Chapter 5
Evolution of Biodiversity

Earth is home to a tremendous diversity of species

- **Ecosystem diversity-** the variety of ecosystems within a given region.
- **Species diversity-** the variety of species in a given ecosystem.
- **Genetic diversity-** the variety of genes within a given species.

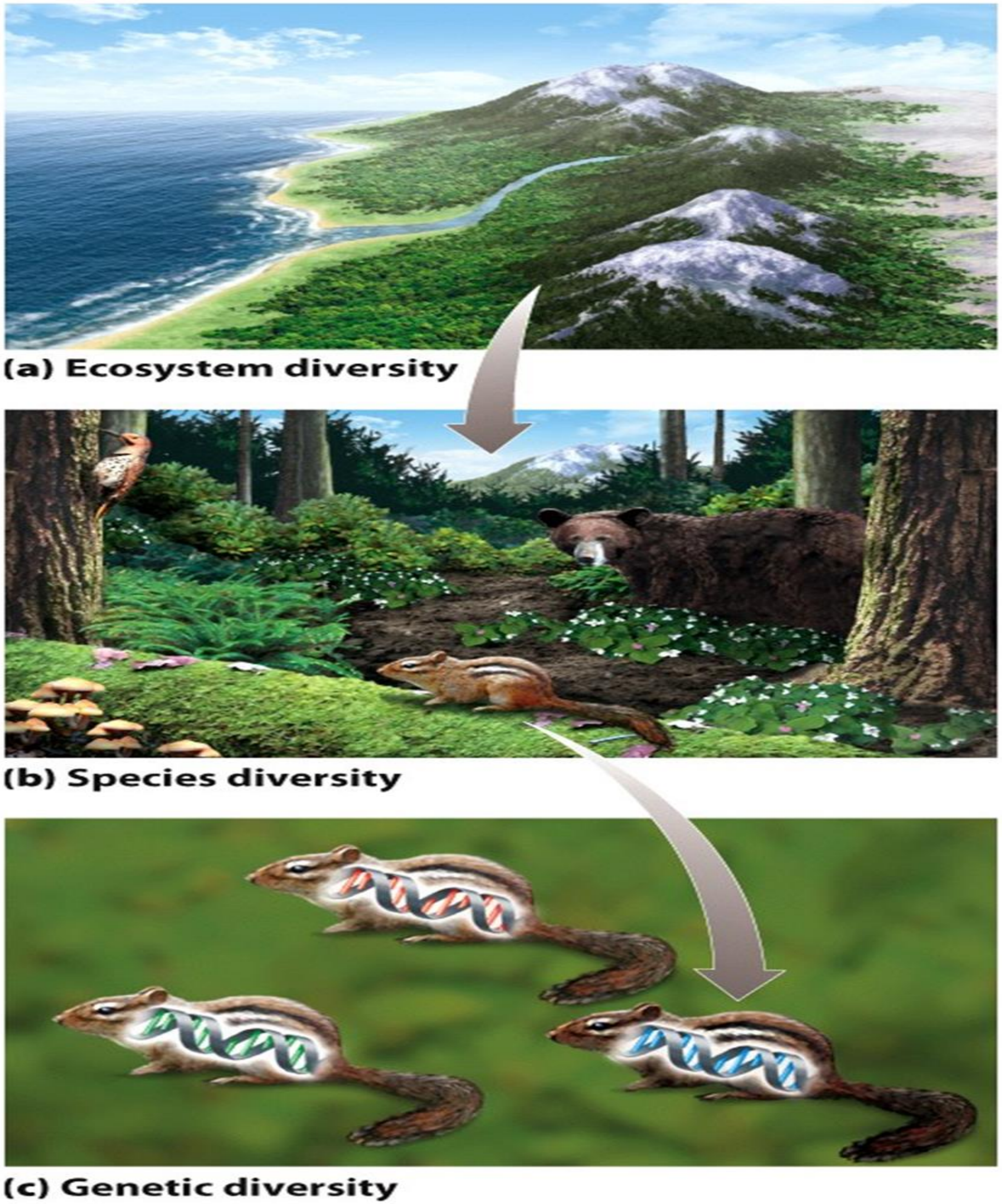

Figure 5.2
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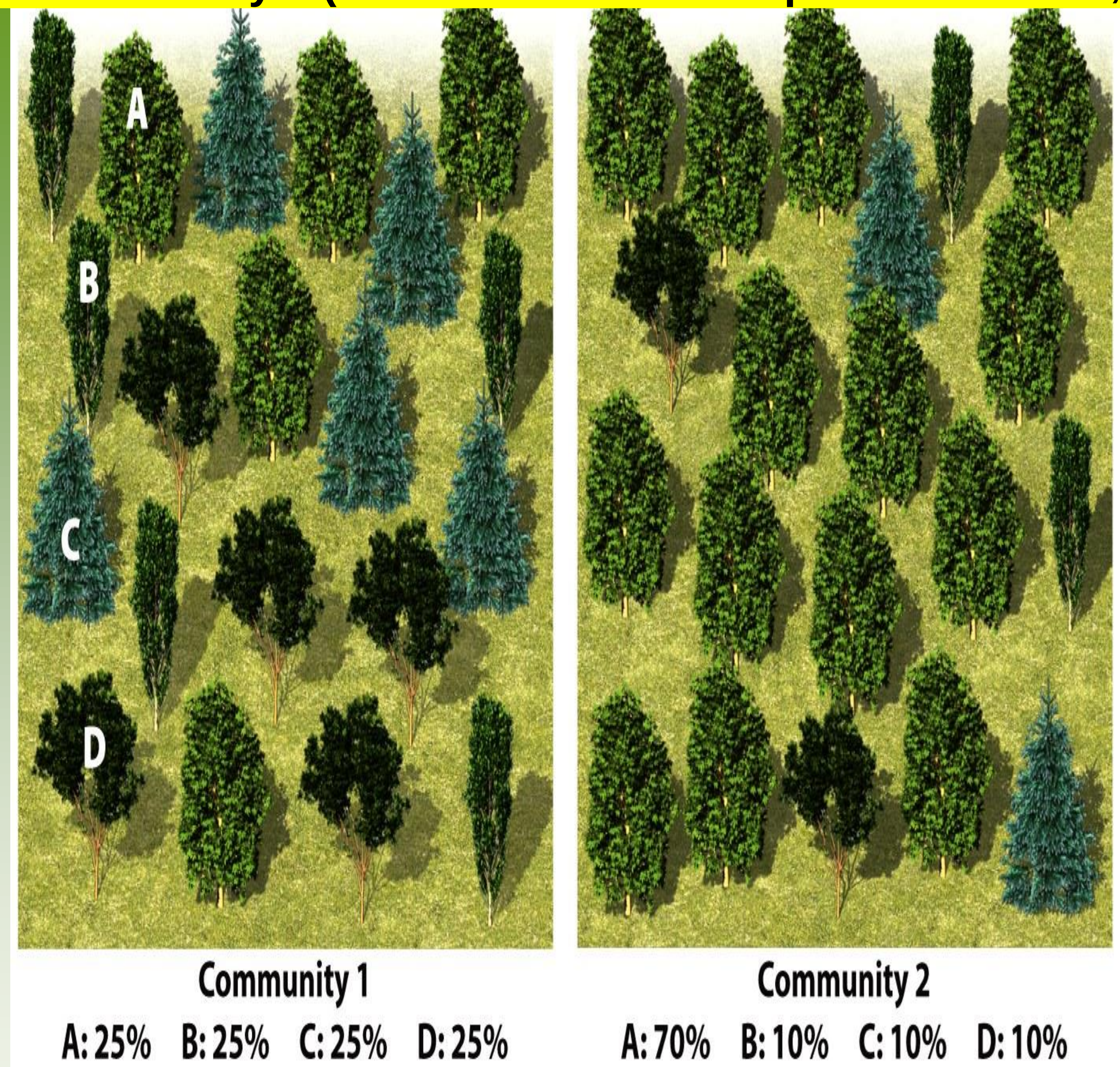
- **Species** – a group of organisms that is distinct from other such groups in terms of size, shape, behavior, or biochemical properties, and that can interbreed with other individuals in the same species to have viable offspring. *(Natural selection – survival of the fittest)*

- Sometimes individuals from different species can mate, but will not produce offspring that will survive.
- ***The number of species in any given place is the most common measure of biodiversity.

- **Species richness-** the number of species in a given area.
- **Species evenness-** the measure of whether a particular ecosystem is numerically dominated by one species or are all represented by similar numbers of individuals.

Community 1 has higher evenness and equal richness to Community 2 (both have the same species richness)



Knowing species richness & evenness, gives scientist a **baseline** of how much an ecosystem has changed over time due to *typically* human disturbances.

Shannon-Wiener Index (H): Measurement of both species richness and evenness (biodiversity)

H = -sum (Pi ln [Pi])

(neg sign makes the index a positive number)

- **H** = uncertainty of predicting species based on diversity
  (0 *single species* - 7 *diverse community*)
- **N** = total # of individual in the ecosystem
- **ni** = # of individuals in species
- $Pi = \frac{ni}{N}$ relative abundance (proportion of indiv.)
- **Ln** = natural log

$$E = \frac{H}{\ln(R)}$$

E = evenness

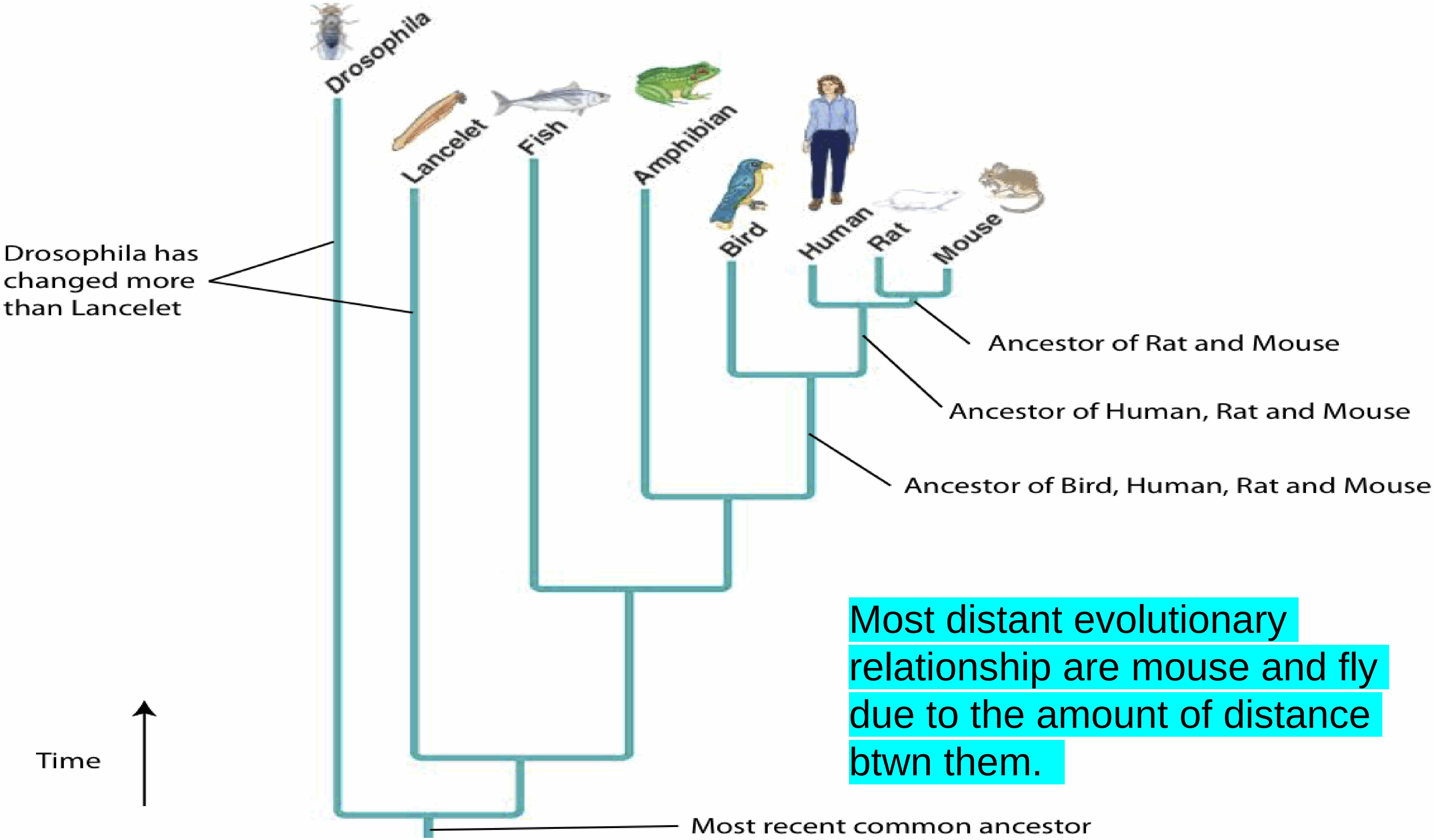
R = richness

Evolution is the mechanism underlying biodiversity

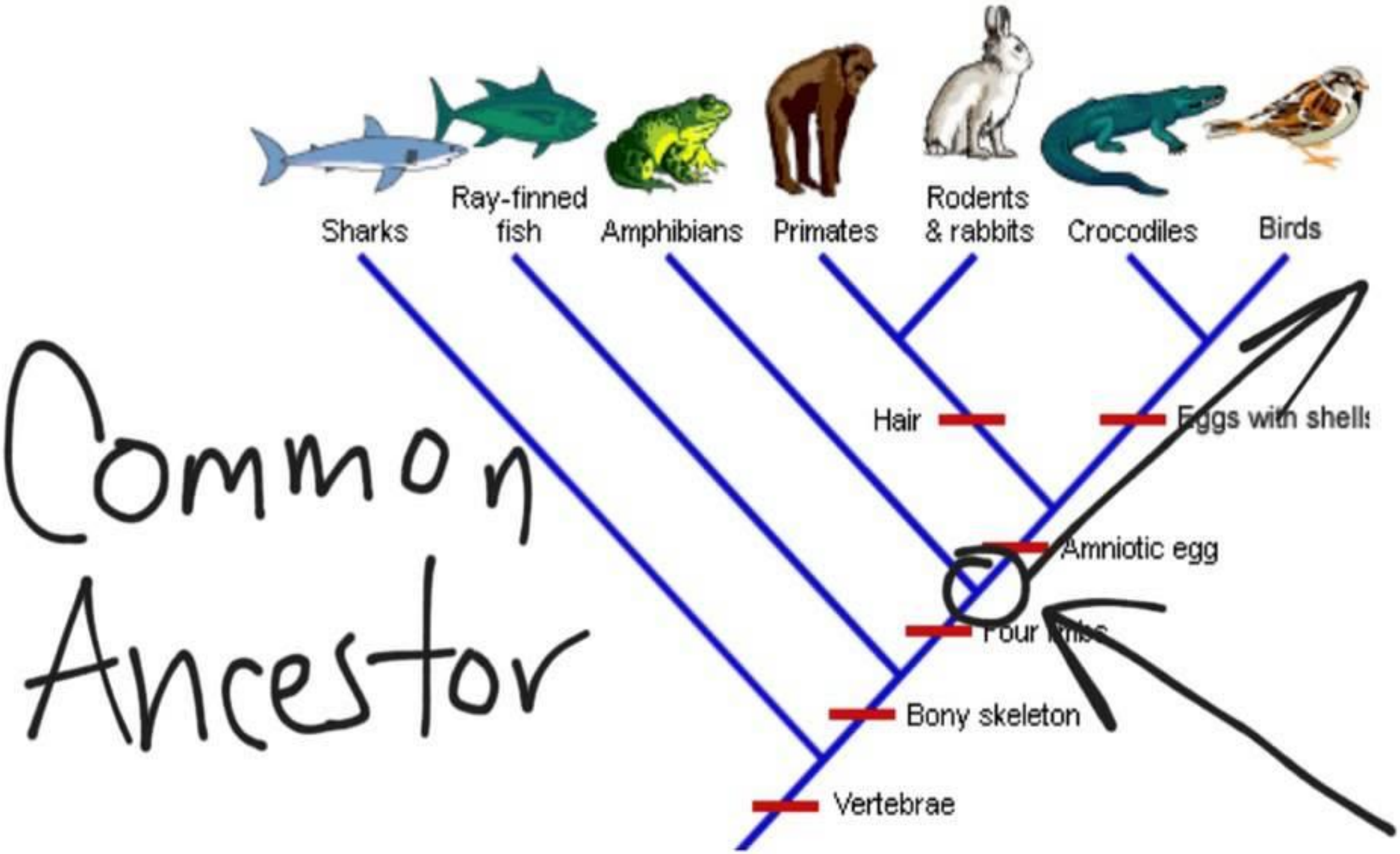
- **Evolution-** a change in the genetic composition of a population over time.
- **Microevolution**- evolution below the species level.
  - Ex. Different varieties of apples or potatoes
- **Macroevolution**- Evolution which gives rise to new species or new genera, family, class or phyla.
  - **Speciation** - evolution of new species

Phylogenies – branching patterns of evolutionary relationships **(phylogenetic tree)**

Scientists base phylogenies on morphology (structure), behavior, and genetic similarity



Most distant evolutionary relationship are mouse and fly due to the amount of distance btwn them.



Sharks
Ray-finned fish
Amphibians
Primates
Rodents & rabbits
Crocodiles
Birds
Hair
Eggs with shell
Amniotic egg
Four
Bony skeleton
Vertebrae
Common Ancestor

Creating Genetic Diversity

- **Genes**- physical locations on chromosomes within each cell of an organism.
- **Genotype**- the complete set of genes in an individual (blueprint)
- **Phenotype**- the actual set of traits expressed in an individual.

Two processes that create genetic diversity…

1. Mutation- a random change in the genetic code (if not lethal, can add the genetic variation to population).

-Random or environmental (lifestyle) factors

-*Good vs. Bad*… in the wild, individuals have a poor chance in survival (ex. stand out more due to predators)

2. Recombination – chromosomes are duplicated during meiosis and piece of the chromosomes breaks off and attaches to another chromosome producing new combinations of the genes (no new genes) produce new traits.

-allow new gene combinations to come together, providing new immune defenses or resistances.

Evolution occurs by artificial and natural selection and random processes

- **Evolution by artificial selection-** when humans determine which individuals breed (we choose our mates – selective breeding, most controlled by humans).
  - Use of chemical agents such as herbicide…as we cover large areas of land with this chemical to kill the weeds, the chances of one weed possessing a mutation resisting that application…weed resistant….trait passed on. (same idea with use of antibiotics & antibacterial cleaners caused artificial selection of harmful drug-resistant bacteria)

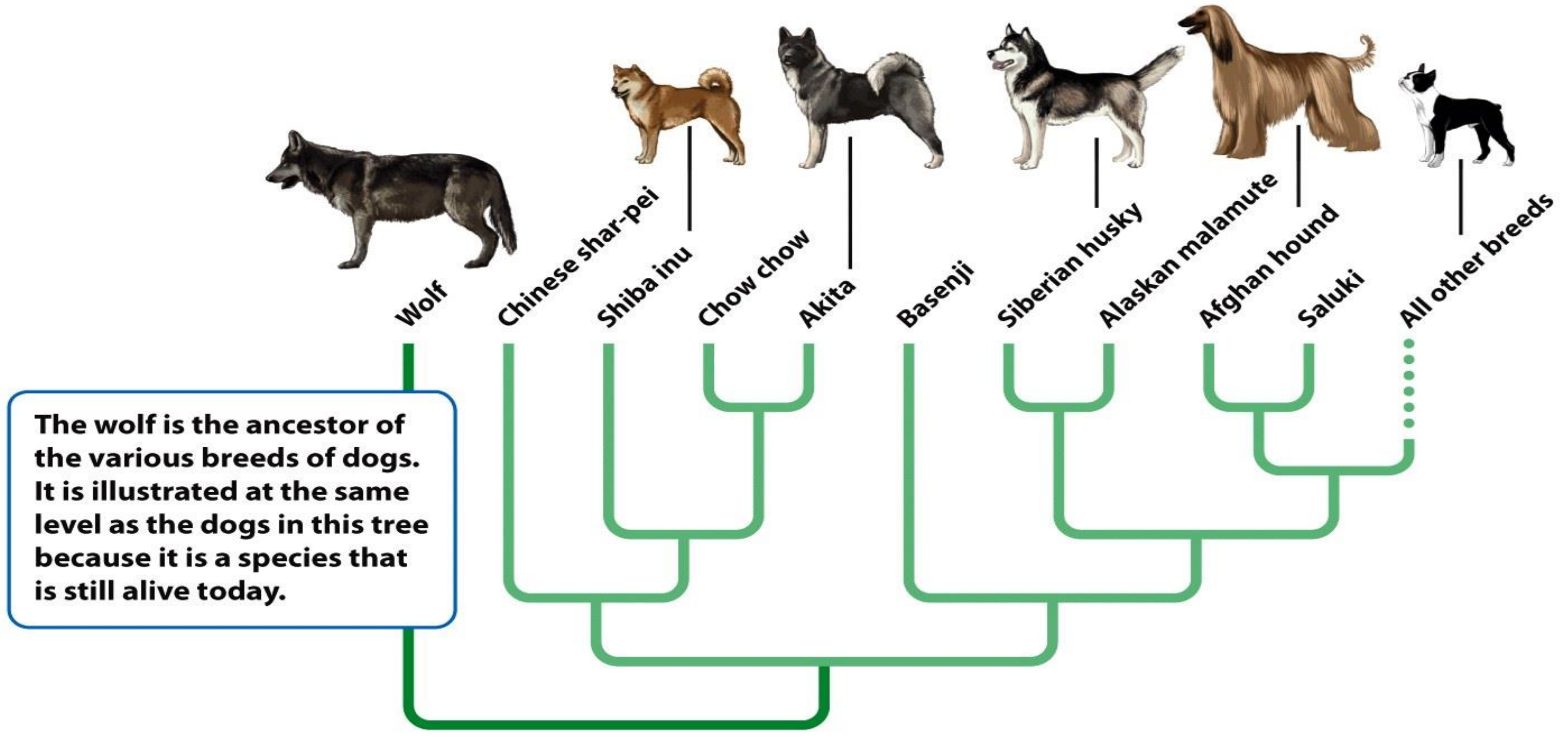


Figure 5.8
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Artificial Selection of Dog Breeding

- **Evolution by natural selection-** the environment determines which individuals are most likely to survive and reproduce.
- Traits or certain combination of traits an individual possess will determine the survival in the environment (*survival of the fittest* – be able to pass on your genetic code….offspring)
- **Fitness** – ability to survive and reproduce
- **Adaptions** – traits that improve an individual's fitness.

Darwin's theory of evolution by natural selection

- Individuals produce an excess of offspring.
- Not all offspring can survive.
- Individuals differ in their traits.
- Differences in traits can be passed on from parents to offspring.
- Differences in traits are associated with differences in the ability to survive and reproduce.

Only those offspring having the fittest genotype will pass on their genes to the next generation.

ex. Prey vs. Predator

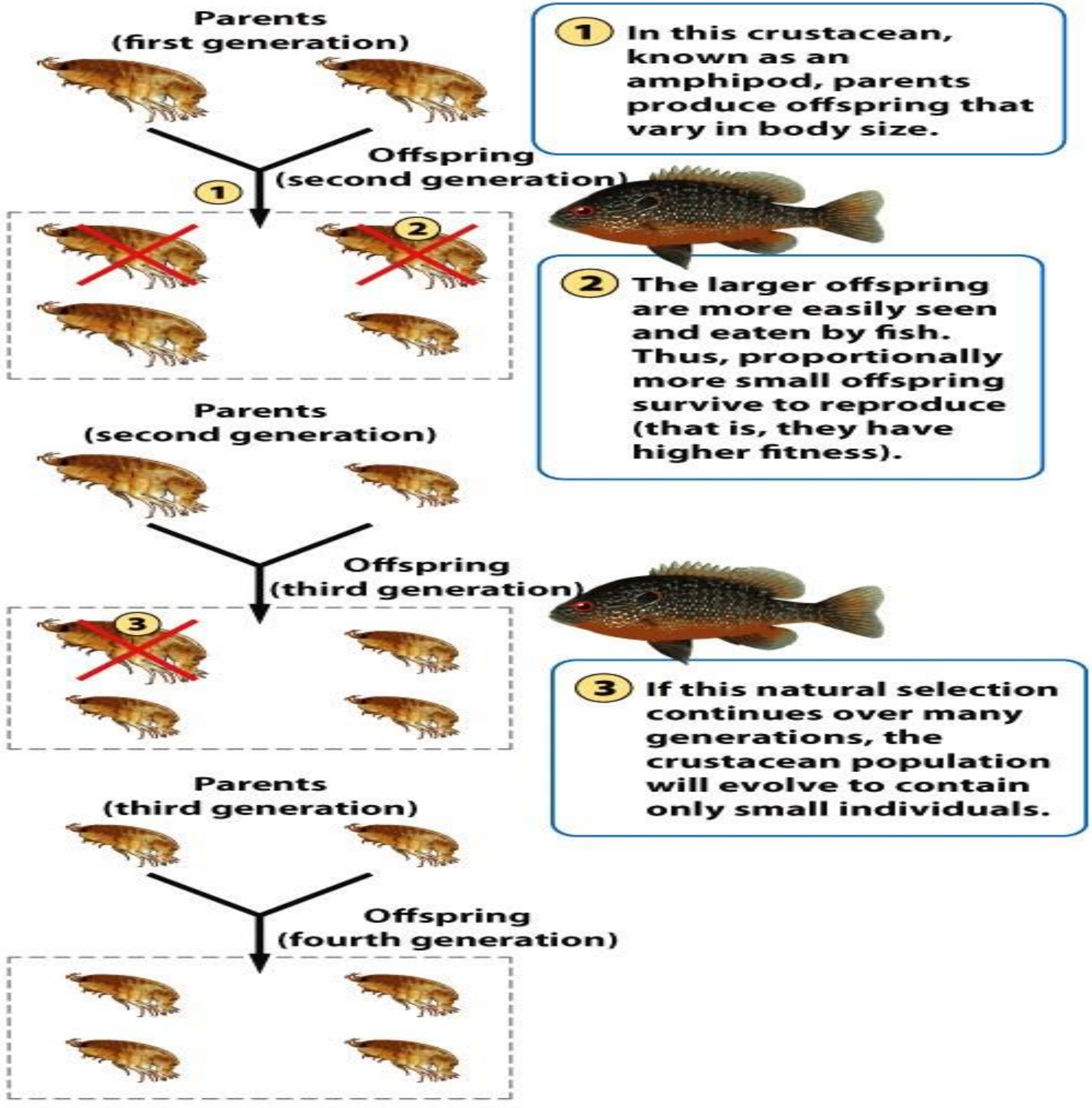

Figure 5.10
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Evolution by Random Processes

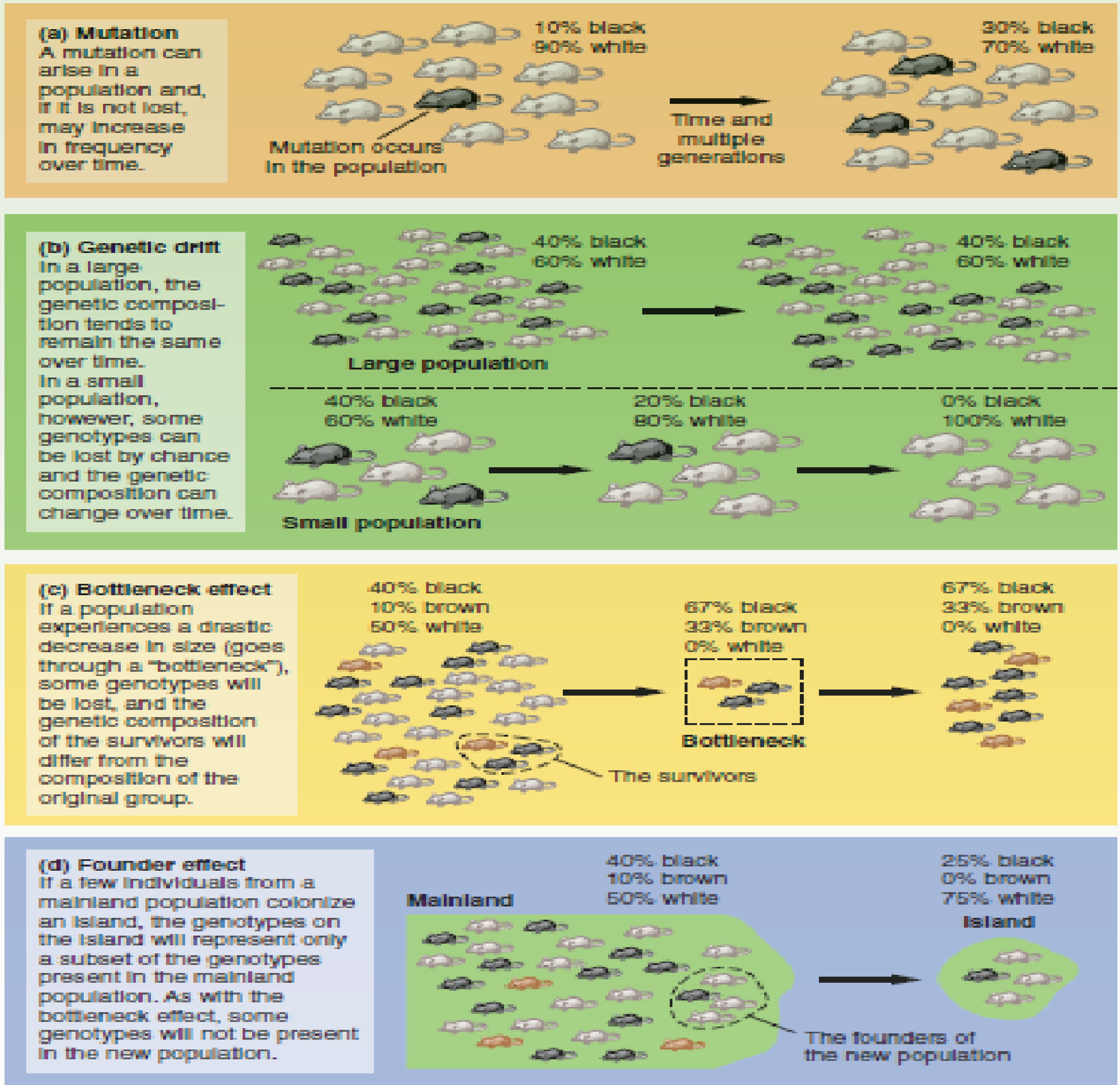
- **Mutations**

- **Genetic drift-** change in the genetic composition of a population over time as a result of random mating.
  Ex. A population of rabbits can have brown fur and white fur with brown fur being the dominant allele. By **random chance**, the offspring may all be brown and this could reduce or eliminate the allele for white fur.

- **Bottleneck effect-** a reduction in the genetic diversity of a population caused by a reduction in its size.
  - *Habitat loss, natural disaster, hunting, or changes in the environment* ...resulting low genetic diversity cause it to decline to extinction.

- **Founder effect-** a change in a population descended from a small number of colonizing individuals (new location to colonize).

Theory of Island Biogeography states that a larger island will have a greater number of species than a smaller island.



Speciation and extinction determine biodiversity

- **Allopatric speciation-** when new species are created by geographic or reproductive isolation.
- If ever reunited…what would happen to species of generations to come???? (no interbreeding…diff. species)

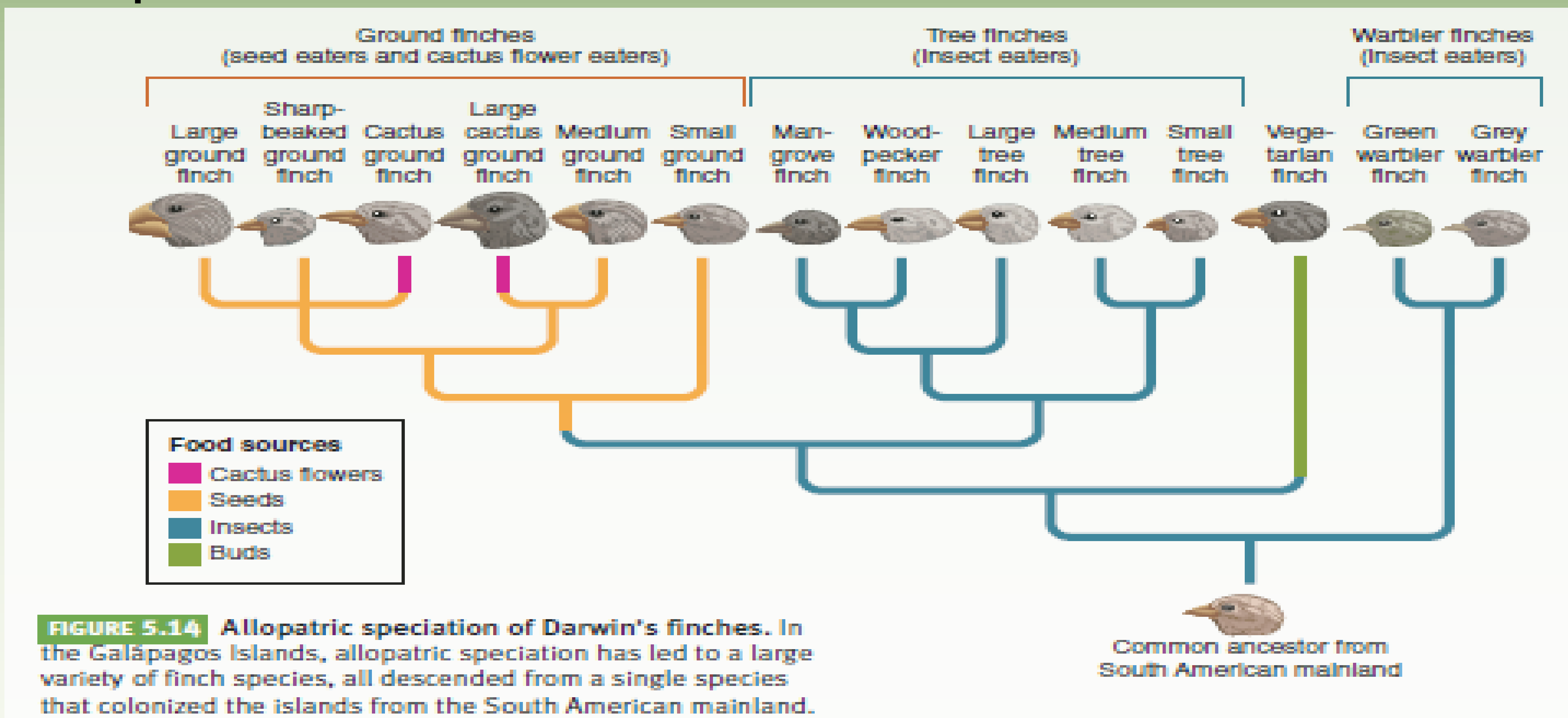


FIGURE 5.14 **Allopatric speciation of Darwin's finches.** In the Galápagos Islands, allopatric speciation has led to a large variety of finch species, all descended from a single species that colonized the islands from the South American mainland.

- **Sympatric speciation-** the evolution of one species into two species in the **absence** of geographic isolation, usually through the *process of polyploidy*, an *increase in the number of sets of chromosomes*.

Ancestor- 2 set of chromosomes | 4 sets chromosomes | 6 sets chromosomes

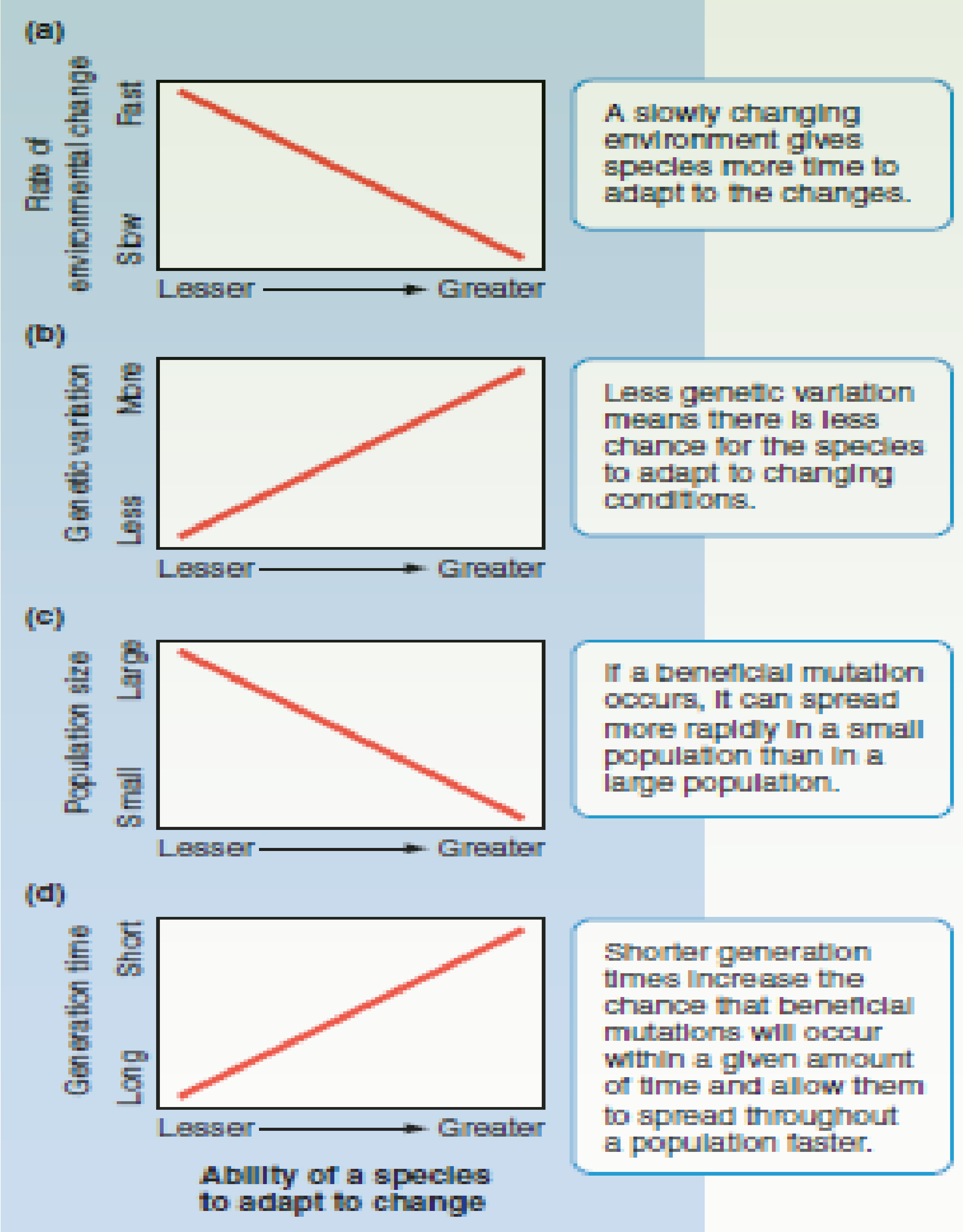
The pace of evolution

a. The rate of the environmental change is slow (more time to adapt = acclimate).

b. The population has high genetic variation (wide variety of phenotypes) allows more rapid evolution by natural selection (less genetic variation means less chance for species to adapt to changing conditions).

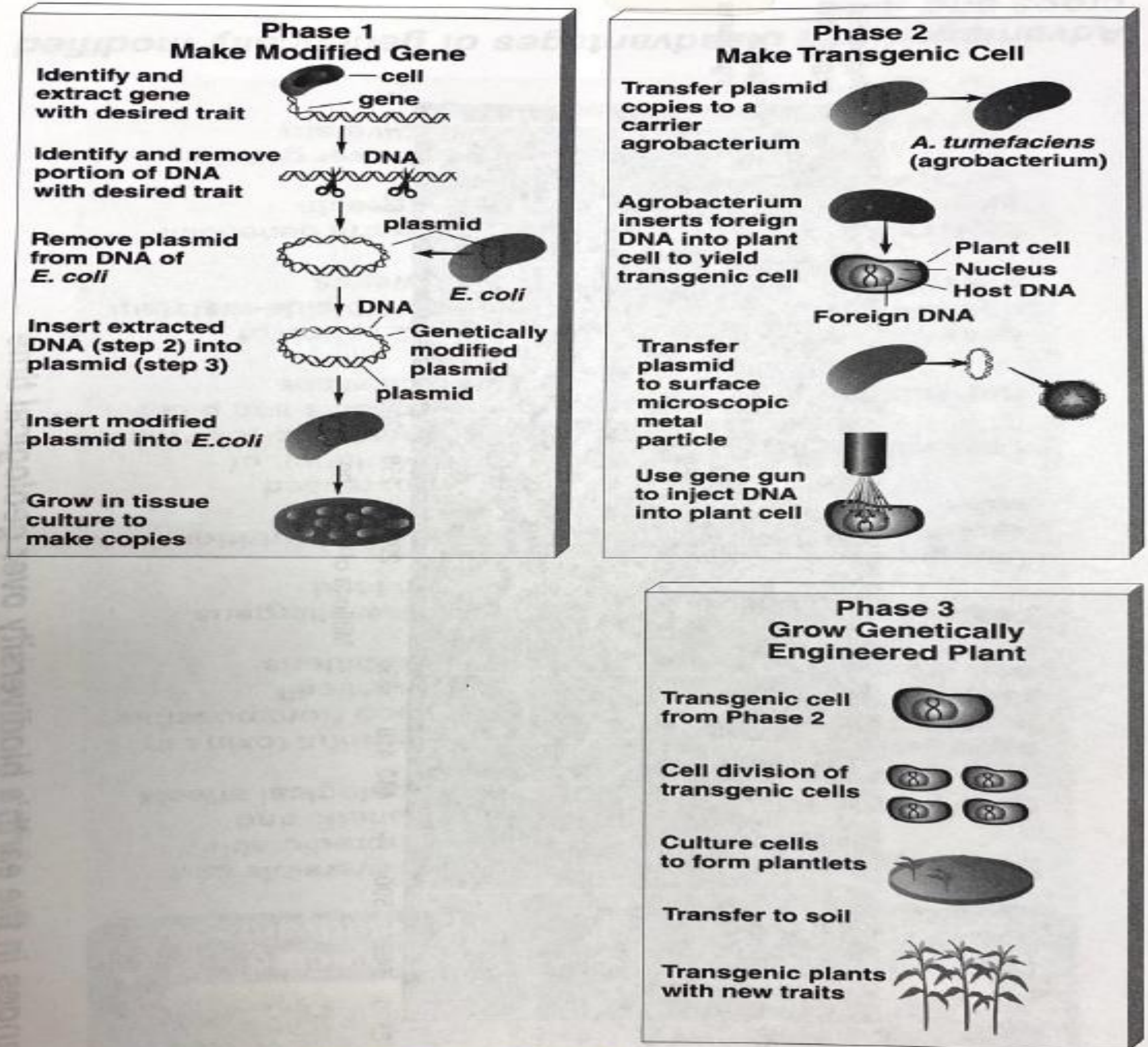
c. The population is relatively small (if a mutation is beneficial, it will be a selective trait, mating w/mutation, spread in the small population faster) =genetic drift.

d. The generation time is short.(shorter generation time increases the chance that mutation spread throughout the population in a shorter time) = more mutations to take place w/a shorter generation time.



- **Genetic engineering** – scientist can uses techniques to copy genes from a species with some desirable traits, such as rapid growth or disease resistance.

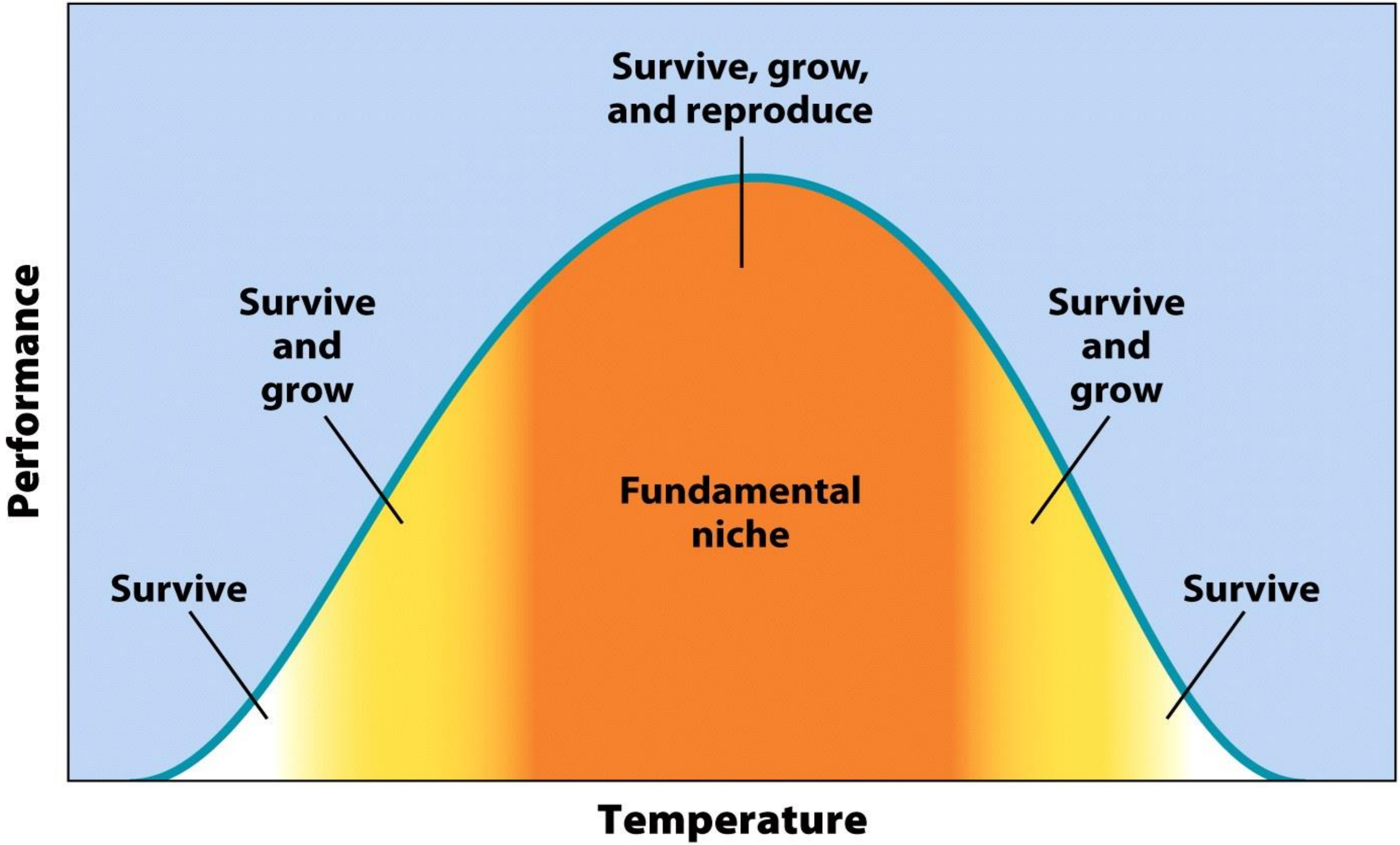
- **Genetically Modified Organisms (GMO's)**– species of plants, animals, or microbes that have had desirable traits inserted into their genotype.
  - Leads to most rapid rate of evolution
  - These inserts become part of the species' "blueprint" which is capable of passing to their offspring's.



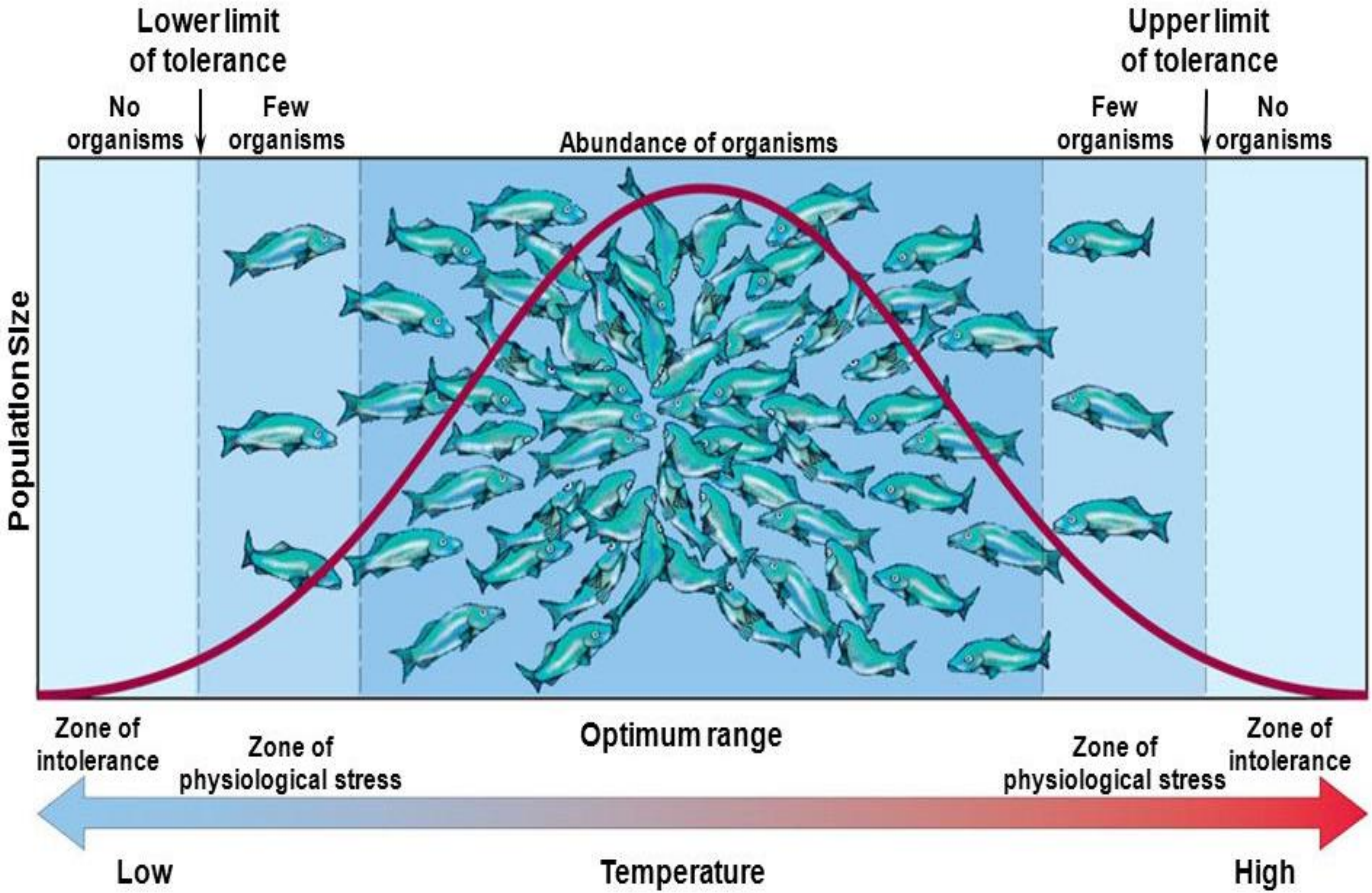
Steps in genetically modifying a plant

Evolution shapes ecological niches and determines species distributions

- **Range of tolerance-** all species have an optimal environment in which it performs well. The limit to the abiotic conditions they can tolerate is known as the range of tolerance.
  - **Potential abiotic limitations**: Extreme temps, humidity, salinity, and pH.
  - **Potential biotic limitations:** presence of competitors, predators, diseases.
- **Fundamental niche-** the ideal conditions for a species.



All species have an ideal/optimal range of biotic and abiotic conditions = **Niche** *(specialized job role or function in an ecosystem*)



Lower limit of tolerance
Upper limit of tolerance
No organisms
Few organisms
Abundance of organisms
Few organisms
No organisms
Population Size
Zone of intolerance
Zone of physiological stress
Optimum range
Zone of physiological stress
Zone of intolerance
Low
Temperature
High

Niches

- **Realized niche-** the range of abiotic and biotic conditions under which a species lives. This determines the species distribution, or areas of the world where it lives.
- **Niche generalist-** species that live under a wide range of conditions.
- **Niche specialist-** species that live only in specific habitats.

Figure 5.19a
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Meadow Spittlebug – niche generalist that have a board diet and wide habitat preference.

Leaf Beetle– niche specialists that have a narrow diet and highly specific habitat preference.

Figure 5.19b
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The Fossil Record

- **Fossils**- remains of organisms that have been preserved in rock. Much of what we know about evolution comes from the fossil record.

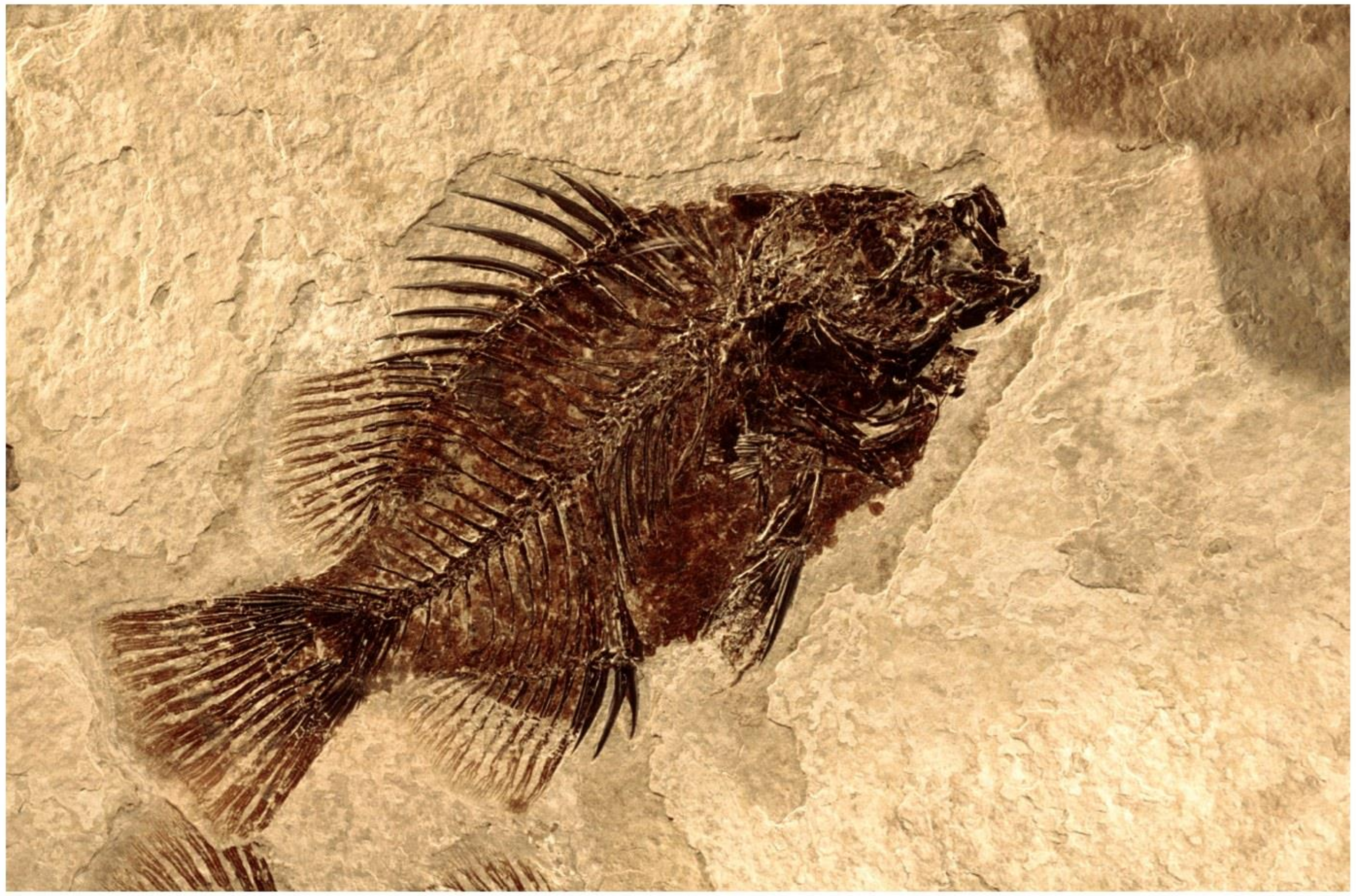

Figure 5.22
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The Five Global Mass Extinctions

Mass extinction- when large numbers of species went extinct over a relatively short period of time.

Ex. Cretaceous period (65 million years ago), roughly half of the Earth's species, including dinosaurs, went extinct.

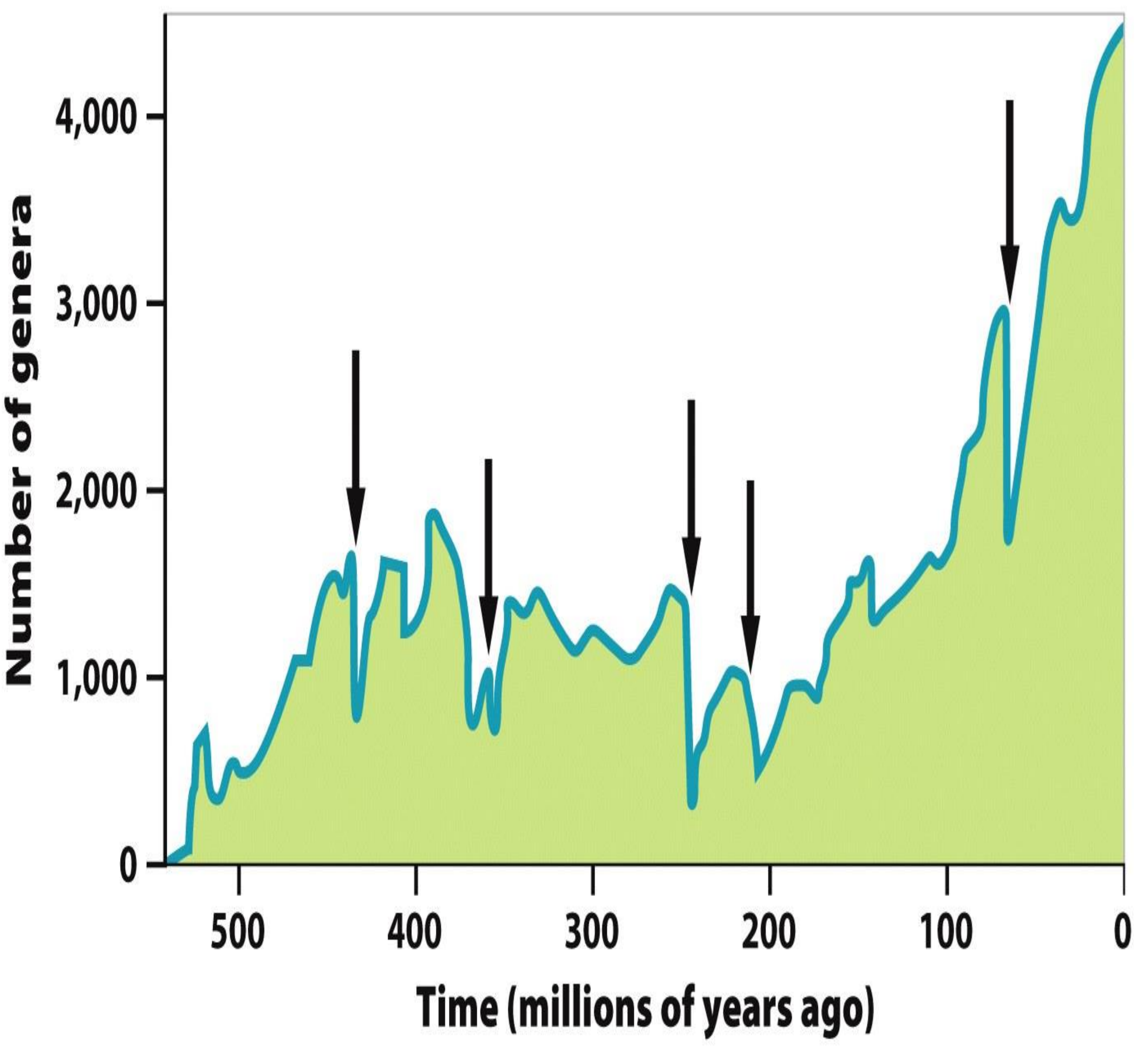

Figure 5.23
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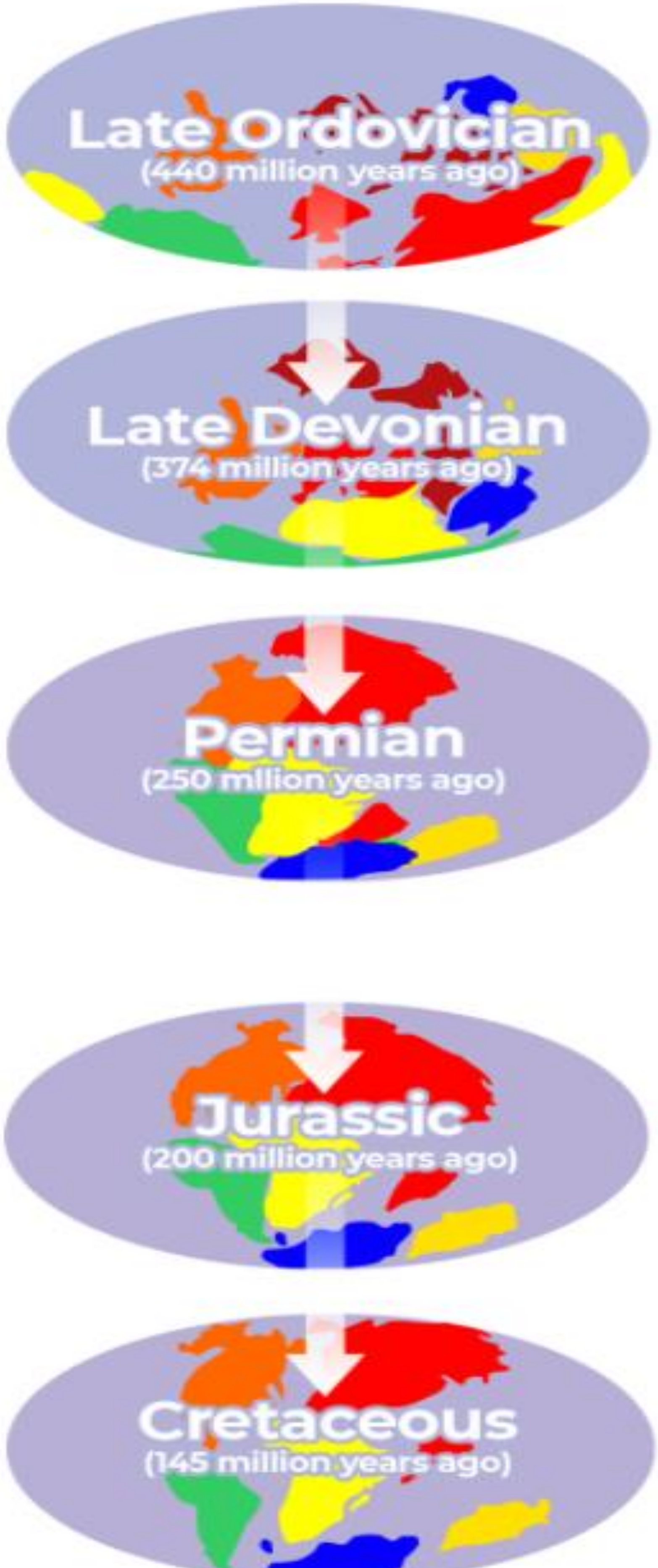
The "Big Five" mass extinctions



First mass extinction

85% of all species, including marine inverterbates like:
- graptolites
- brachiopods
- conodonts.

Second mass extinction

75% of all species including:
- brachiopods
- bivalves
- sarcopterygians.

Third mass extinction (the largest)

95% of all species, including marine animals like:
- *Dimetrodon*
- *Estemmenosuchus*
- *Orthacanthus*
- trilobites
- *Moschops*.

Fourth mass extinction

80% of all species, including:
- icthyosaurs
- paddle-finned plesiosaurs
- phytoplankton
- many species of frogs, salamanders, turtles, snakes, spiders and grasshoppers.

Fifth mass extinction

76% of all species including:
- non-avian dinosaurs
- bivalves (*Exogyra* and *Gryphaea*)
- inoceramids
- flying reptiles (pterosaurs).

The Sixth Mass Extinction

- **Paleontologists characterize mass extinctions as times when the Earth loses more than three-quarters of its species in a geologically short interval**; Our results confirm that *current extinction rates are higher* than would be *expected from the fossil record*, highlighting the need for effective conservation measures

- About 2 dozen species were declared extinct (or nearly so) in 2019, although the total number of species lost this year probably in the thousands *(said goodbye to three bird species, a shark, two frogs, several plants, and a whole lot more)*

- Estimated an extinction rate that was later calculated at up to 8,700 species a year, or 24 a day

- Recovery of biodiversity from last mass extinction took about 10 million years.

- It would likely take several millions of years of normal evolutionary diversification to "restore" the Earth's species to what they were prior to human beings rapidly changing the planet.

- Scientists claim 99% of species that have lived on the planet is now thought to be extinct.

As per the 2018 report of World Wildlife Foundation (WWF), there's a 60% decline in the population of mammals, birds, fish, reptiles, amphibians in just 40 years. As per the IUCN Red List, more than 30,000 species are threatened with extinction, which means 27% of the nearly 1,12,000 species accessed so far are under grave danger.
Segregating it further the threat table looks like:

41%	Amphibians
25%	Mammals
34%	Conifers
14%	Birds
30%	Sharks and rays
33%	Reef corals
27%	Selected crustaceans

- In contrast to previous mass extinctions, scientists agree that this one is caused by humans (mix of direct & indirect activities).
- Wide-ranging causes include habitat destruction/loss, overharvesting, loss of genetic variation, intro to invasive species, climate change, chemical pollution and emerging disease.

Today the loss of species is estimated to be between 1,000 and 10,000 times than that of the natural extinction rate.

Considering the fact that there are around **two million species on the planet**, it means between 200 and 2,000 extinctions occur every year.