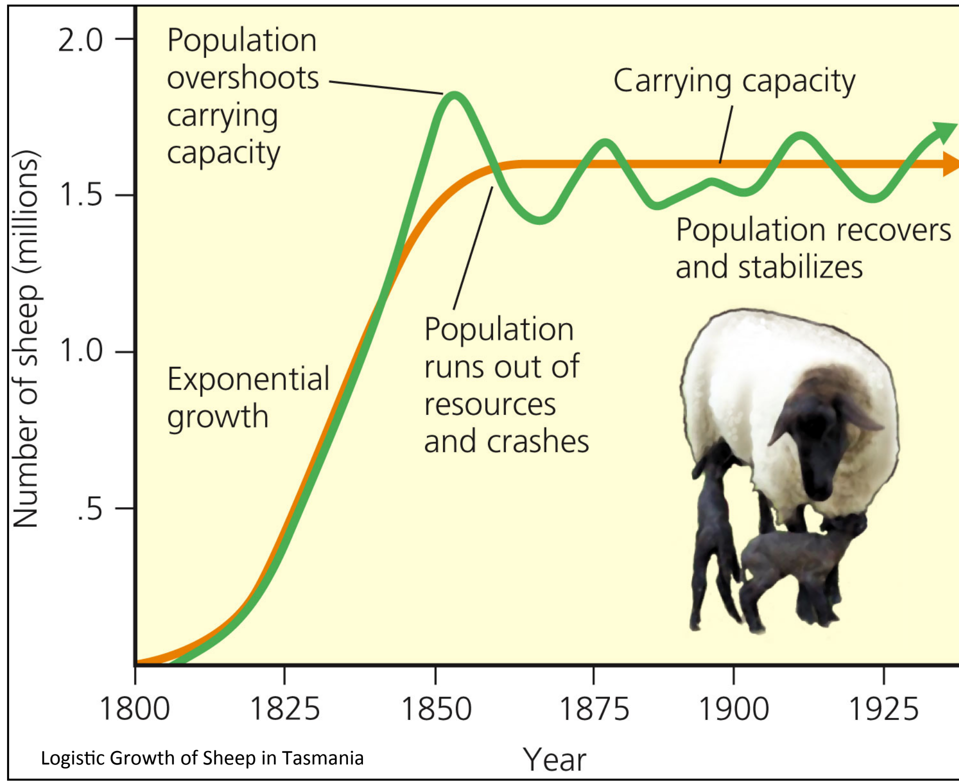
- Maximum population a given habitat can sustain

Exponential growth

Starts slowly, then accelerates to carrying capacity when meets environmental resistance

Logistic growth

Decreased population growth rate as population size reaches carrying capacity



Logistic Growth of Sheep in Tasmania

No Population Can Grow Indefinitely: J-Curves and S-Curves

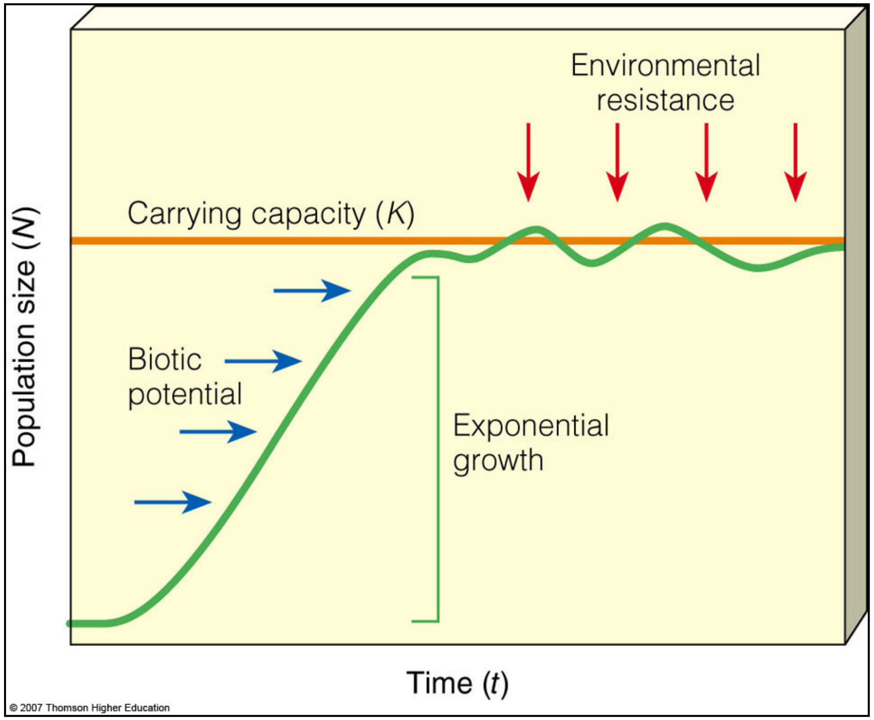
Population growth is affected by biotic or intrinsic factors that are built into the genetic basis of each species.

Biotic potential: the maximum size a population would get it there were nothing holding it back.

Logistic Growth Model

Together, biotic potential & environmental resistance determine **carrying capacity (*K*)**

Environmental Resistance + Biotic Potential = Carrying Capacity

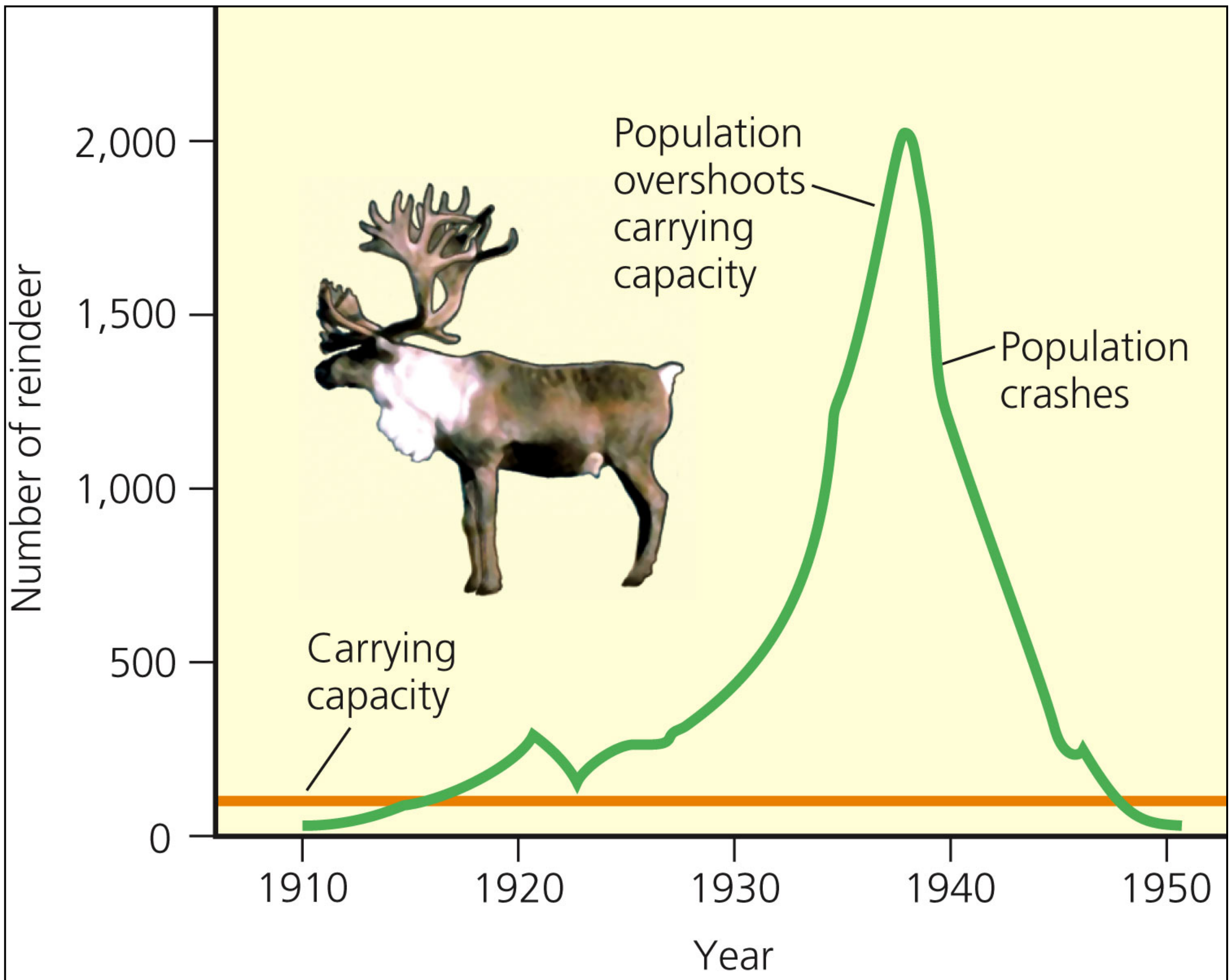


Some populations will **overshoot** *K*, there will be a lack of resources and the population will experience a **die-off/crash**.

When a Population Exceeds Its Habitat's Carrying Capacity, Its Population Can Crash

- Reproductive time lag may lead to overshoot then **Population crash**
- Damage may reduce area's carrying capacity

Exponential Growth, Overshoot, and Population Crash of a Reindeer

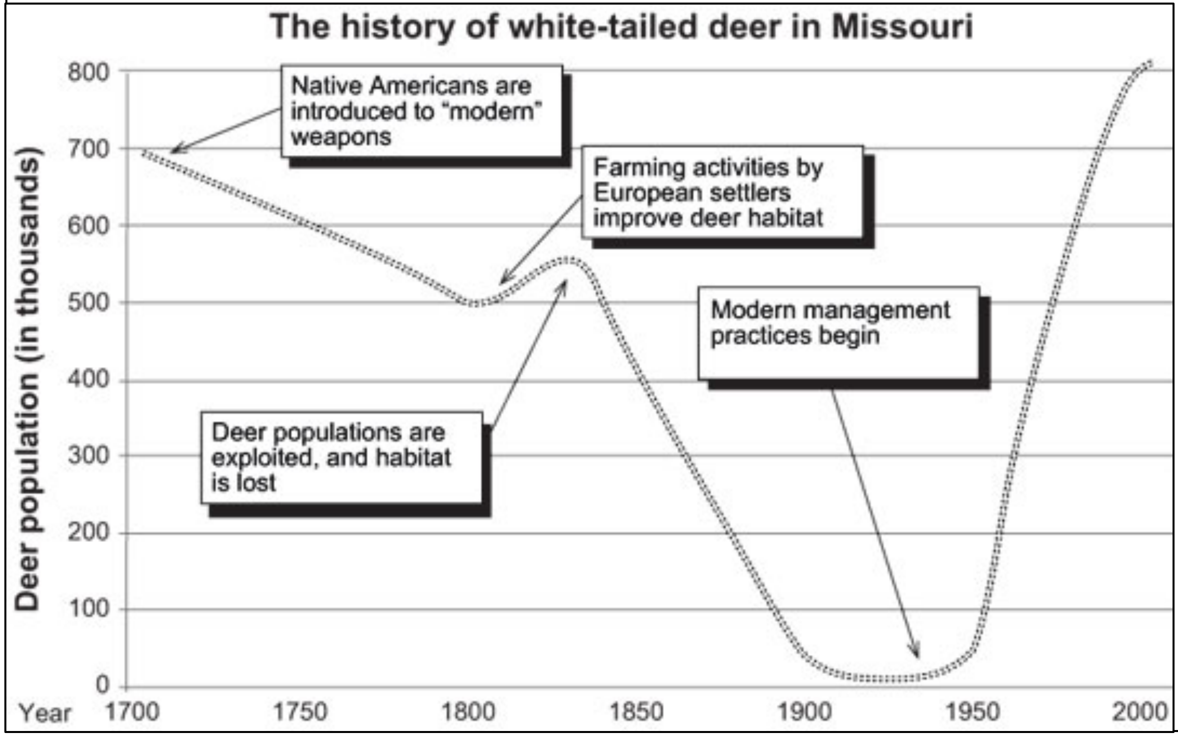


Exploding White-Tailed Deer Population in the U.S.

- 1900: deer habitat destruction and uncontrolled hunting
- 1920s–1930s: laws to protect the deer

  + Removal of natural predators

Current population explosion for deer



Some Factors Can Limit Population Size

Limiting Factors/Environmental Resistance Factors

Density Dependent Factors: Influence an individuals probability of survival and reproduction in a manner that depends on the size of the population

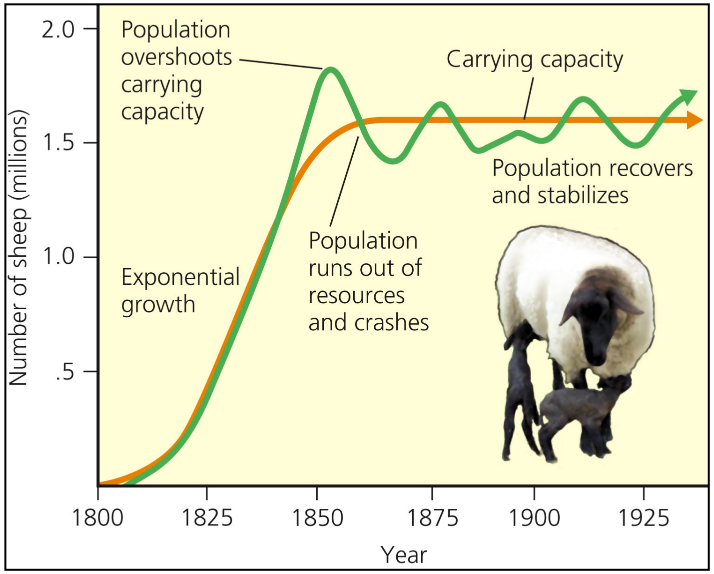
Ex. Competition, space, resources, predation, disease, parasitism

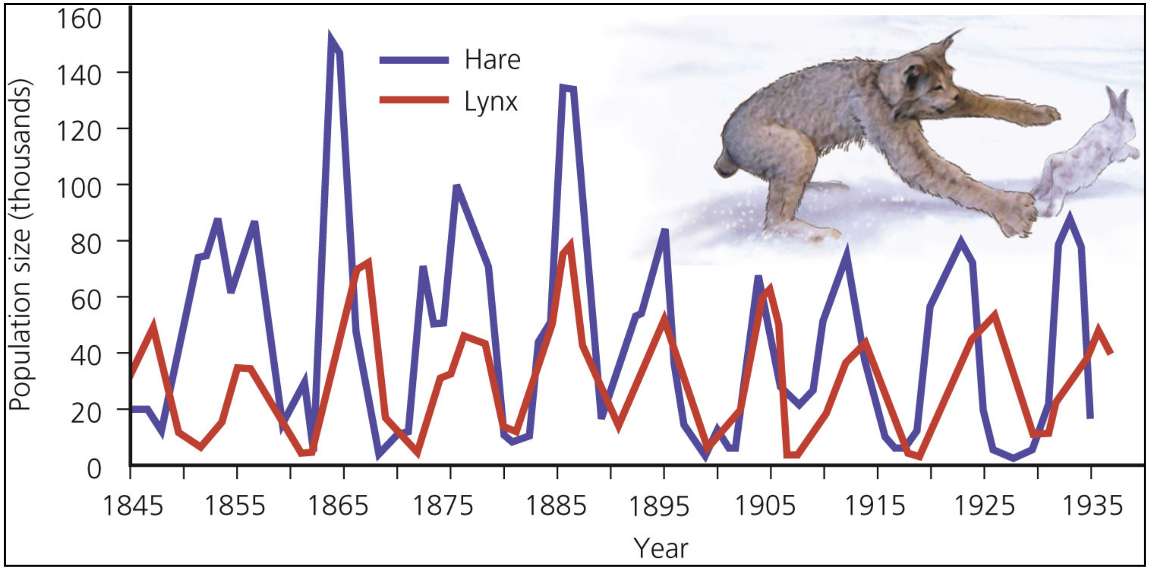
Density Independent Factors: have same effect on an individual's probability of survival

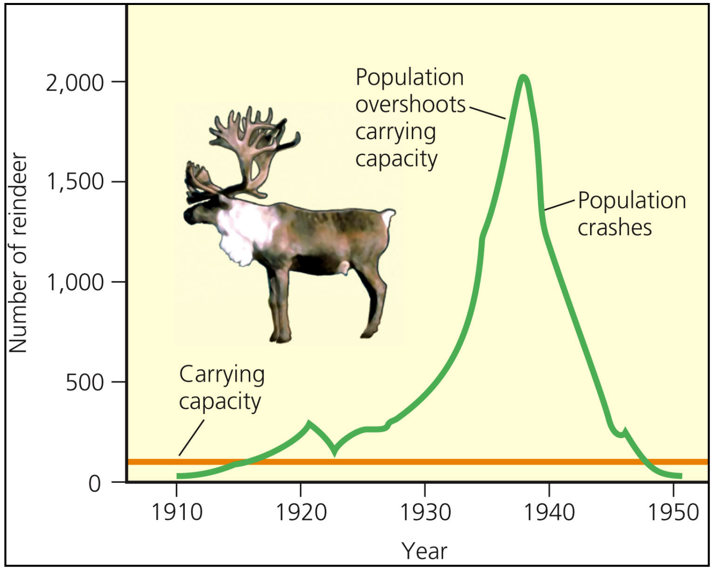
Ex. fire, drought, hurricane, pest spraying

Types of Population Change in Nature

- Stable
- Irruptive
  - Population surge, followed by crash
- Cyclic fluctuations, boom-and-bust cycles
  - Top-down population regulation
  - Bottom-up population regulation
- Irregular



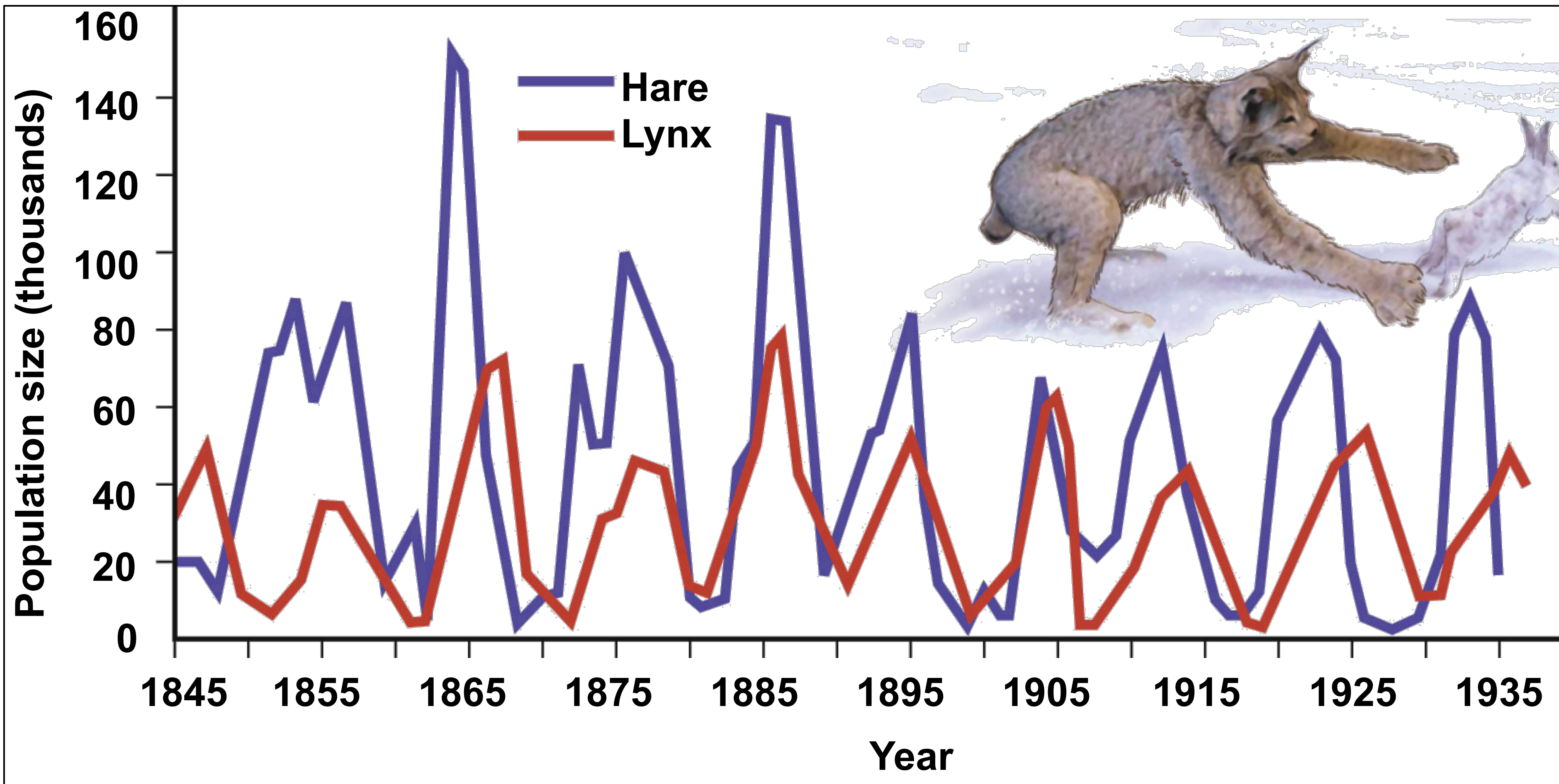


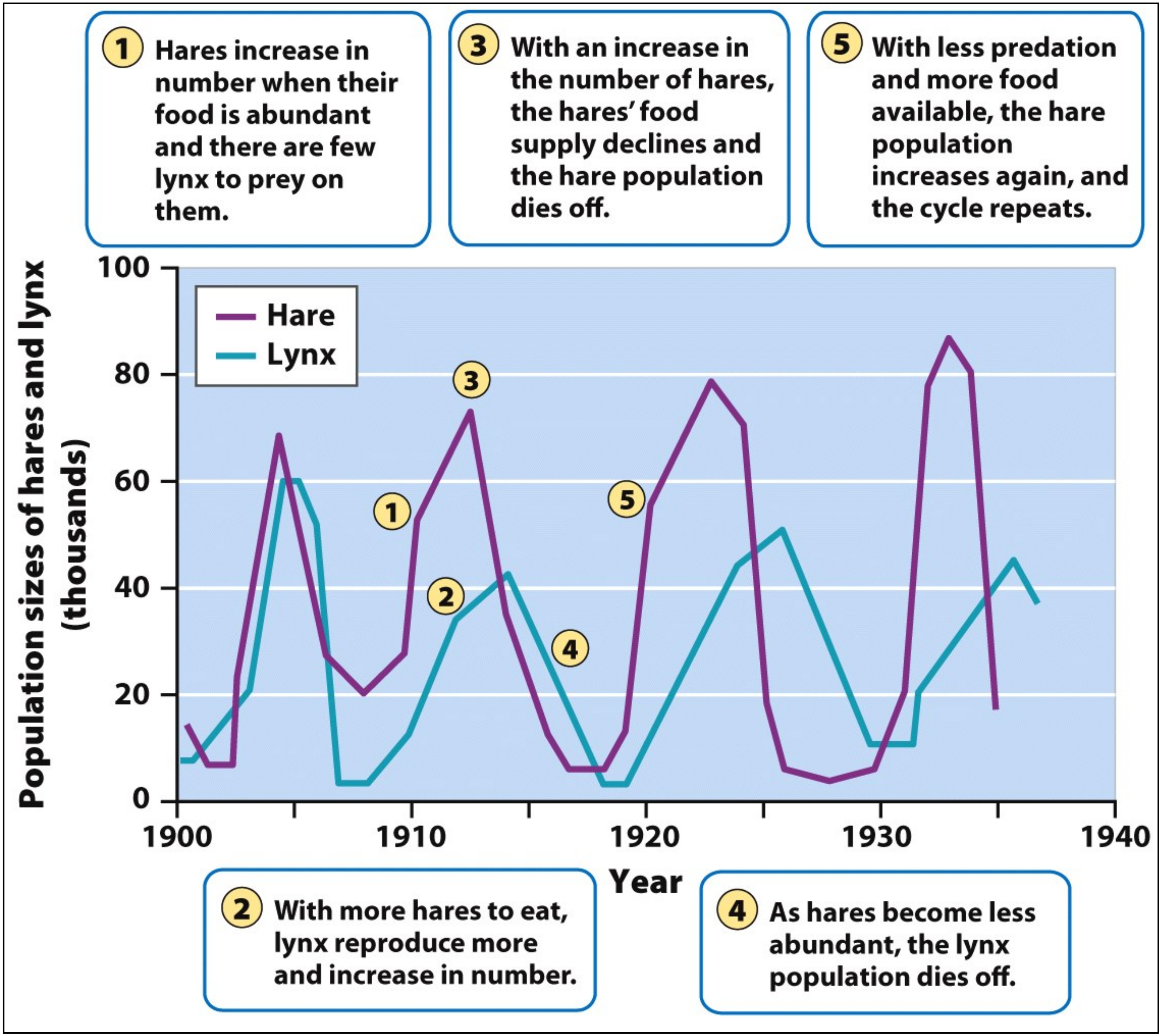


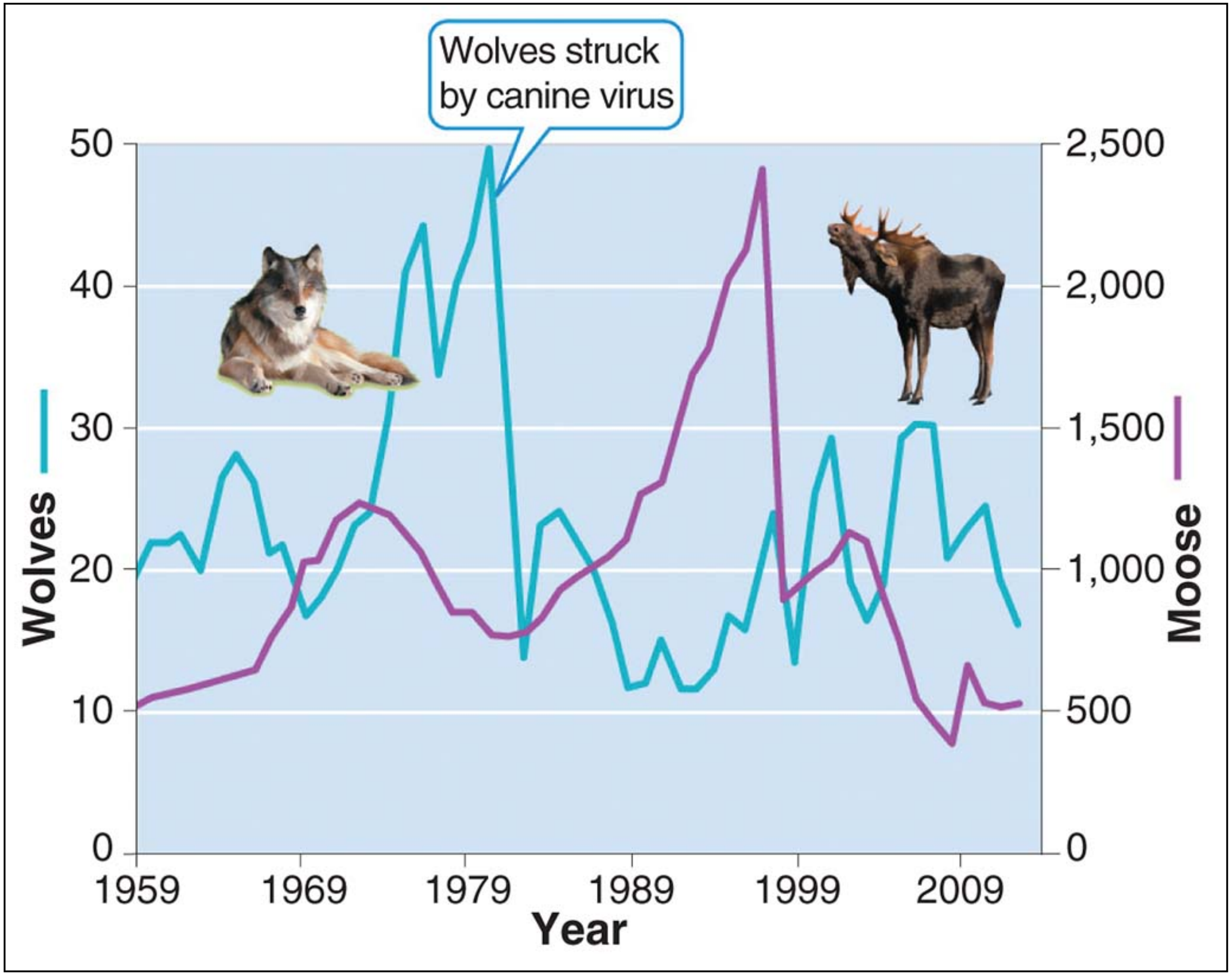
Population Cycles for the Snowshoe Hare and Canada Lynx

Cyclic fluctuations, boom-and-bust cycles

- Top-down population regulation
- Bottom-up population regulation




1 Hares increase in number when their food is abundant and there are few lynx to prey on them.
3 With an increase in the number of hares, the hares' food supply declines and the hare population dies off.
5 With less predation and more food available, the hare population increases again, and the cycle repeats.
Hare
Lynx
Population sizes of hares and lynx (thousands)
100
80
60
40
20
0
1900
1910
1920
1930
1940
Year
1
2
3
4
5
2 With more hares to eat, lynx reproduce more and increase in number.
4 As hares become less abundant, the lynx population dies off.



Wolves struck by canine virus
Wolves
Moose
Year
50
40
30
20
10
0
2,500
2,000
1,500
1,000
500
0
1959
1969
1979
1989
1999
2009

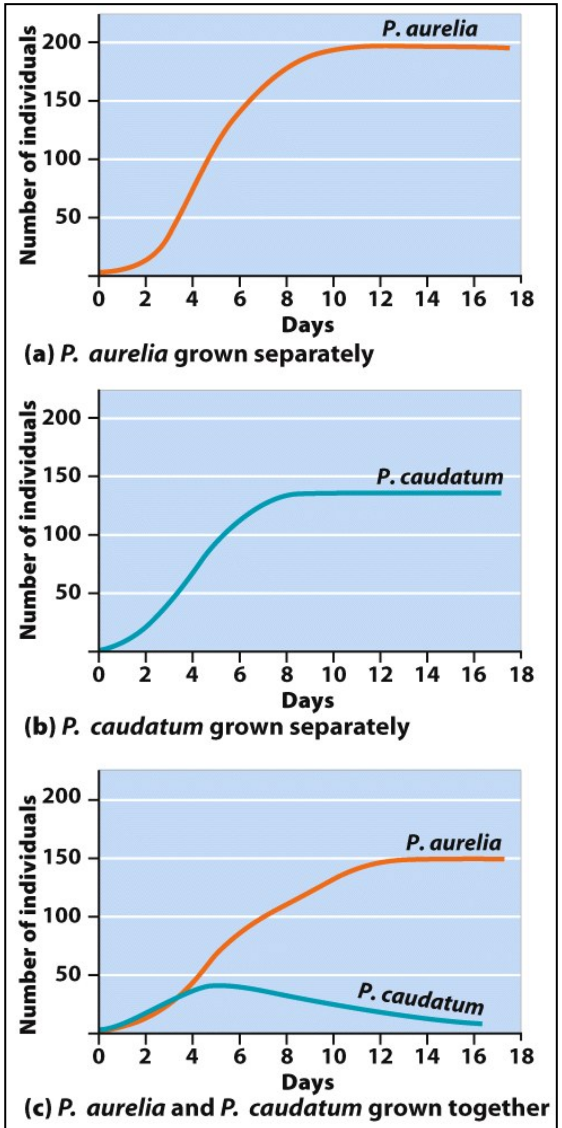
Species Interactions

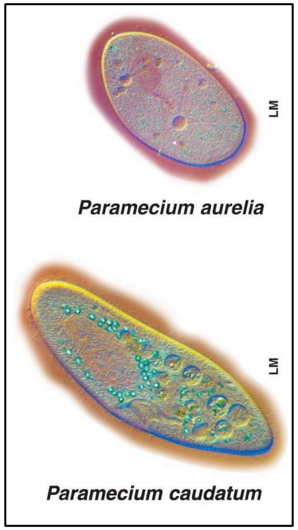
Competition: Struggle of individuals to obtain a limited resource

Interspecific competition: competition in which individuals of different species compete for the same resource in an ecosystem (e.g. food or living space).

Intraspecific competition: organisms of the same species.

Competitive Exclusion Principle: Two species competing for same limited resource cannot coexist

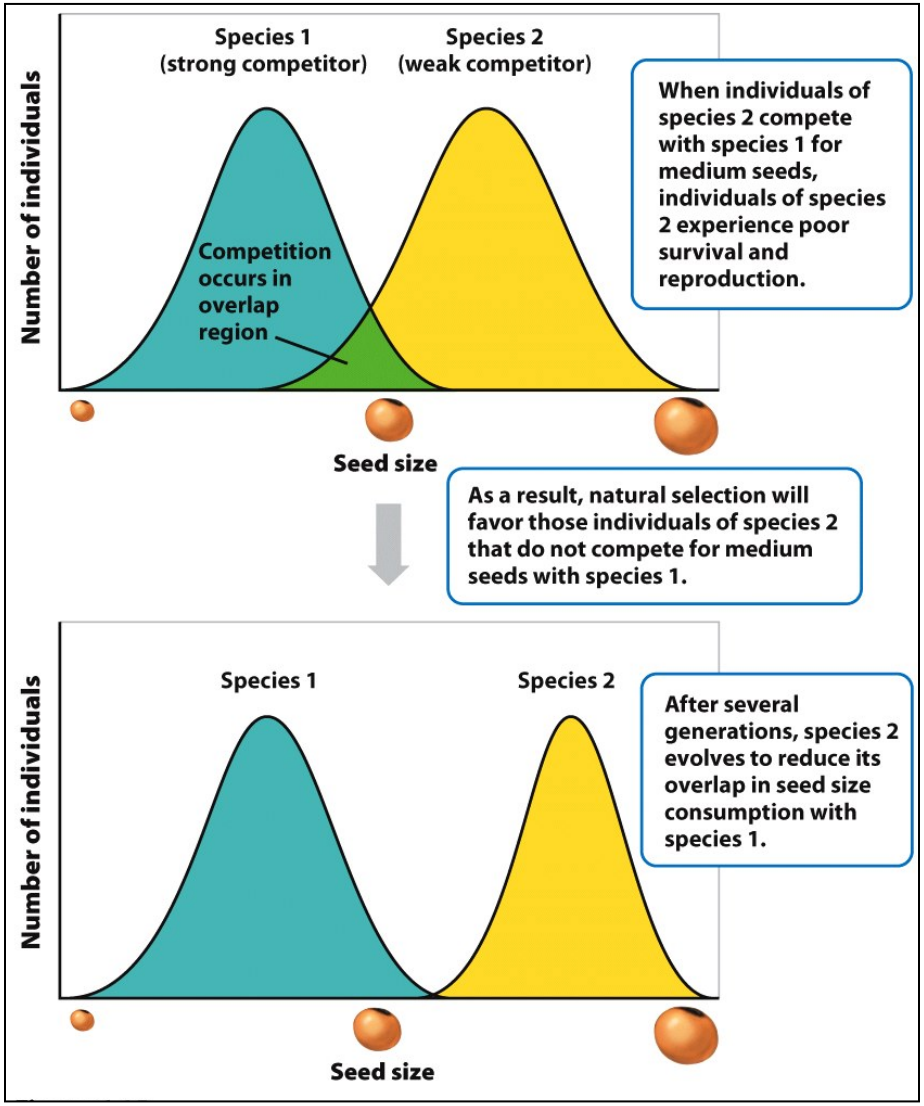




Species Interactions

Most Species Compete with One Another for Certain Resources

- For limited resources
- Ecological niche for exploiting resources
- Some niches overlap →
- Niche differentiation
  - Resource partitioning



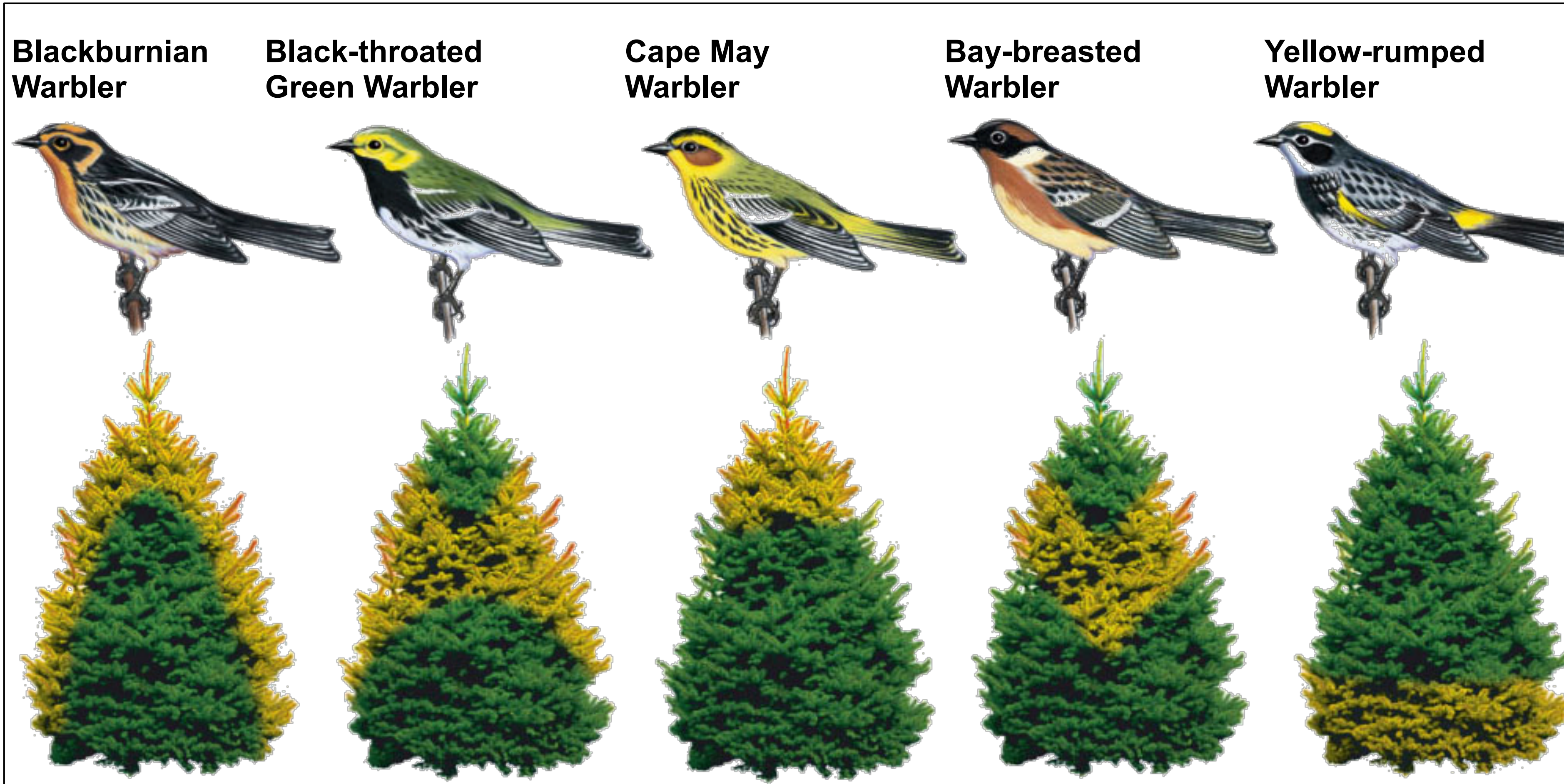
Three Types of Resource Partitioning

1. **Temporal**; e.g. wolves & coyotes that shear same space hunt at different times of day; plants flower at different times of year.
2. **Spatial**; e.g. birds use different parts of same tree.
3. **Morphological**; e.g. Darwin's finches beaks adapted to different foods.

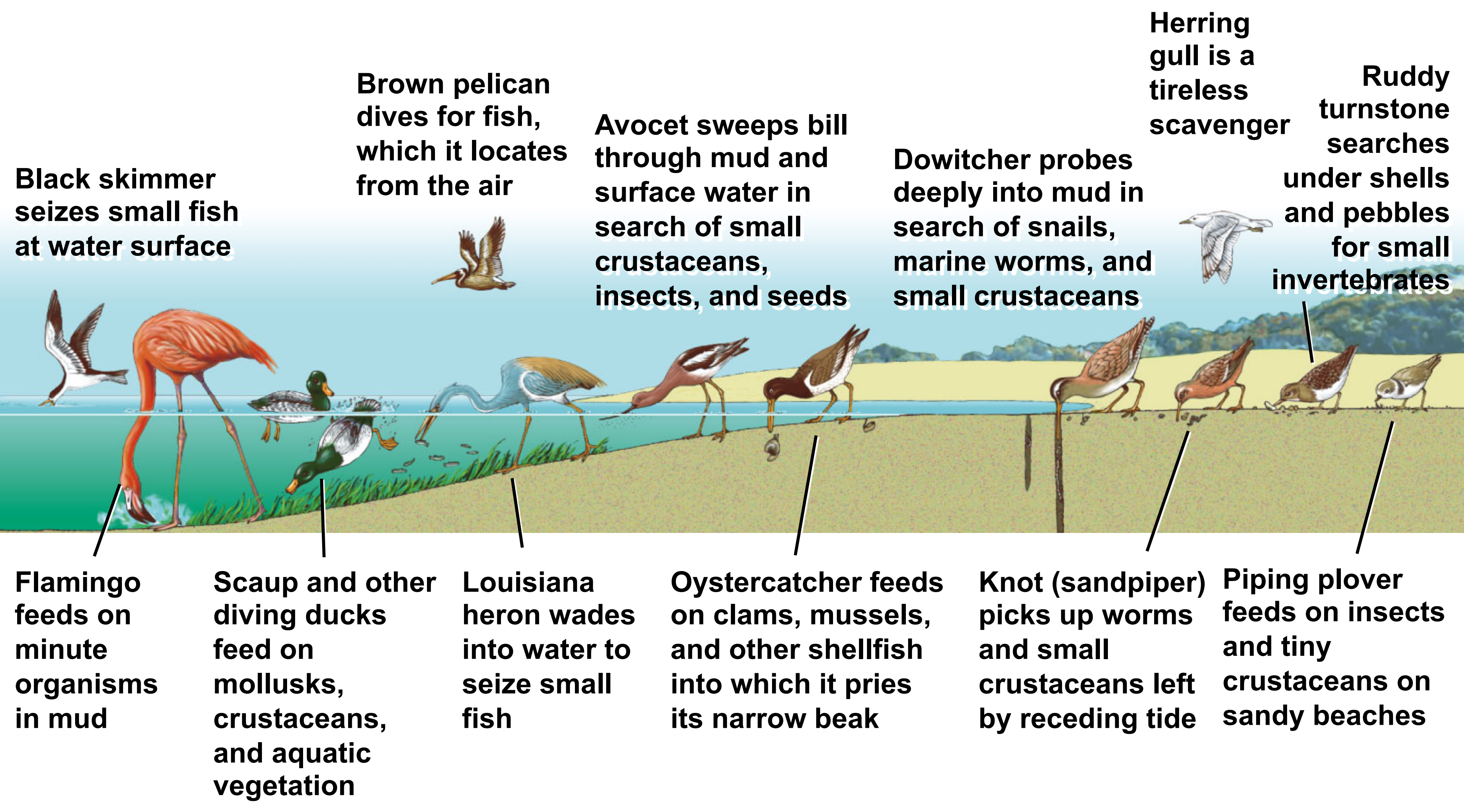
Some Species Evolve Ways to Share Resources

Resource partitioning

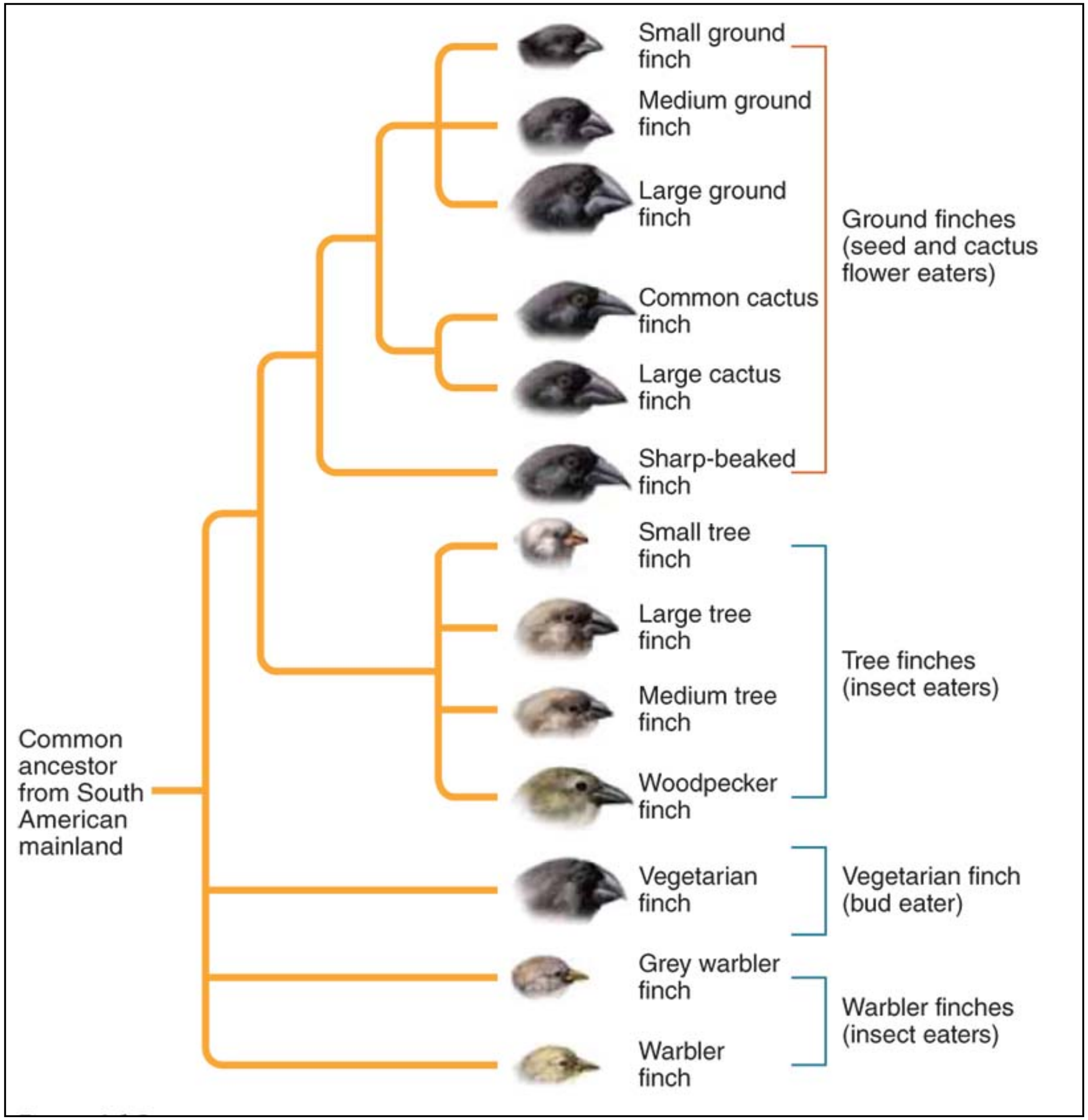
- Using only parts of resource
- Using at different times
- Using in different ways



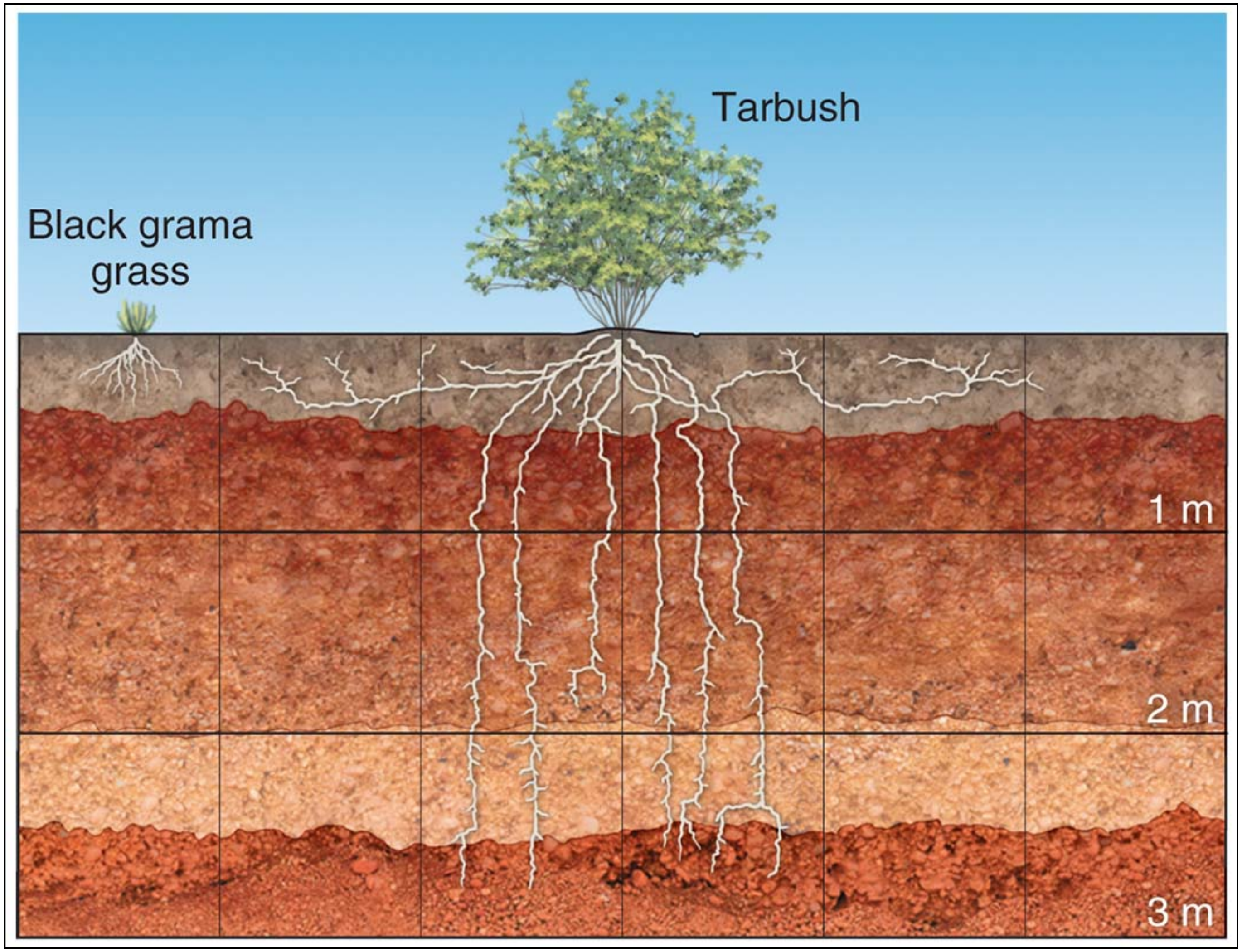
Specialized Feeding Niches of Various Bird Species in a Coastal Wetland



Darwin's Finches- Morphological Resource Partitioning



Spatial Resource Partitioning

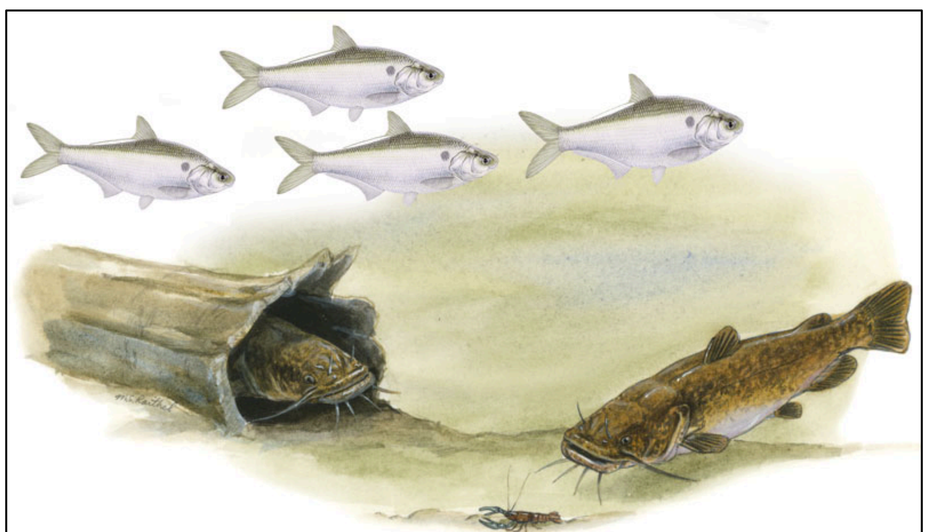


Ecological Niche

An organism's pattern of living (way of life); Each species fits into an ecological community in its own special way and has its own tolerable ranges for many environmental factors; Everything that affects survival and reproduction.

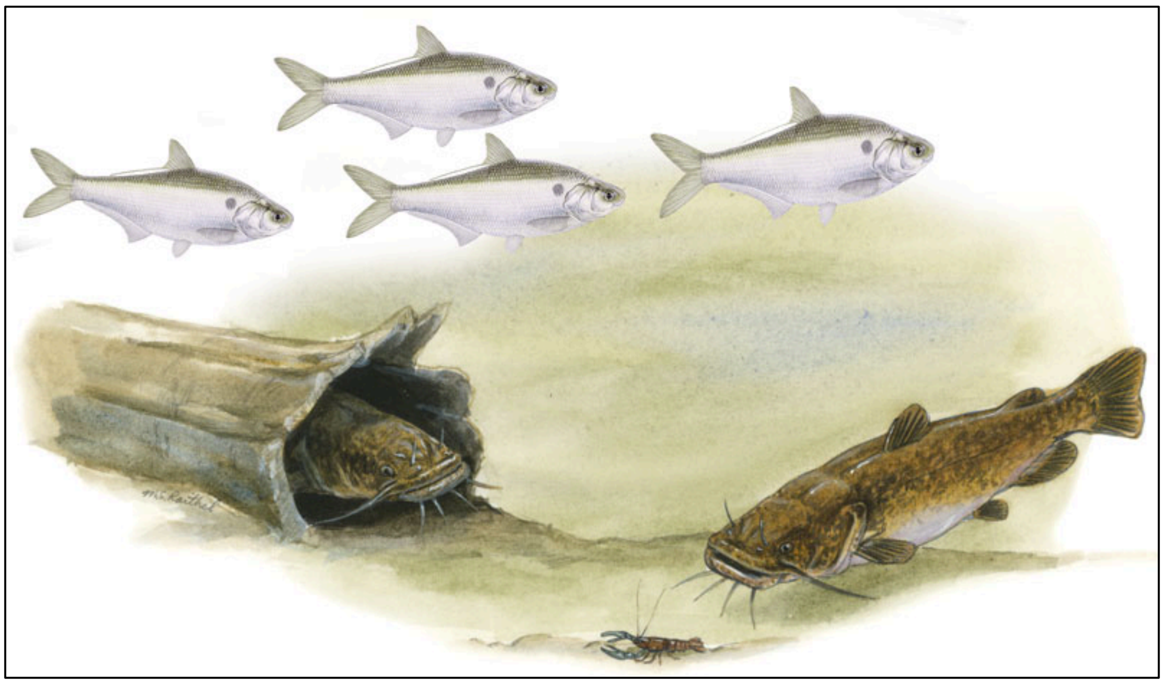
- Water, space, sunlight, food, temperatures
- Includes adaptations acquired through evolution

For example, a fish species' niche might be defined partly by ranges of salinity (saltiness), pH (acidity), and temperature it can tolerate, as well as the types of food it can eat.



Ecological Niche

Within a community every species has a particular niche. A species' niche defines how a species fits into its environment. It includes its way of getting food, the habitat it needs, and the role it performs in the community.



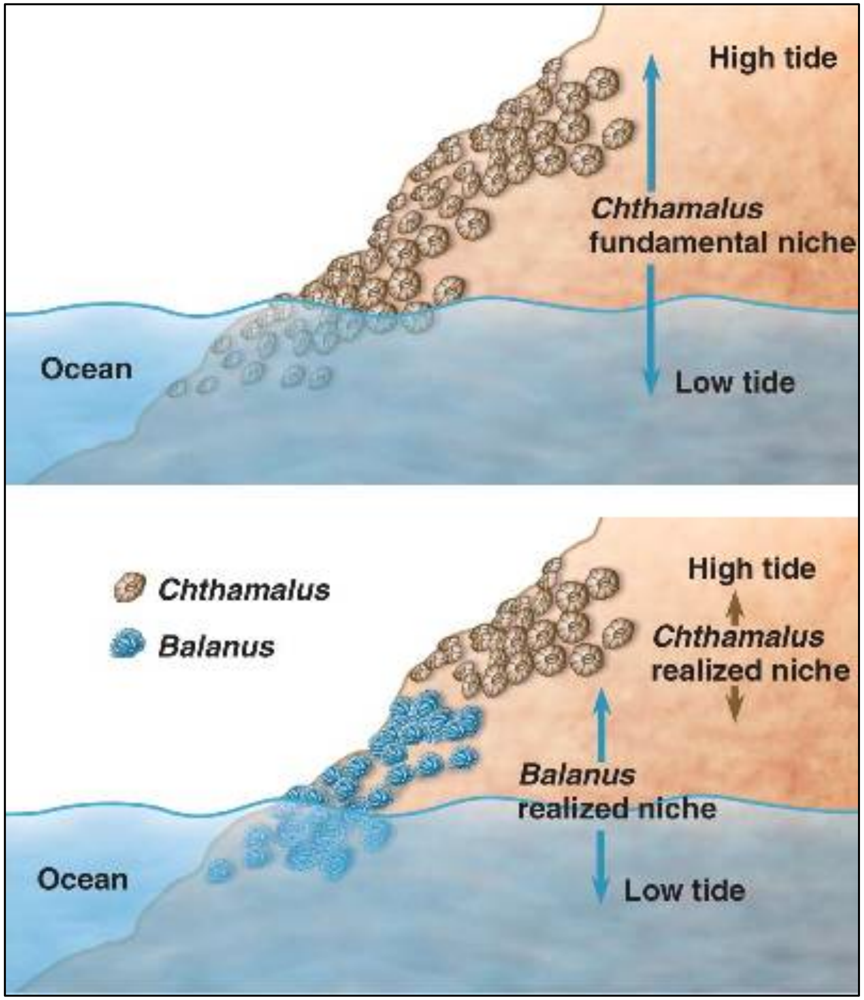
Flathead catfish can live in the same reservoir with gizzard shad because they don't compete for the same niche.

Principle of competitive exclusion

- Chthalamus barnacles can live in both deep and shallow intertidal zones (***fundamental niche***).
- Competition from Balanus forces Chthalamus to occupy a smaller ***realized niche*** on higher, drier habitat.

Fundamental Niche:
Full potential range of conditions if there were no competition

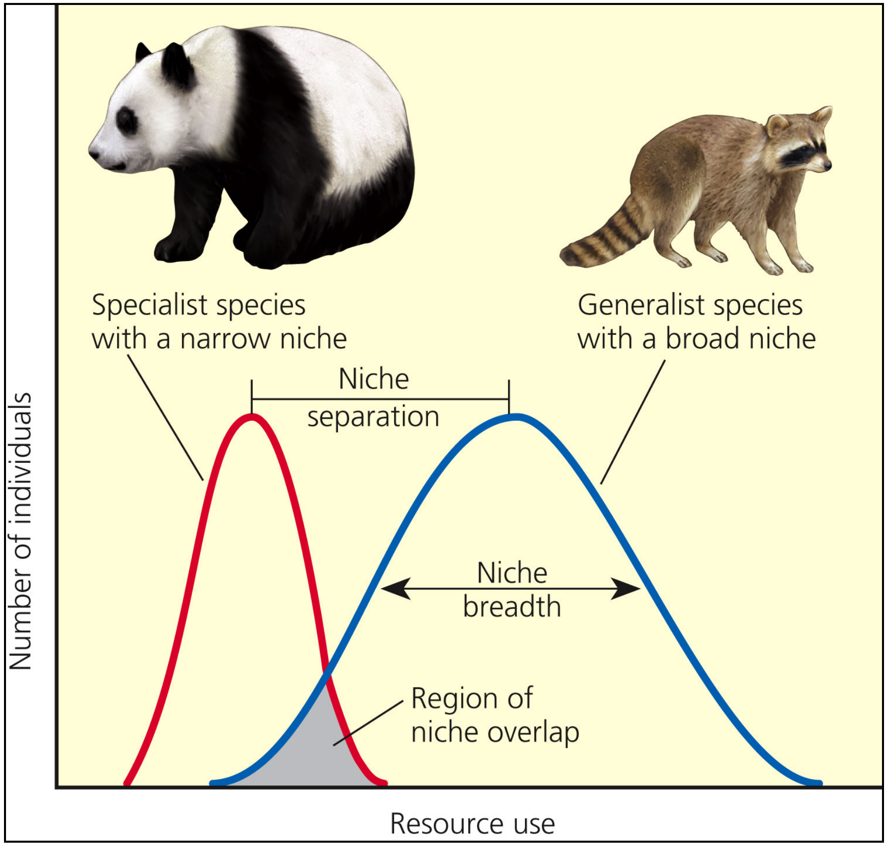
Realized Niche:
The portion of niche fulfilled due to competition or other species interactions



Ecological Niche: Each Species Plays a Unique Role in Its Ecosystem

A **generalist species:** Broad Niches able to thrive in a wide variety of environmental conditions and can make use of a variety of different resources (*r*-strategist)

A **specialist species:** Narrow Niches can only thrive in a narrow range of environmental conditions or has a limited diet. Often prone to extinction.(K-Strategist)



Ex. Cockroaches are generalists (*r*-strategist)

- Eat almost anything
- Live in almost any climate
- High reproductive rates

r strategists (*r*-selected species)

High intrinsic growth rate because they reproduce often and produce large number of off spring. Populations do not typically remain near *K*, but exhibit rapid growth followed by overshoots and die-offs

K strategists (K-selected species)

Low intrinsic growth rate so pop increases slowly until reach *K (carrying capacity)*. Fluctuations are small

r-Selected Species	K-Selected Species
Many small offspring	Fewer, larger offspring
Little or no parental care and protection of offspring	High parental care and protection of offspring
Early reproductive age	Later reproductive age
Most offspring die before reaching reproductive age	Most offspring survive to reproductive age
Small adults	Larger adults
Adapted to unstable climate and environmental conditions	Adapted to stable climate and environmental conditions
High population growth rate (*r*)	Lower population growth rate (*r*)
Population size fluctuates wildly above and below carrying capacity (*K*)	Population size fairly stable and usually close to carrying capacity (*K*)
Generalist niche	Specialist niche
Low ability to compete	High ability to compete
Early successional species	Late successional species

Species Have Different Reproductive Strategies

K-selected species

- Reproduce later in life
- Small number of offspring with long life spans
- Young offspring grow inside mother
- Long time to maturity
- Protected by parents, and potentially groups
- Large mammals and birds
- Humans, elephants, whales

***r*-selected species**

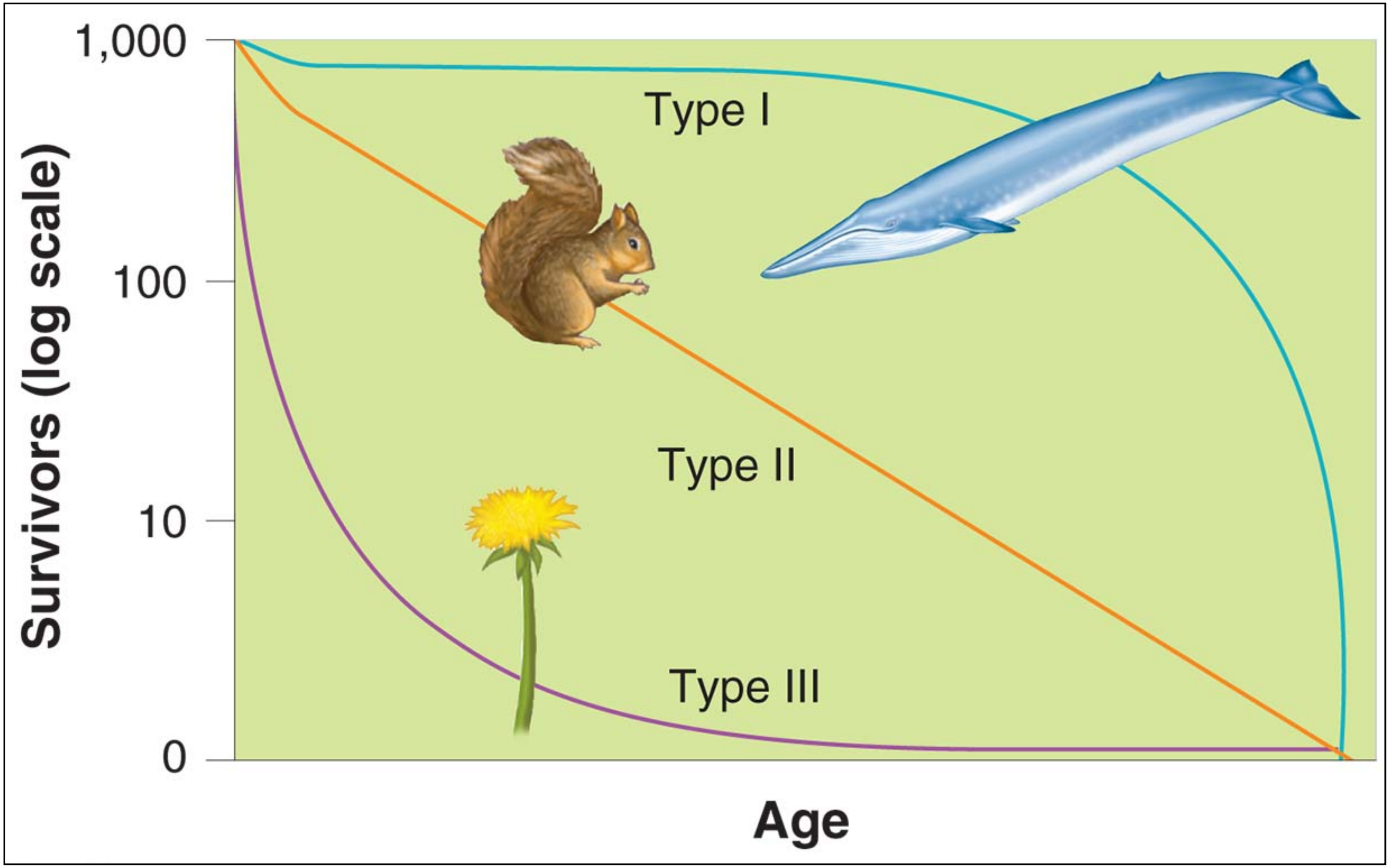
- Many, usually small, offspring
- Little or no parental care
- Massive deaths of offspring
- Insects, bacteria, algae—cockroaches, dandelions, rats, etc.

Species Have Different Reproductive Strategies

TABLE 19.1 Traits of *K*-selected and *r*-selected species

Trait	*K*-selected species	*r*-selected species
Life span	Long	Short
Time to reproductive maturity	Long	Short
Number of reproductive events	Few	Many
Number of offspring	Few	Many
Size of offspring	Large	Small
Parental care	Present	Absent
Population growth rate	Slow	Fast
Population regulation	Density dependent	Density independent
Population dynamics	Stable, near carrying capacity	Highly variable

Survivorship Curves



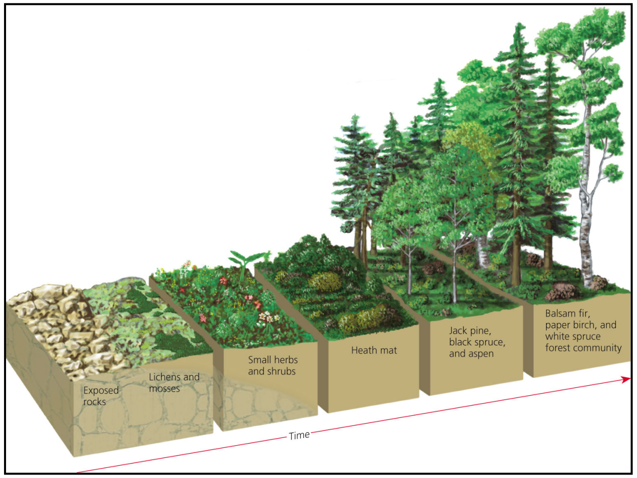
Different species have distinct patterns of survivorship over the life span. Species range from exhibiting excellent survivorship until old age (type I curve) to exhibiting a relatively constant decline in survivorship over time (type II curve) to having very low rates of survivorship early in life (type III curve). *K*-selected species tend to exhibit type I curves, whereas *r*-selected species to exhibit type III curves.

Communities and Ecosystems Change over Time: Ecological Succession

Ecological Succession is natural ecological restoration

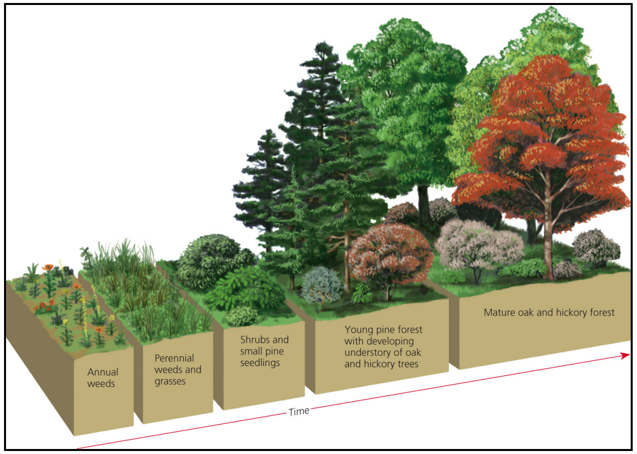
Primary succession

- No soil in a terrestrial system
- No bottom sediment in an aquatic system
- Takes hundreds to thousands of years
- Need to build up soils/sediments to provide necessary nutrients

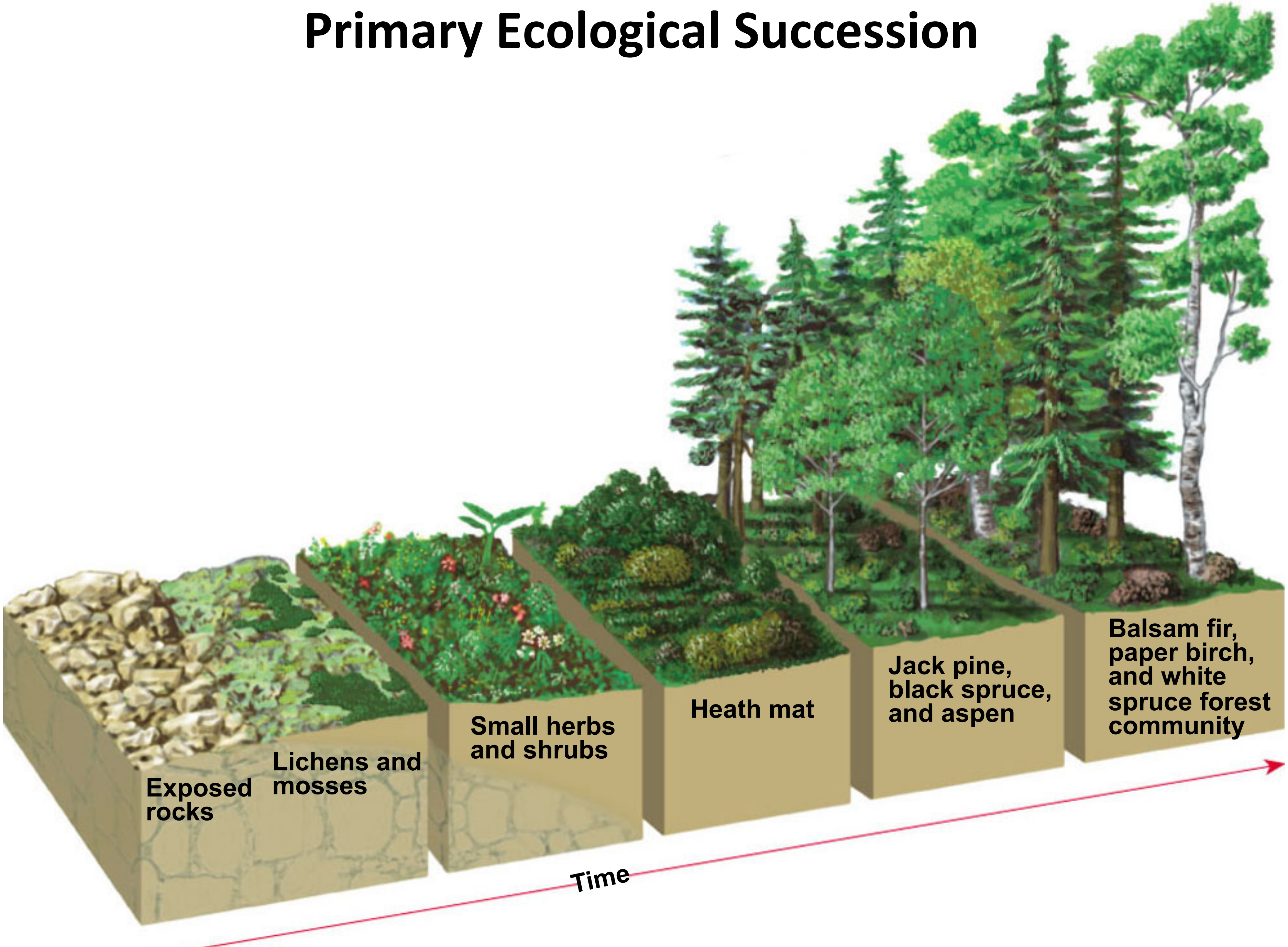


Secondary succession

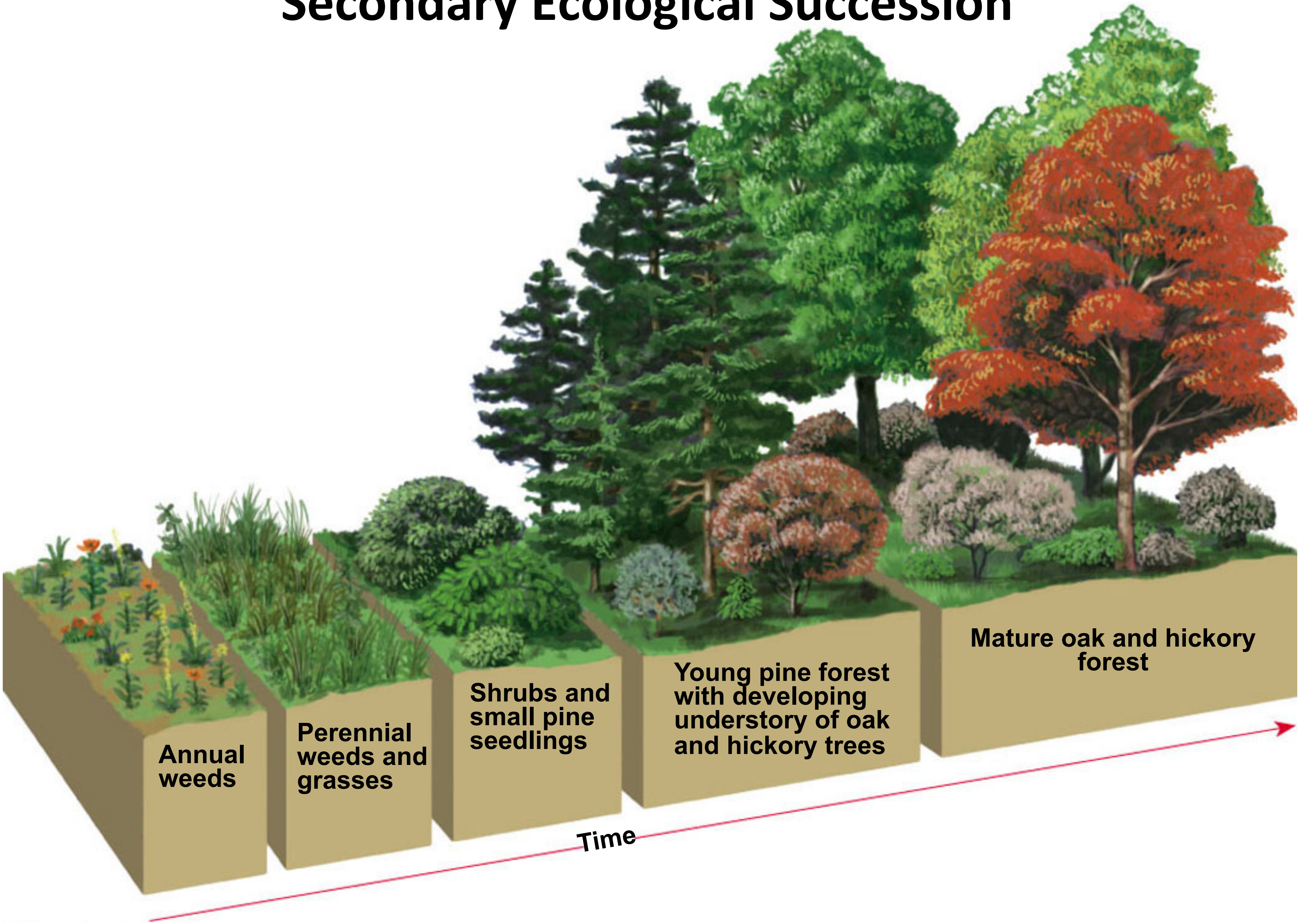
- Some soil remains in a terrestrial system
- Some bottom sediment remains in an aquatic system
- Ecosystem has been
  - Disturbed
  - Removed
  - Destroyed



Primary Ecological Succession



Secondary Ecological Succession



Communities and Ecosystems Change over Time: Ecological Succession

Some Ecosystems Do Not Have to Start from Scratch: Secondary Succession

- Primary and secondary succession
  - Tend to increase biodiversity
  - Increase species richness and interactions among species

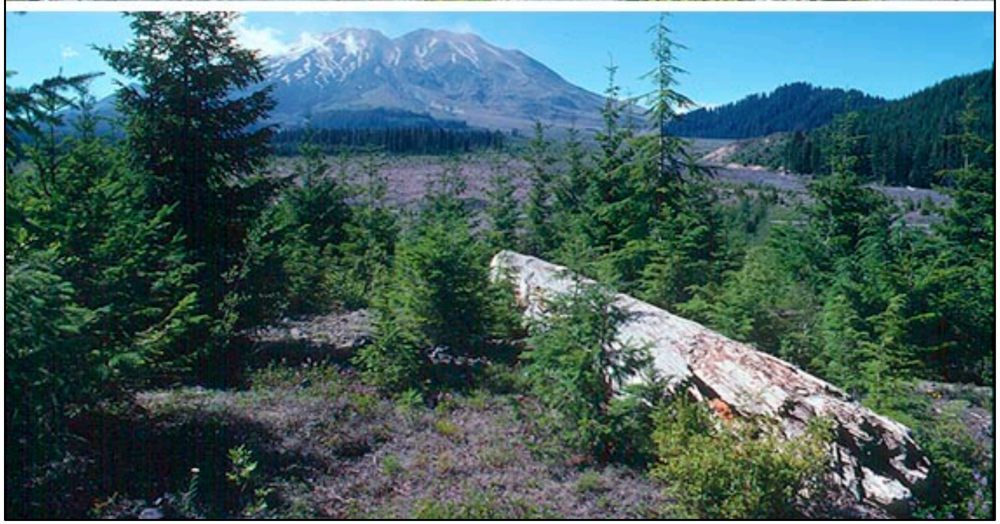
- Primary and secondary succession can be interrupted by
  - Fires
  - Hurricanes
  - Clear-cutting of forests
  - Plowing of grasslands
  - Invasion by nonnative species

Secondary Ecological Succession in Yellowstone Following the 1998 Fire

Communities and Ecosystems Change over Time: Ecological Succession

3-years after the eruption →

20-years after the eruption →



Mt. Saint Helens: One of the most violent natural disasters of our time, the colossal eruption of Mt. St. Helens in 1980 blasted away an entire mountainside. Over 200 square miles of pristine forest were buried under millions of tons of lava, ash, mud, and avalanche debris.

Communities and Ecosystems Change over Time: Ecological Succession

Inertia, persistence

Ability of a living system to survive moderate disturbances

Resilience

Ability of a living system to be restored through secondary succession after a moderate disturbance

Some systems have one property, but not the other:

- ***Tropical rain forests: high inertia/low resilience*;** Tropical rainforests have high species richness and high inertia and thus are resistant to change. But once a large tract of tropical rainforest is cleared, the resilience of the resulting degraded forest ecosystem is so low that it reaches an ecological tipping point and may succeed to tropical grassland; an irreversible change.
- ***Grasslands: high resilience/low inertia;*** Grasslands are much less diverse than most forests, and consequently they have low inertia and can burn easily. However, because most of their plant matter is stored in underground roots, these ecosystems have high resilience and can recover quickly after a fire, as their root systems produce new grasses.

Communities and Ecosystems Change over Time: Ecological Succession

Facilitation: One set of species makes an area suitable for species with different niche requirements, but less suitable for itself; e.g. lichens and mosses (often called *colonizer* species) gradually build up soil on rock in primary succession, herbs and grasses can colonize the site site and crowd out the original pioneer species (lichens and mosses).

Inhibition: An earlier species hinder the establishment and growth of other species. Inhibition often occurs when plants such as butternut or black walnut release toxic chemicals that reduce competition from other plants.

Tolerance: Plants in the late stages of succession are largely unaffected by plants that came in during earlier stages because the later plants are not in competition with the earlier ones for key resources. For example, shade tolerant trees and other plants can thrive beneath the older, larger trees of a mature forest because they do not need to compete with the taller species for access to sunlight.

Pioneer Species: Trees such as aspen and cherry are often called pioneer species because of their ability to colonize new areas rapidly and grow well in full sunshine. Shade tolerant species eventually grow up through the pioneer canopy and dominate the forest community.

Communities and Ecosystems Change over Time: Ecological Succession

Succession occurs in aquatic ecosystems. Over a time span of hundreds to thousands of years, lakes are filled in with sediments and slowly become terrestrial habitats.