Evolution

THE EVER-CHANGING LIVING WORLD

Evolution Overview

History of Evolutionary Theory

Evidence for Evolutionary Theory

Microevolutionary Principles

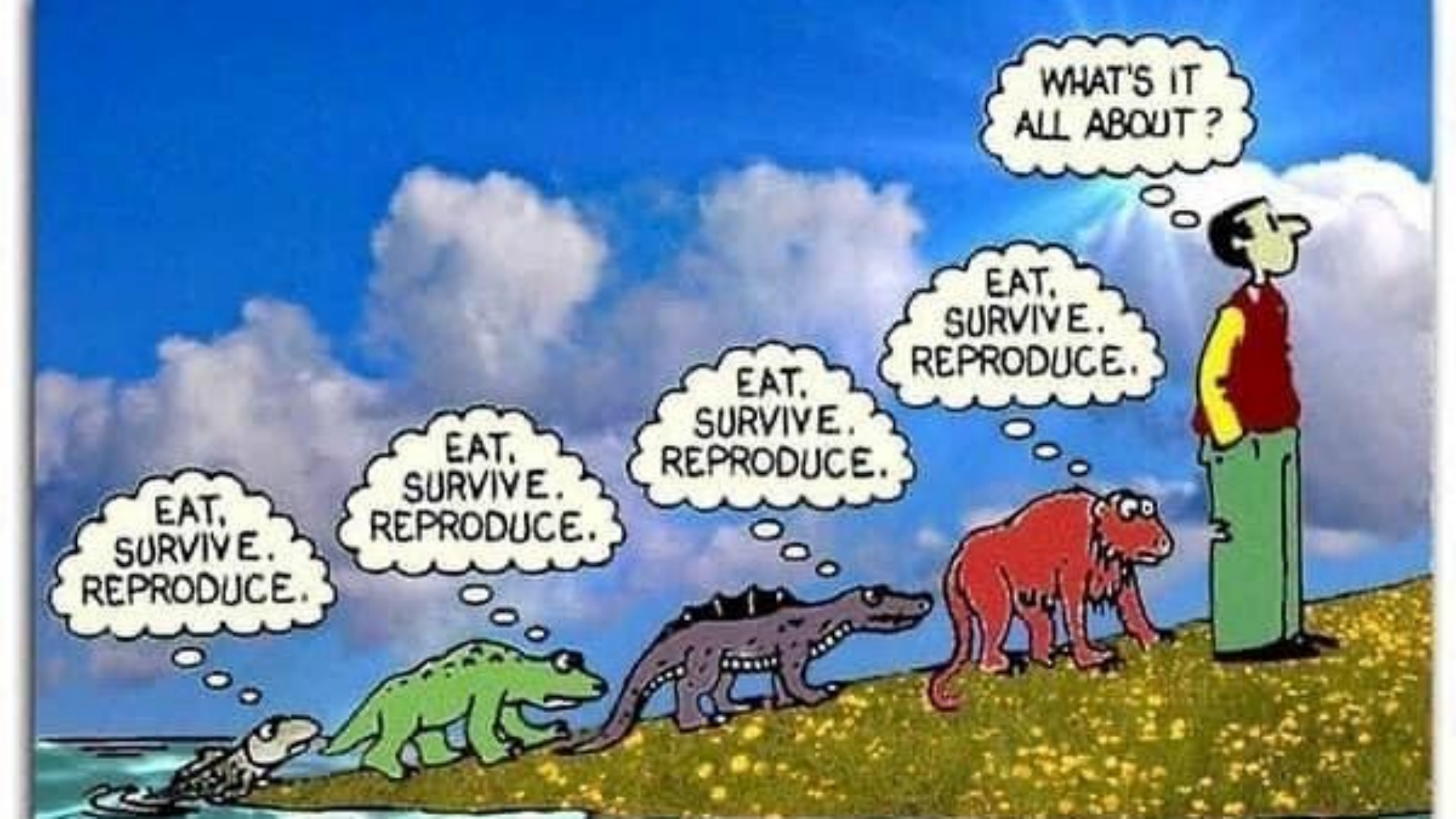
- Mutation, Genetic Drift, Migration, Natural Selection

Macroevolution

- Speciation, Extinction
- Adaptive Radiation, Coevolution, Convergent Evolution

Biological Classification / Taxonomy

Phylogenetic Trees


EAT, SURVIVE. REPRODUCE.
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WHAT'S IT ALL ABOUT?

Darwin's Theory of Evolution

- ***Fitness:*** the physical traits and behaviours that enable organisms to survive and reproduce in their environments
- Modern organisms were produced by ***evolution:*** gradual change in species over time
- ***Common descent:*** all species have descended from common ancestors
- ***Adaptation:*** inherited characteristic that increases fitness; AND the evolutionary process by which adaptations arise

Darwin's Theory of Evolution

Populations evolve through ***natural selection:***

1. Natural, heritable variation exists in the population
2. Organisms with adaptive traits, on average, survive and reproduce more ***(survival and reproduction of the fittest)***
3. Over generations, adaptations become more common in the population

Microevolution

14-2: EVOLUTION BY NATURAL SELECTION* (ONLY ROUGHLY BASED ON CHAPTER)

14-3: GENETICS AND EVOLUTIONARY THEORY* (ONLY ROUGHLY BASED ON CHAPTER)

14-5: EVOLUTIONARY THEORY EVOLVES* (HAS PORTION ON GENETIC DRIFT)

MUTATION

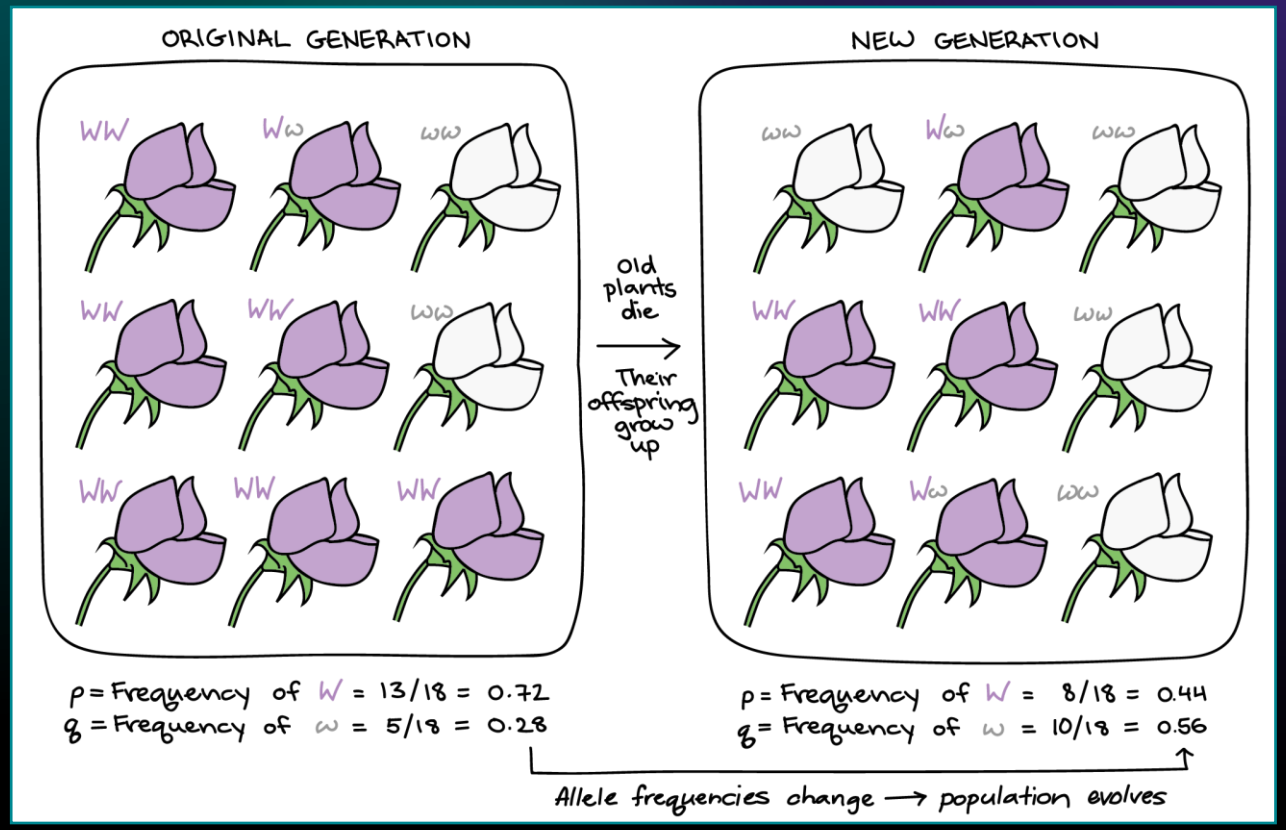
GENETIC DRIFT

MIGRATION

NATURAL SELECTION

What is Microevolution?

- **Microevolution**: a change in the frequency of alleles in a population over generations
- Main causes of allele frequency change:
  - **Natural selection**
  - **Mutation**
  - **Genetic drift**
  - **Migration**



Natural Selection

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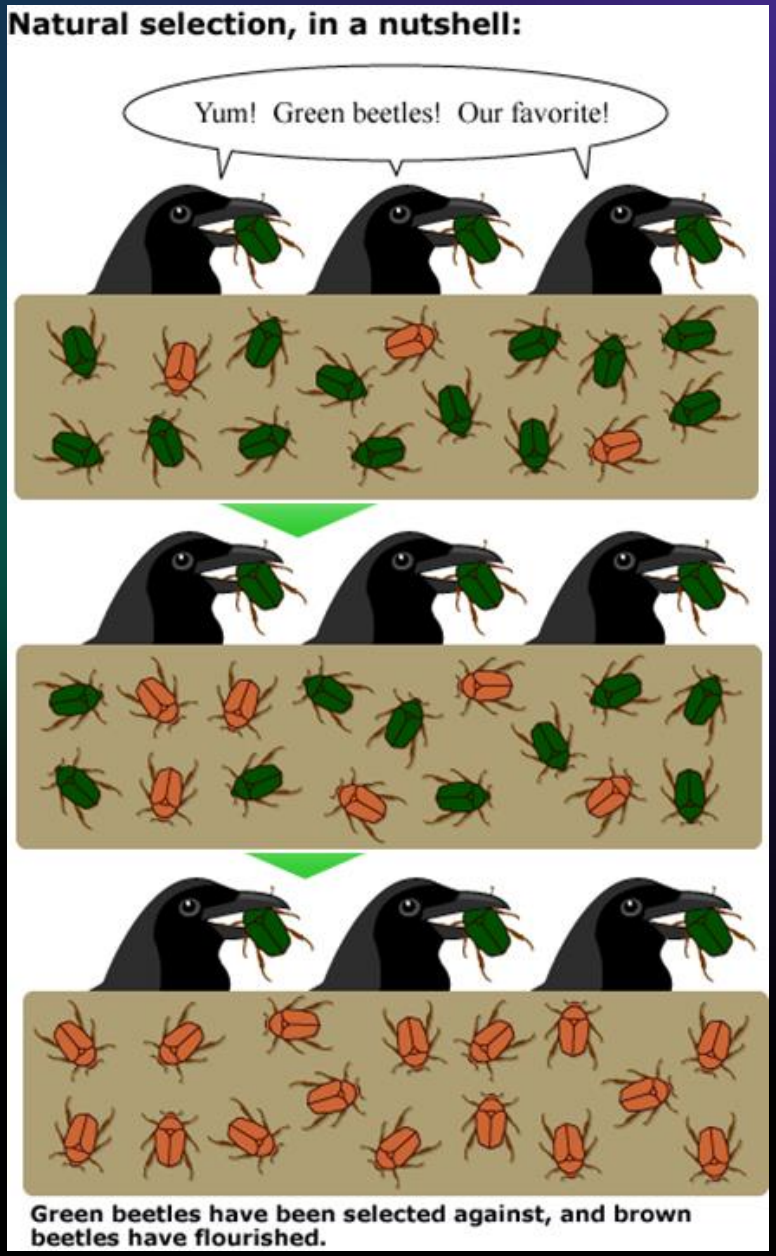
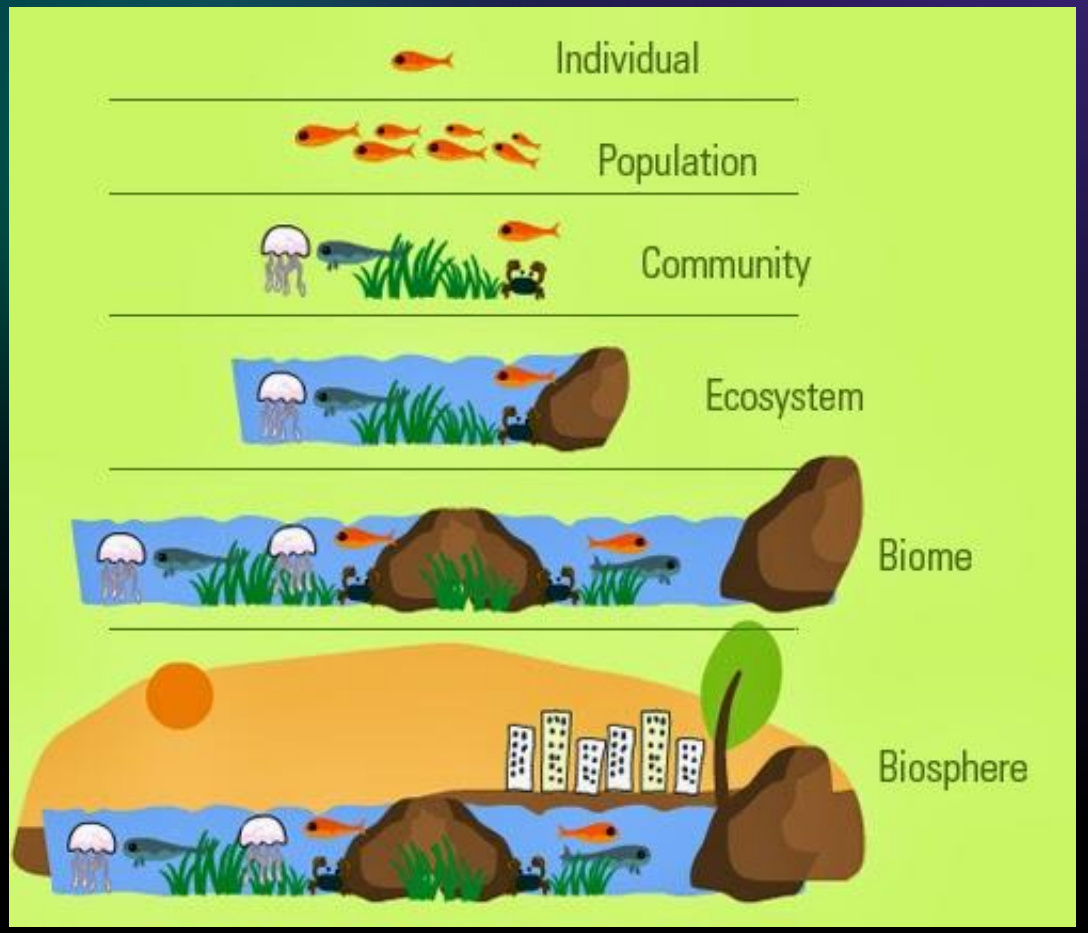
2. Organisms with adaptive traits, on average, survive and reproduce more ***(survival and reproduction of the fittest)***
3. Over generations, adaptive traits become more common in the population



Variation in Populations

- In populations, individuals differ from each other
  - (**Population**: group of individuals of the same species)
- If a trait is genetically determined, variation for that trait is heritable and evolution can act on it



Variation in Populations

Variation: differences in traits between individuals in a population or species. Two types:

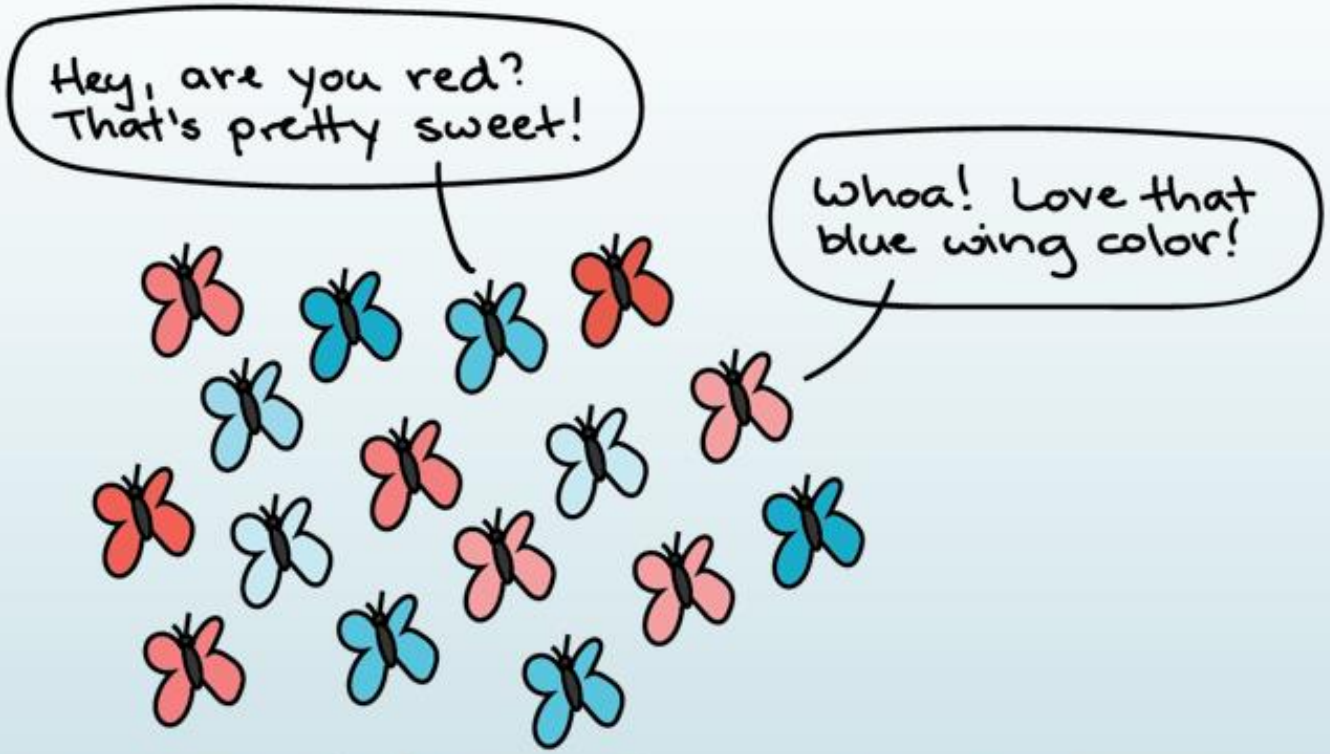
Heritable variation has a genetic basis and can be passed on to offspring
(e.g. fur colour, eye colour, height, reflexes)

Acquired variation is not genetic and cannot be passed on to offspring
(e.g. haircut, cancer, surgery, scars, knowledge, language, learned behaviours)

Evolution involves heritable variation only.

Variation in Populations

There is natural variation of heritable traits in the population.



https://www.khanacademy.org/science/ap-biology/natural-selection/natural-selection-ap/a/darwin-evolution-natural-selection

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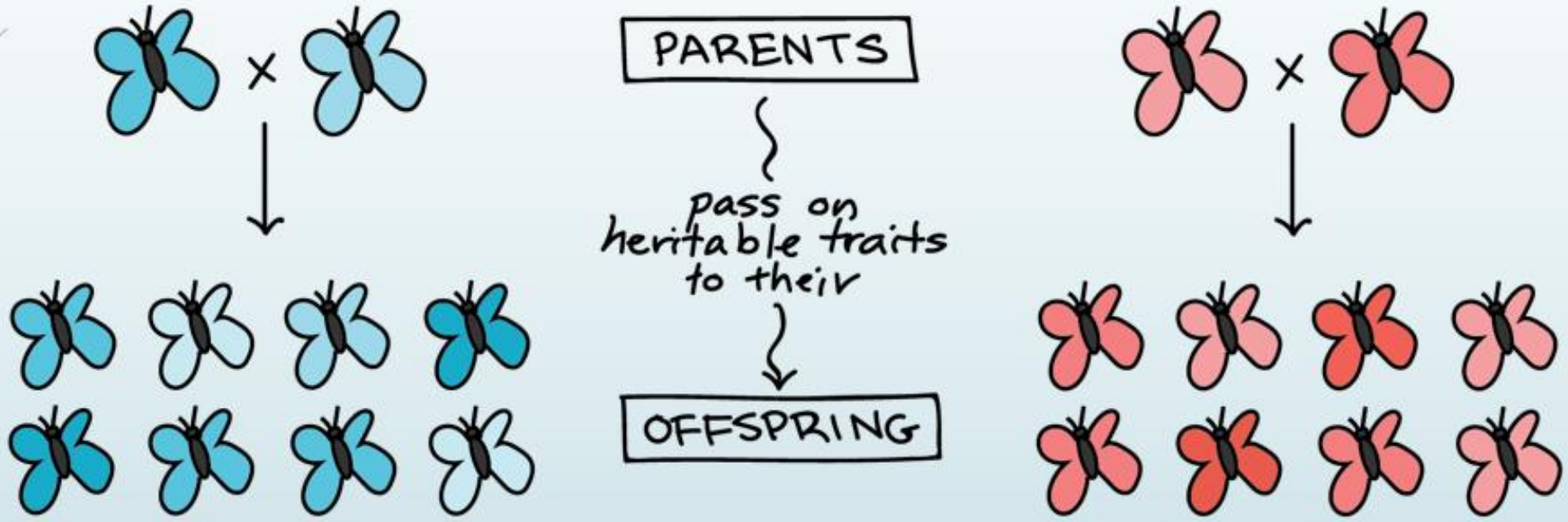


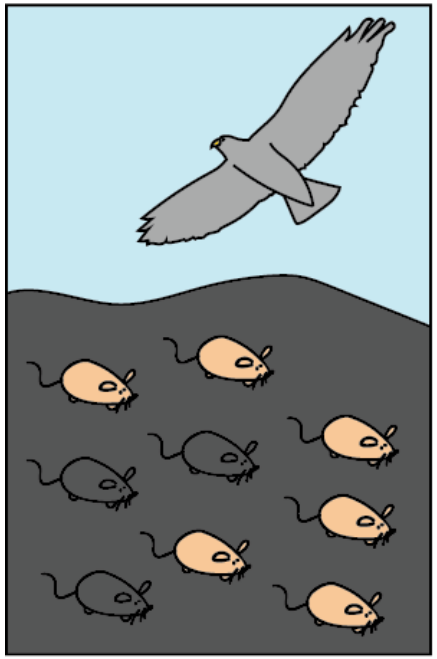
https://www.khanacademy.org/science/ap-biology/natural-selection/natural-selection-ap/a/darwin-evolution-natural-selection

Variation in Populations

Variation = differences between individuals

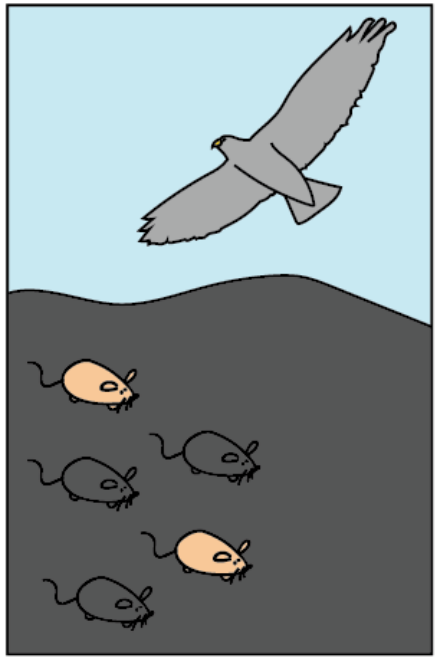
These differences can be good or bad; it ***depends on the "selection" process.***

Natural Selection: Example 1



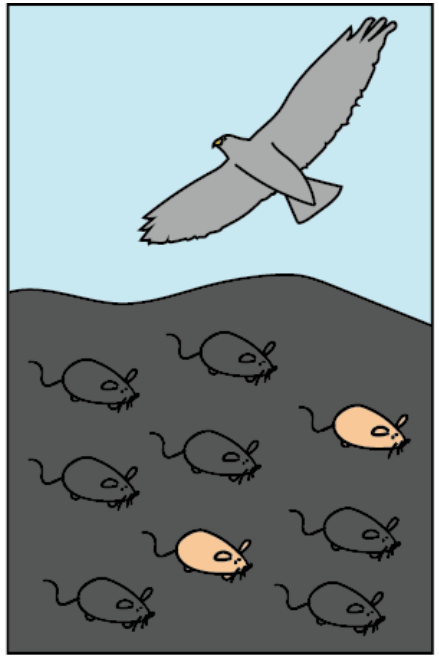
A population of mice has moved into a new area where the rocks are very dark. Due to natural genetic variation, some mice are black, while others are tan.

Some mice are eaten by birds



Tan mice are more visible to predatory birds than black mice. Thus, tan mice are eaten at higher frequency than black mice. Only the surviving mice reach reproductive age and leave offspring.

Mice reproduce, giving next generation

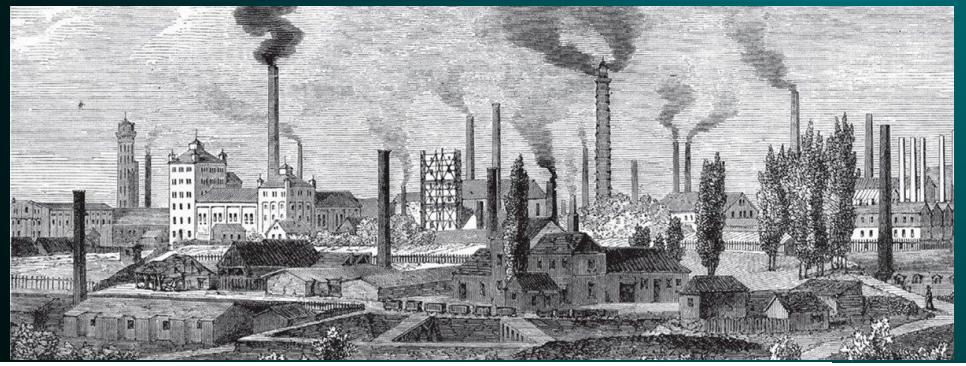


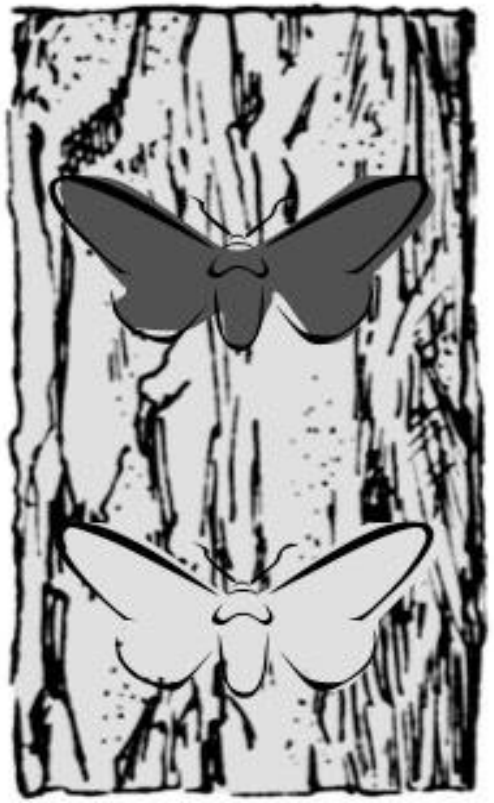
Because black mice had a higher chance of leaving offspring than tan mice, the next generation contains a higher fraction of black mice than the previous generation.

Natural Selection: Example 2

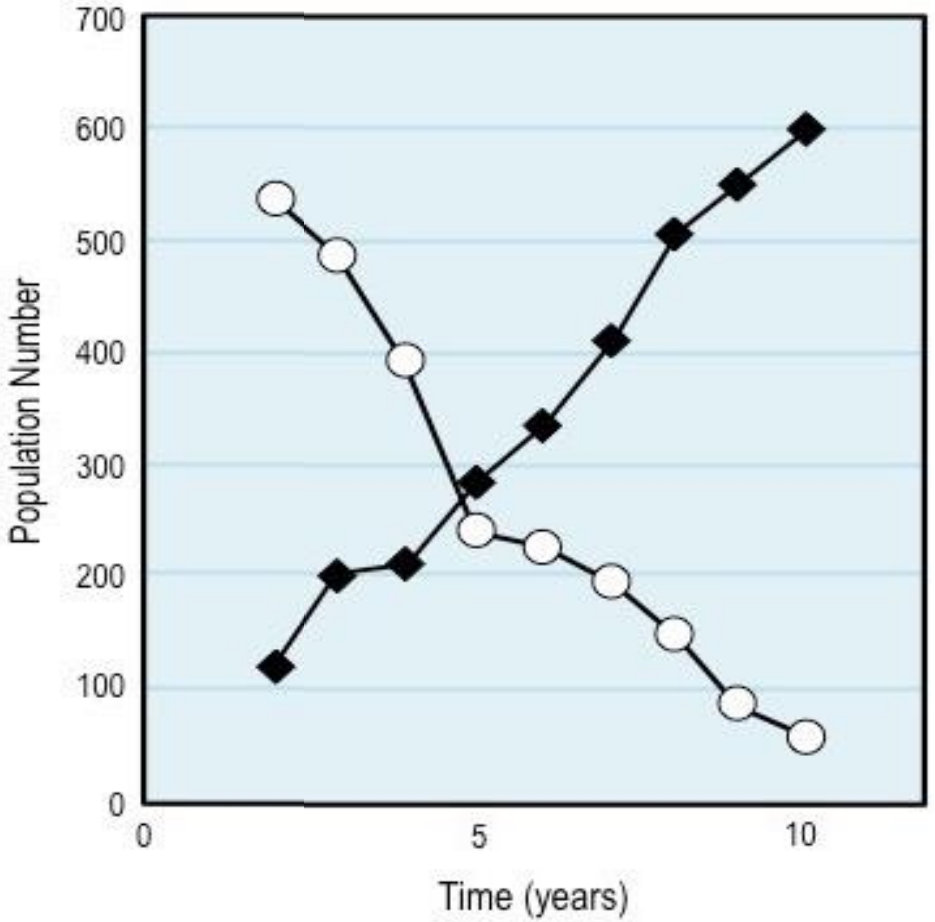
Variation:

Some moths are black. Most moths are white.





Pre-Industrial Revolution



Post-Industrial Revolution

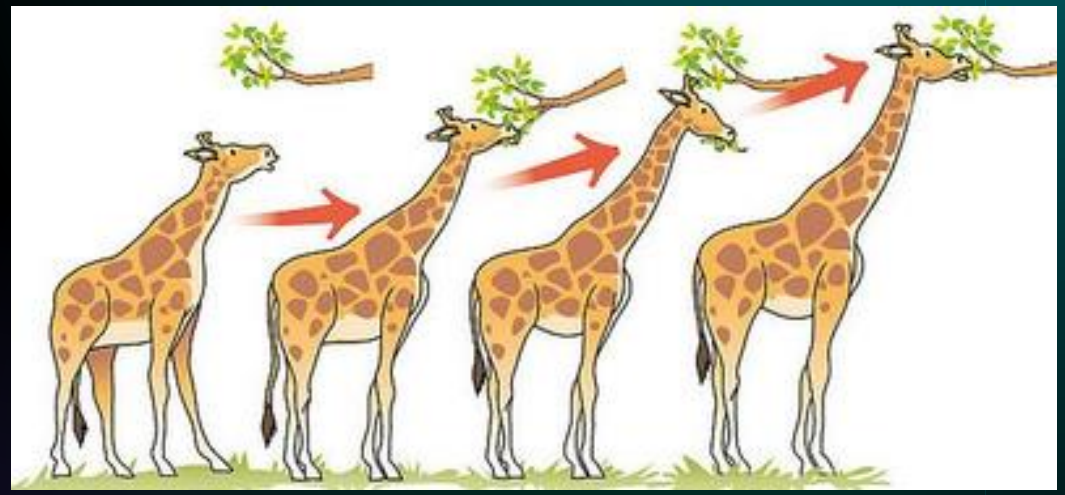
Natural Selection: Example 2

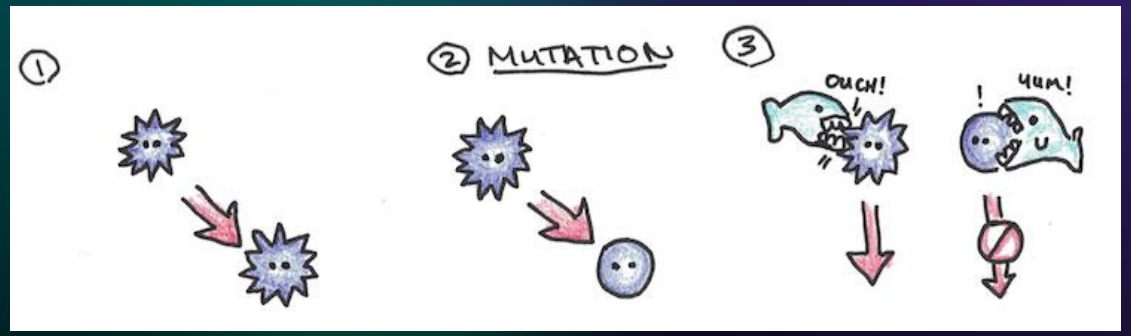
Survival and reproduction of the fittest: predation from birds favours moths able to blend in with tree trunks.

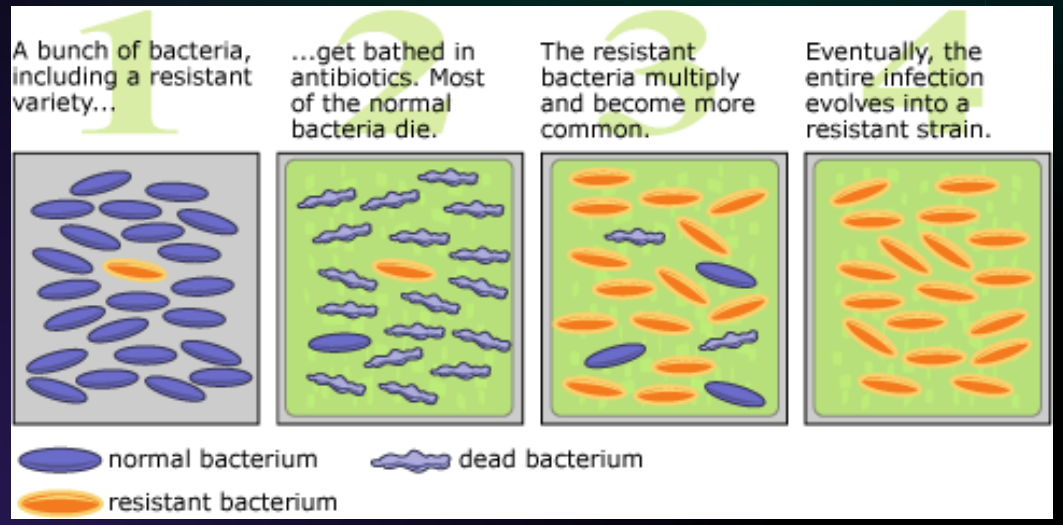
- Pre-Industrial Revolution, white moths were favoured. The proportion of white moths was higher.
- Post-Industrial Revolution, black moths were now better camouflaged, and more likely to survive and reproduce.

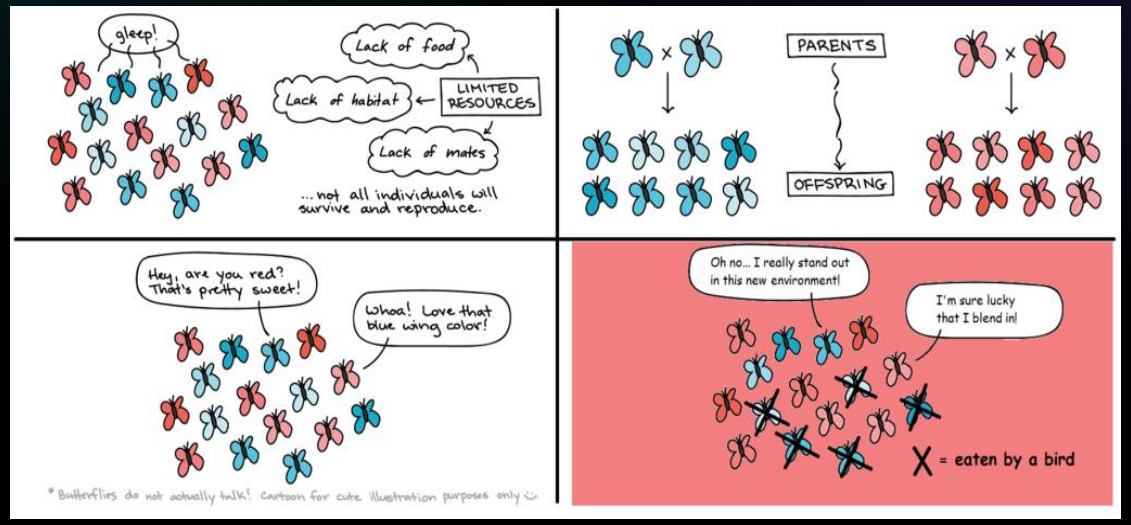
Adaptation/Evolution: Over time, the proportion of black moths in the population increased. Evolution had occurred.

Natural Selection Activity









Natural Selection Activity

You have been given a handout with images representing natural selection.

In a small group (2-3):

1. Discuss how each image shows evolution by natural selection occurring, according to the three steps of natural selection (variation, survival and reproduction of the fittest, evolution).
2. Assign each group member to one image. Individually, each person writes down a detailed, step-by-step description of how natural selection occurred in that population.
3. Share and critique descriptions within your groups.
4. Select one description from your group to revise and hand in. Write your names on it, as well as the title of the image.

*Note: none of the images are perfect. Some may show certain step(s) of natural selection better than others.

Mutation

- **Mutation:** random change in DNA sequence of an organism; can give rise to new traits
- If mutation occurs in reproductive cells (sperm, egg), it is heritable and thus can be involved in microevolution

Genetic Drift Activity Ver 1

1. Students will be assigned a number from 1-6. (Some will start 'dead'.) Record how many of each.
2. Roll a die.
   - If you roll a different number than your assigned number, you are now dead.
   - If you roll the same number you were assigned, you survive and reproduce: assign 5 'dead' people your number.
3. At the end of each round, record the distribution of numbers.

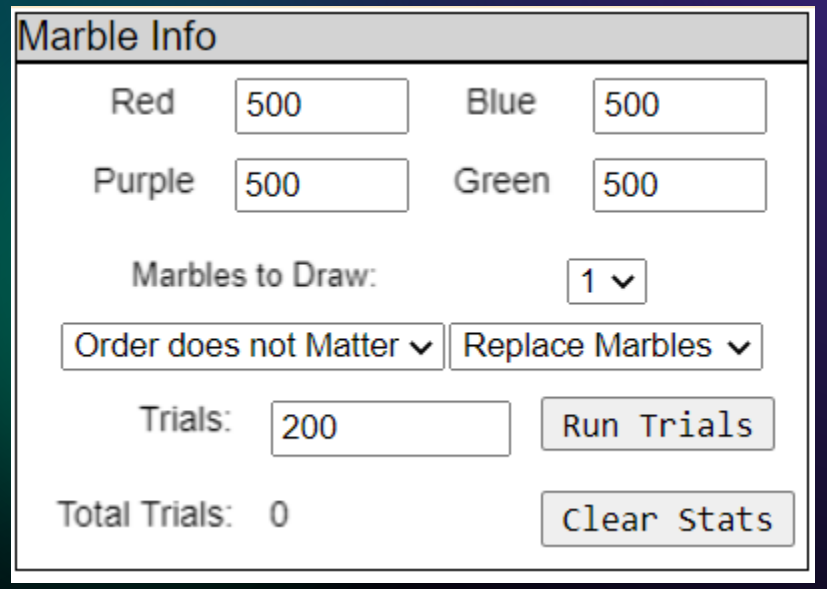
Genetic Drift Activity Ver 2

http://www.shodor.org/interactivate/activities/Marbles/

Large Population (200 reproductive individuals)				
Trial #	**red**	**blue**	**purple**	**green**
Start	500	500	500	500
1				
2				
3				
4				
5				

Small Population (20 reproductive individuals)				
Trial #	**red**	**blue**	**purple**	**green**
Start	500	500	500	500
1				
2				
3				
4				
5				

Genetic Drift Activity Ver 2

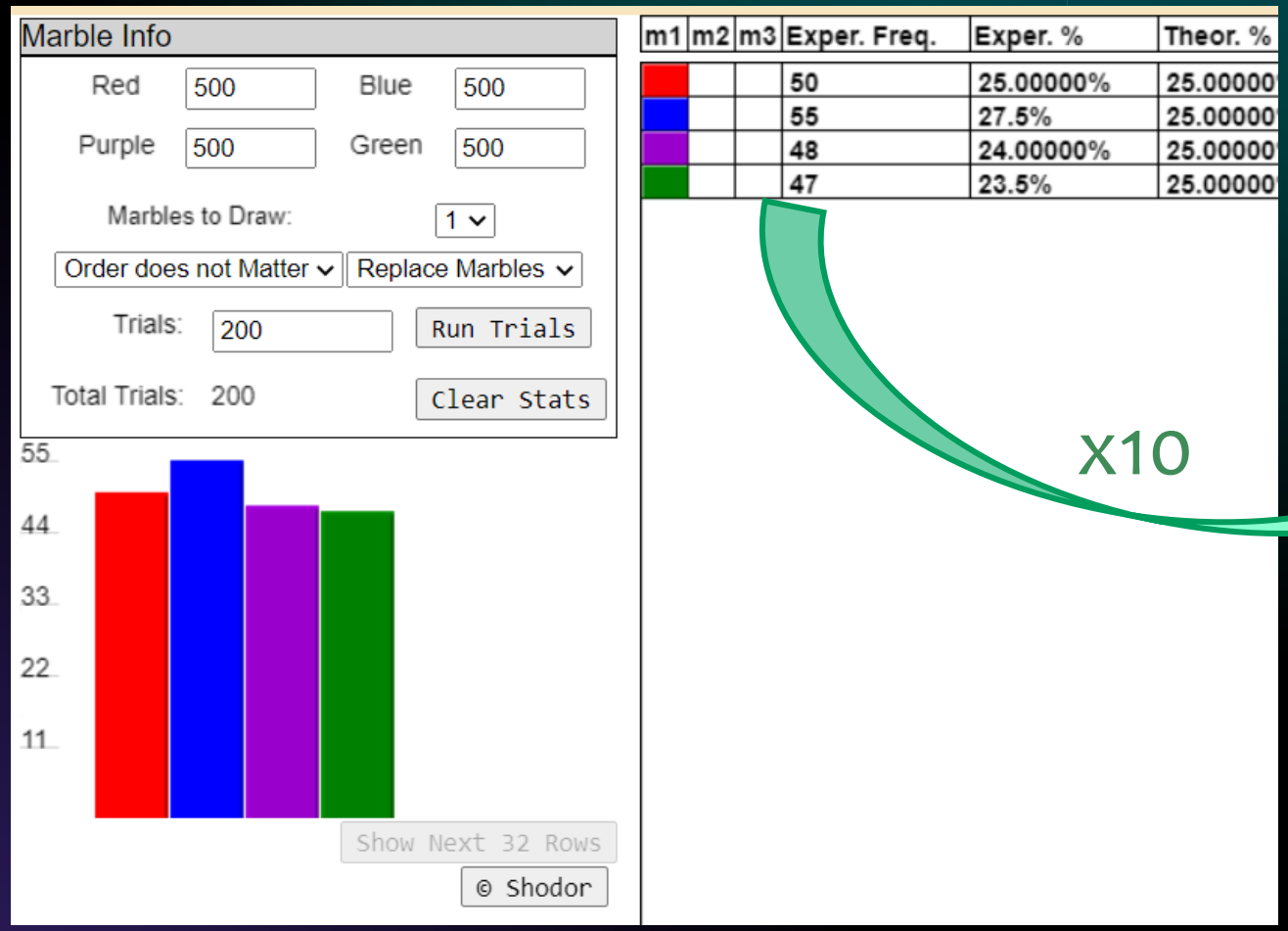


Instructions:

- Go to the simulation and set it up as shown. http://www.shodor.org/interactivate/activities/Marbles/
- Drawing marbles:
  - "Run Trials". Then, record the "Exper. Freq." Replace the starting marble numbers by the data x10.
  - Repeat 4 more times.

Now, try the whole process again except replace "Trials" with 20 instead of 200, and multiply by x100 instead of x10. What happens?

Genetic Drift Activity Ver 2

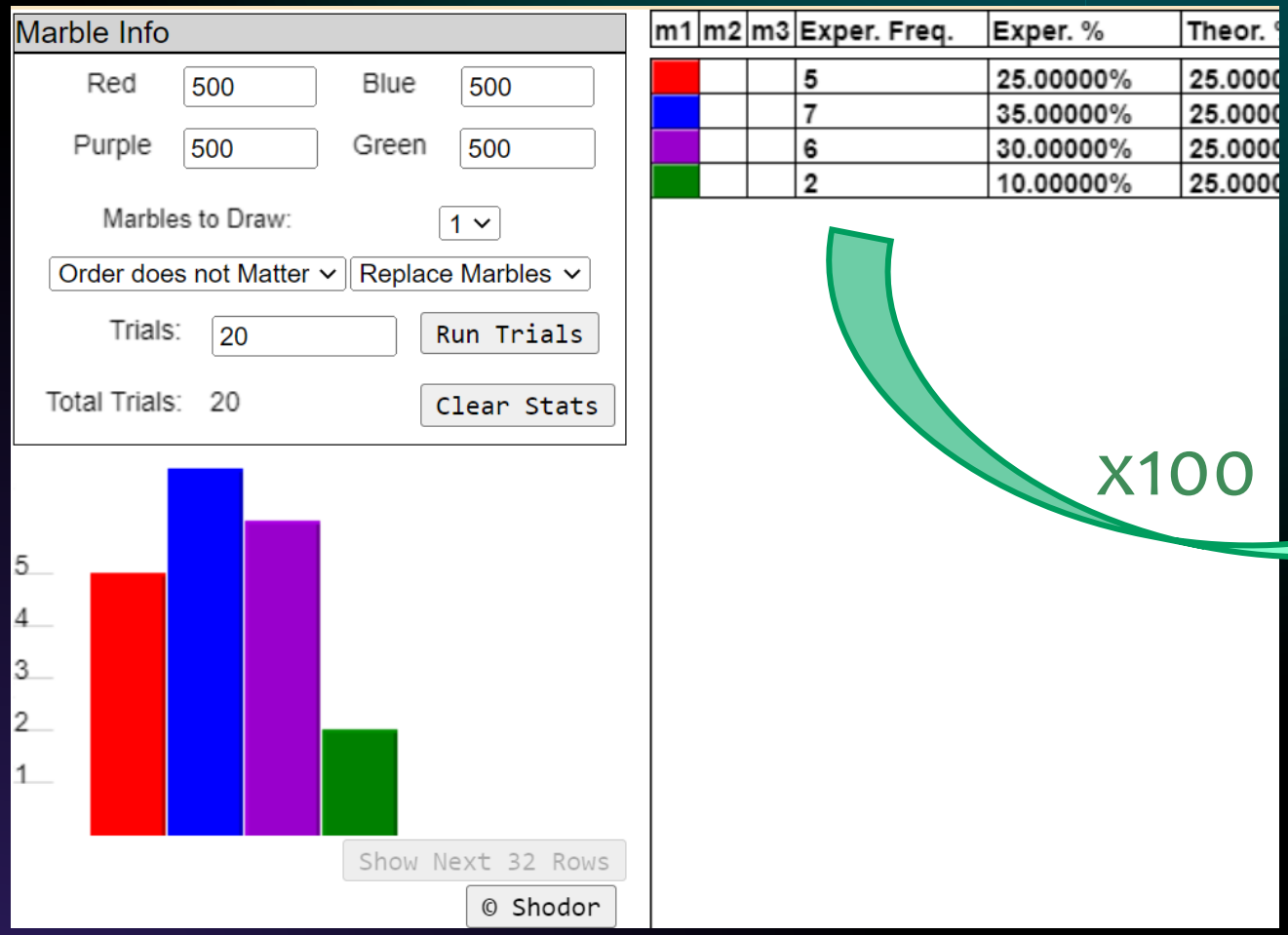


m1	m2	m3	Exper. Freq.	Exper. %	Theor. %
			50	25.00000%	25.00000
			55	27.5%	25.00000
			48	24.00000%	25.00000
			47	23.5%	25.00000

x10

Large Population (200 reproductive individuals)				
Trial #	red	blue	purple	green
Start	500	500	500	500
1	**500**	**550**	**480**	**470**
2				
3				
4				
5				

Genetic Drift Activity Ver 2



m1	m2	m3	Exper. Freq.	Exper. %	Theor.
			5	25.00000%	25.0000
			7	35.00000%	25.0000
			6	30.00000%	25.0000
			2	10.00000%	25.0000

x100

Small Population (20 reproductive individuals)				
Trial #	red	blue	purple	green
Start	500	500	500	500
1	**500**	**700**	**600**	**200**
2				
3				
4				
5				

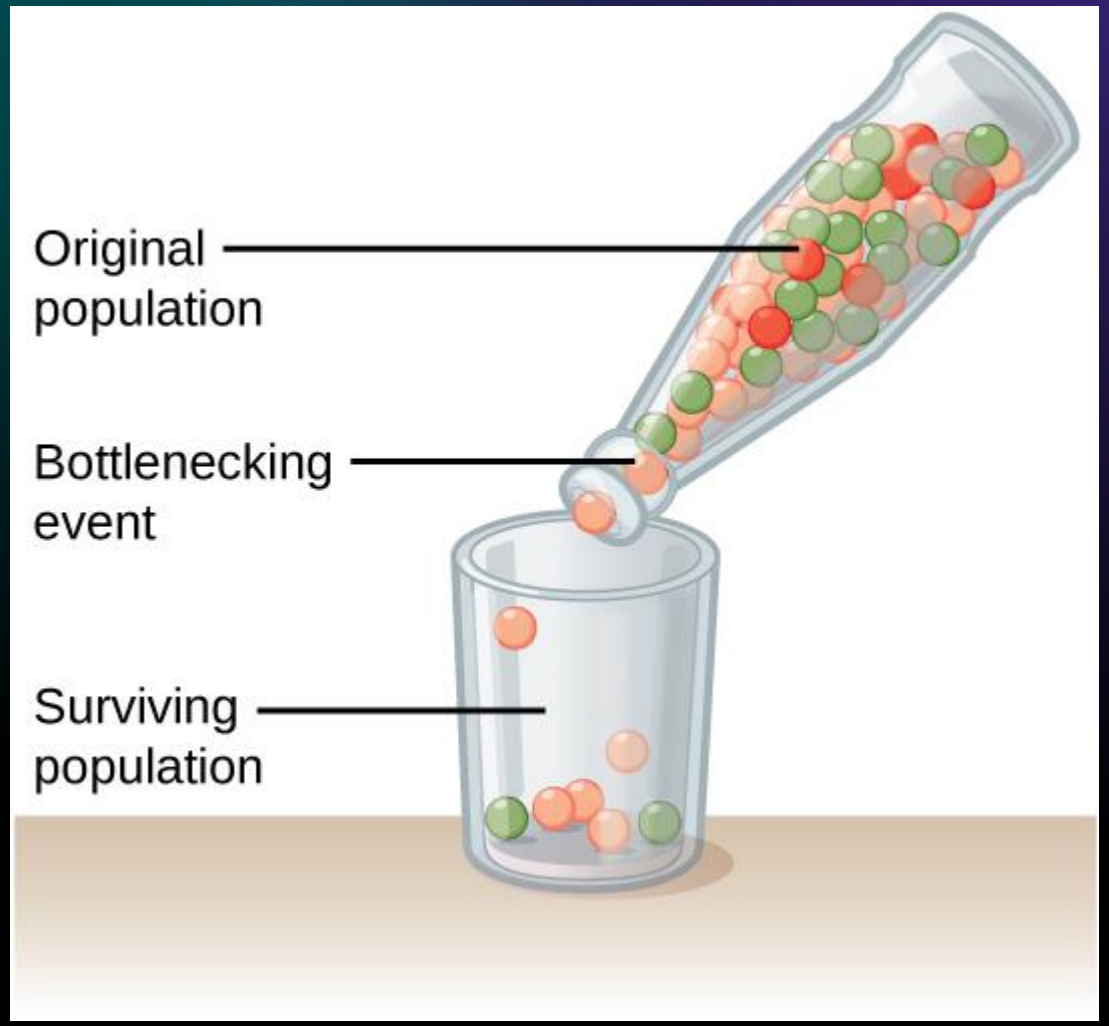
Genetic Drift

Genetic drift: change in allele frequencies in a population over generations due to chance

- Small populations more prone to genetic drift
- Genetic drift is random: does not matter if allele is beneficial or not
- When population size is very small, the following are observed:
  - **Bottleneck effect**
  - **Founder effect**

Bottleneck Effect

- **Bottleneck effect**: when population size is reduced (even temporarily), the population is more prone to genetic drift
- E.g. volcano erupts and randomly wipes out 95% of population
- E.g. Northern elephant seals have reduced genetic variation because of hunting in 1890s



Founder Effect

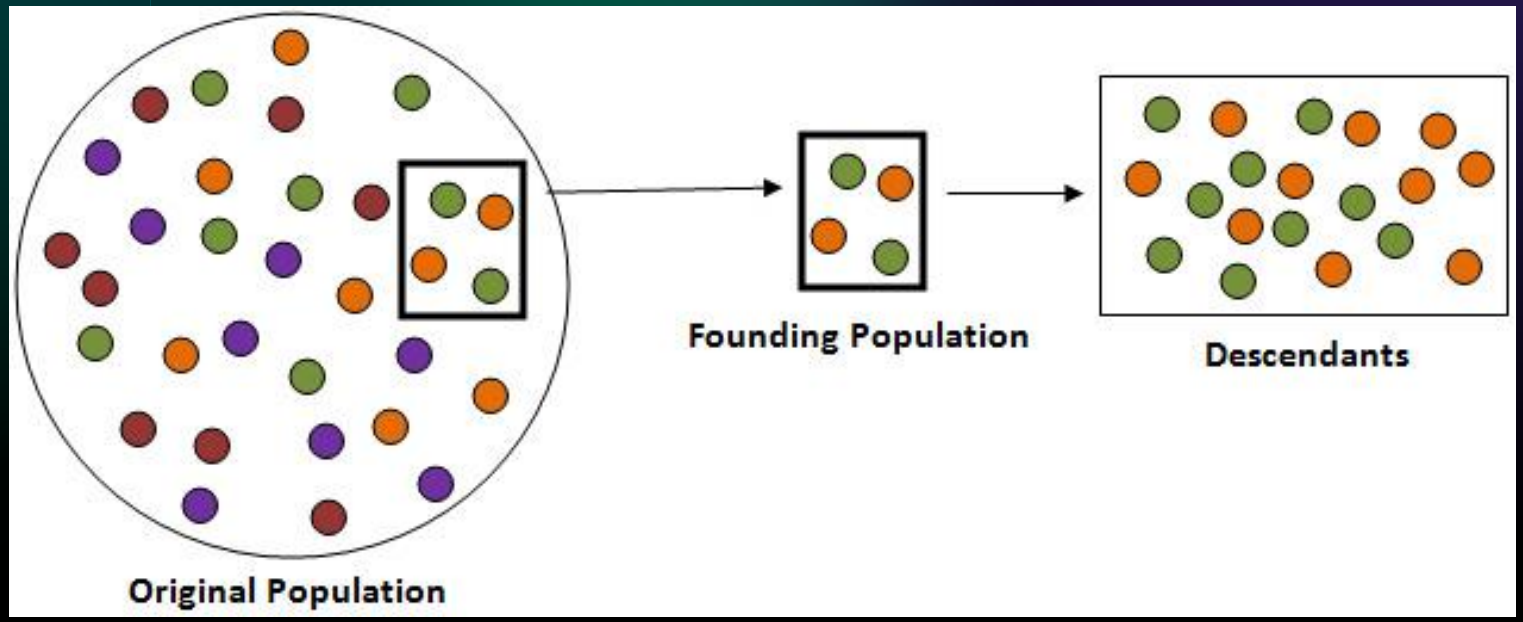
Article: “Observing the founder effect in human evolution”

After reading:

1. What is the founder effect?
2. How can the founder effect cause very high frequencies of disorders or disease? Include an example from the reading.

Founder Effect

- **Founder effect**: genetic drift often occurs when a new colony is formed by a few individuals
- E.g. Afrikaner population of Dutch settlers in South Africa: high frequency of Huntington's disease allele



Bottleneck Vs Founder Effect

Task: Create a table for yourself in your notes comparing and contrasting these two related concepts.

http://www.differencebetween.net/science/health/difference-between-bottleneck-effect-and-founder-effect

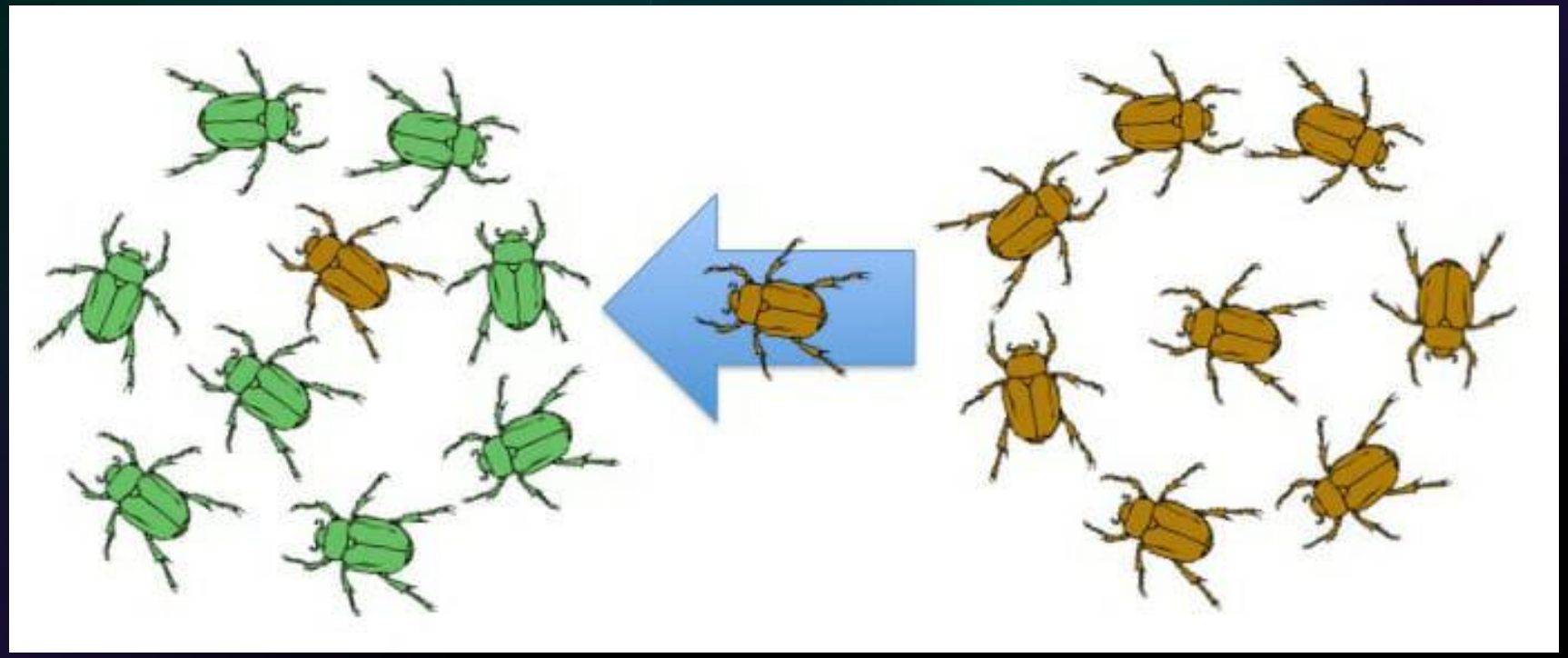
Bottleneck Vs Founder Effect

	Bottleneck Effect	Founder Effect
Definition		
Causes		
Isolation?		
Impact on Original Population		
Examples		

Source: http://www.differencebetween.net/science/health/difference-between-bottleneck-effect-and-founder-effect/

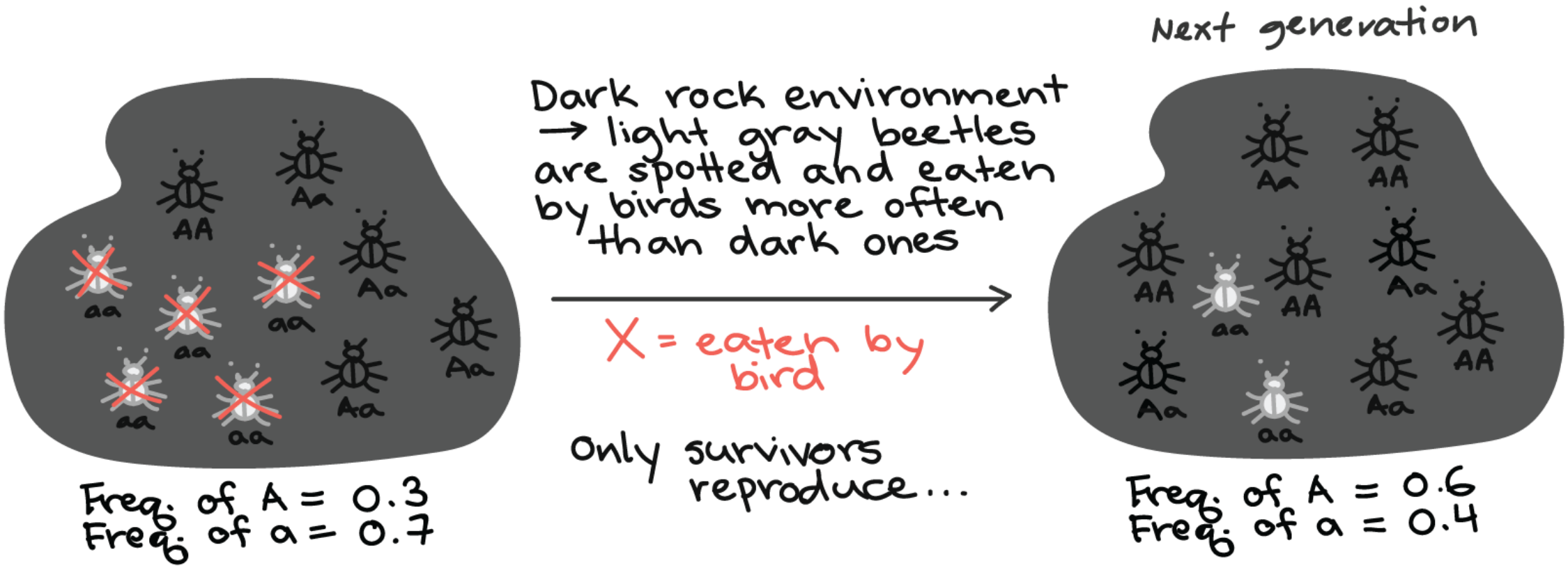
Migration (aka gene flow)

- Movement of individuals into or out of population changes allele frequencies



Practice

Each of the following images shows one of the following concepts: genetic drift, migration, mutation, natural selection. Which is which? (Source: https://www.khanacademy.org/science/ap-biology/natural-selection/hardy-weinberg-equilibrium/a/hardy-weinberg-mechanisms-of-evolution)



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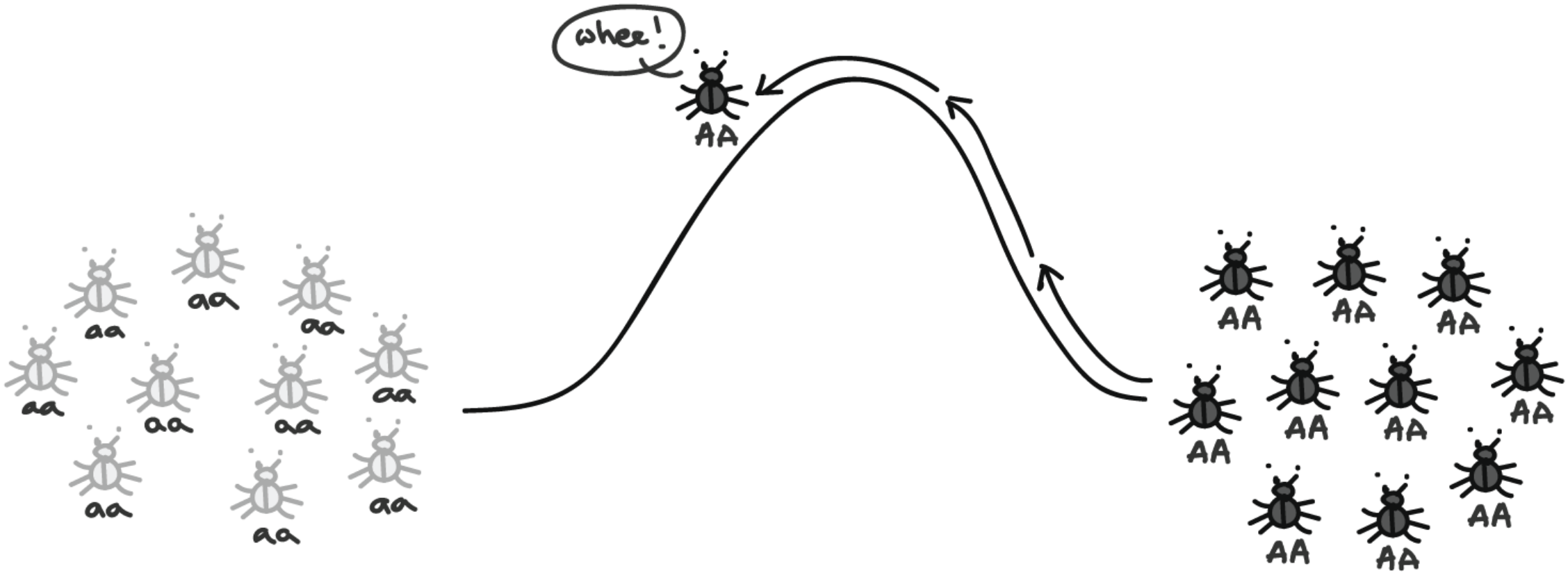

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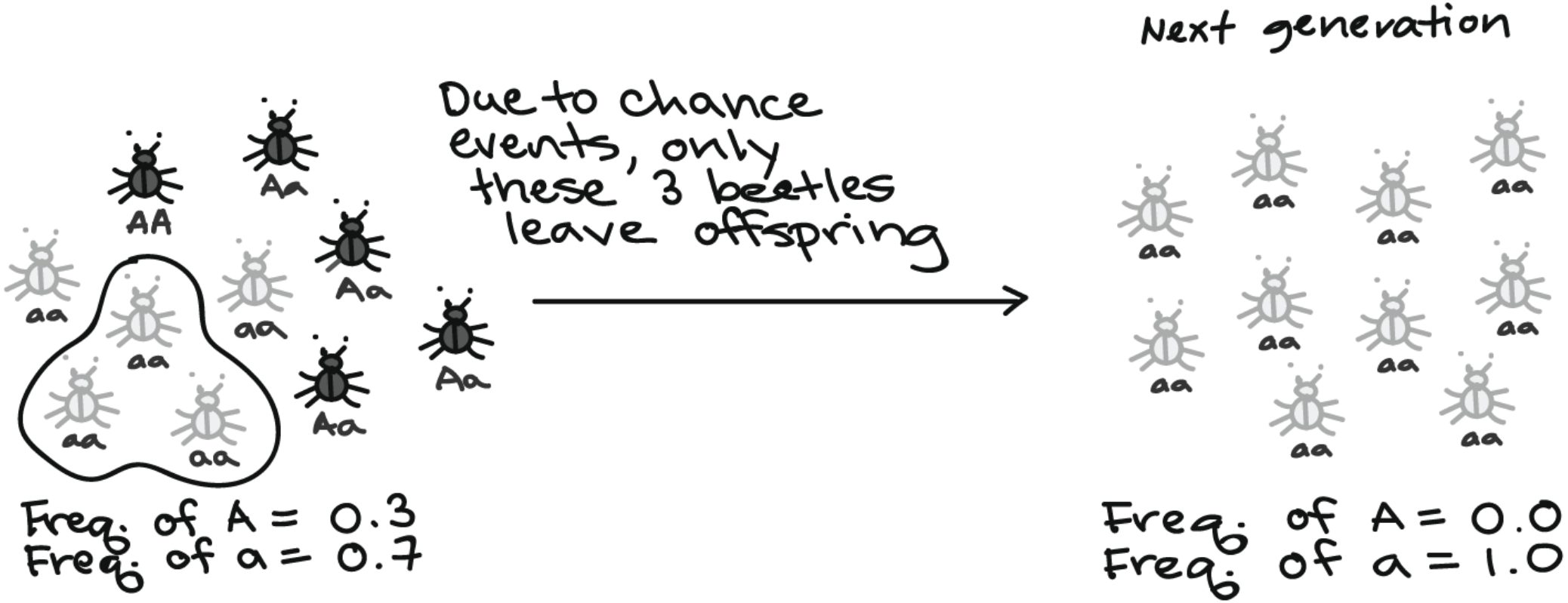

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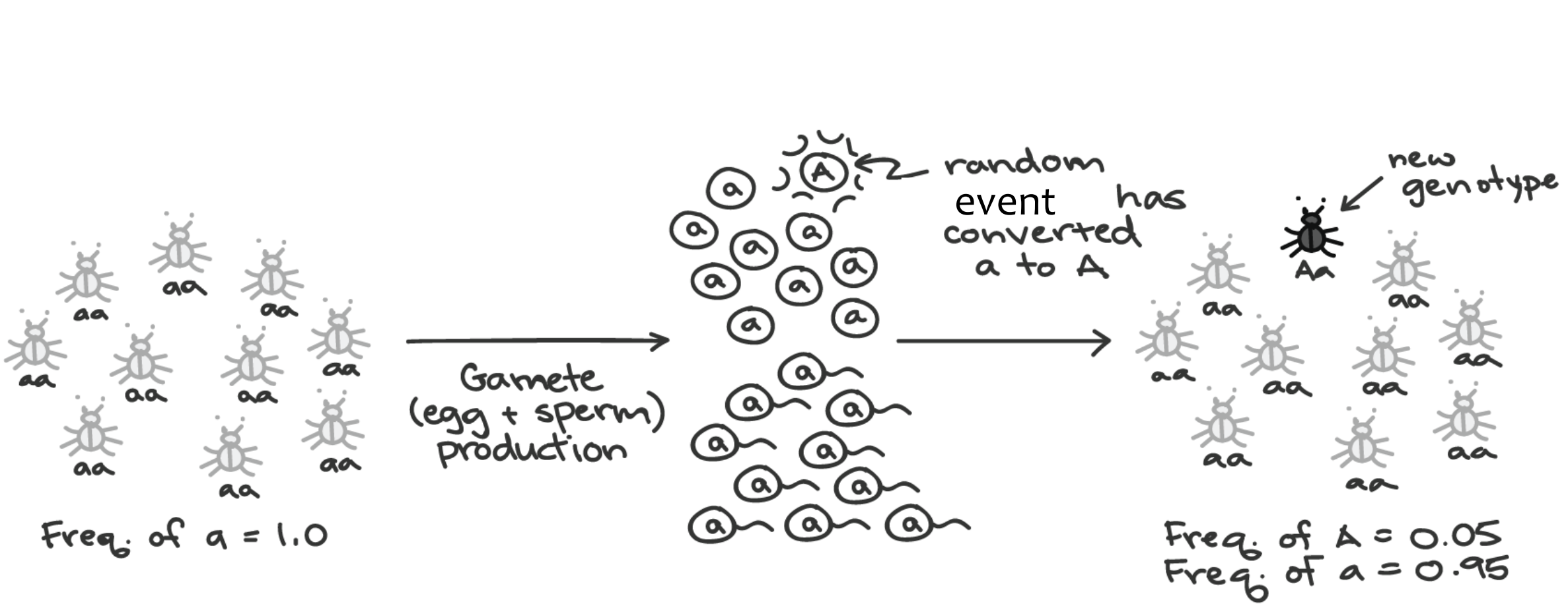


Discussion

1. In news and social media, there is often talk of “saving endangered species”. One strategy is to keep animals in zoos, let them reproduce, and then re-release them safely into the wild. What are some problems with this approach? Is “saving endangered species” good enough? If you were a conservation biologist, what approach would you use instead?

2. Explain why heritable variation is important to the survival of species.

Macroevolution

14-4: THE DEVELOPMENT OF NEW SPECIES* (ROUGHLY BASED)

SPECIATION

EXTINCTION

PROCESSES OF MACROEVOLUTION: ADAPTIVE RADIATION, COEVOLUTION, CONVERGENT EVOLUTION

What is Macroevolution?

Macroevolution: larger patterns in evolution

- How do species form? How do species go extinct?
- When do new species tend to form or go extinct?

Warm-up

- What career(s) are you interested in?
- How do/will you know if a job is right for you?
- What could possibly stop you from reaching your goals?

Some Definitions

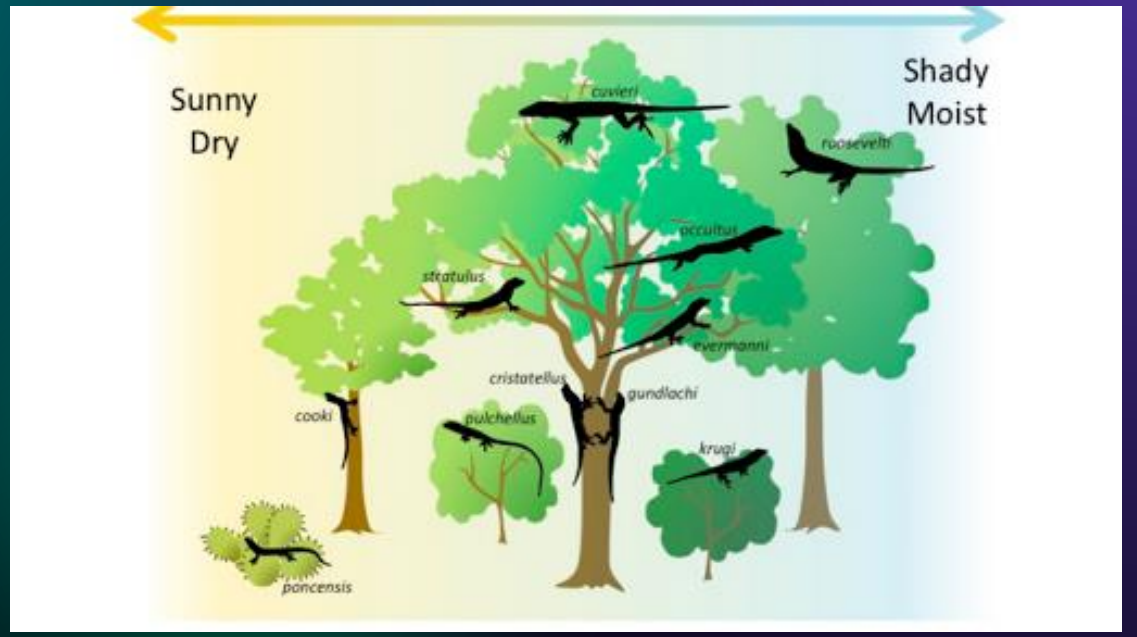
Species: group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring*

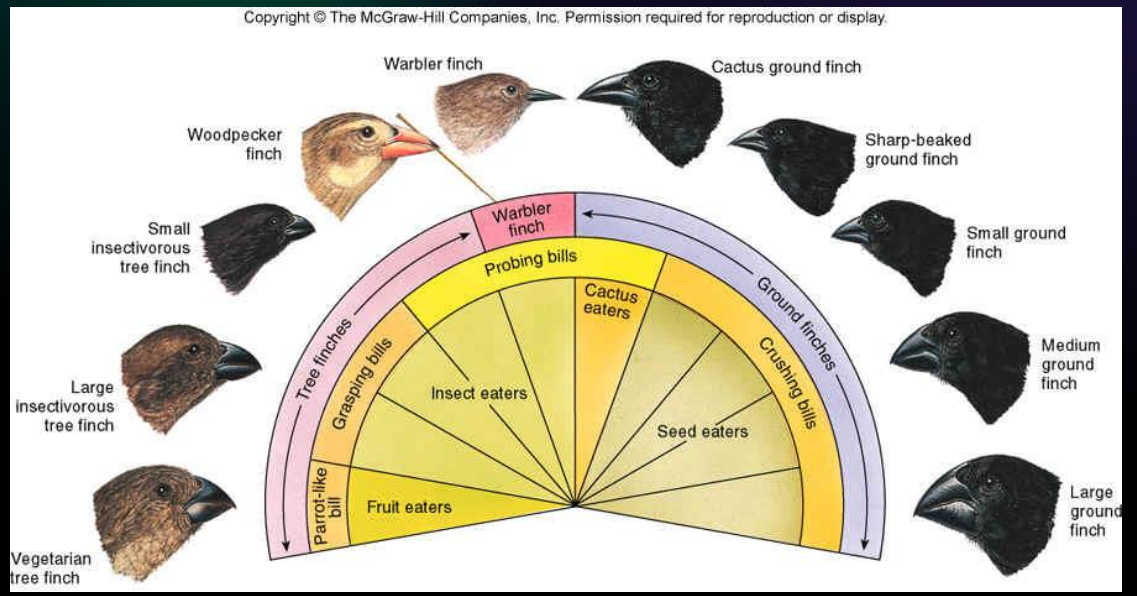
*This is the most commonly used definition, but many others exist. The definition of a species is hotly debated between biologists.

Niche

Niche: role of an organism in its community, including…

- Environmental conditions it requires (e.g. habitat, climate)
- Food sources
- Interactions with other organisms (especially predation, competition)

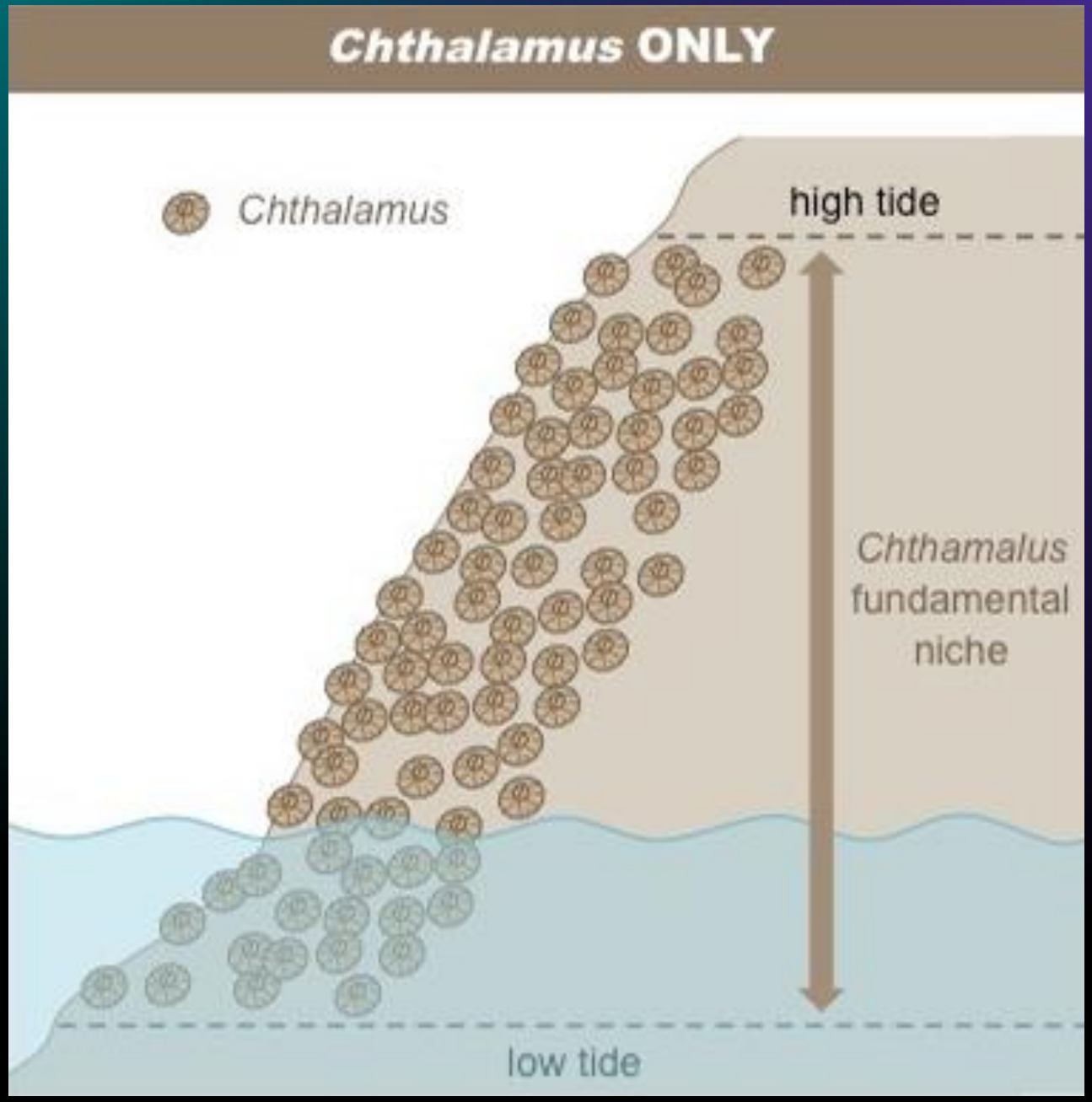




Niche

Fundamental niche: conditions under which an organism can survive and reproduce (where it *could* live, in theory)

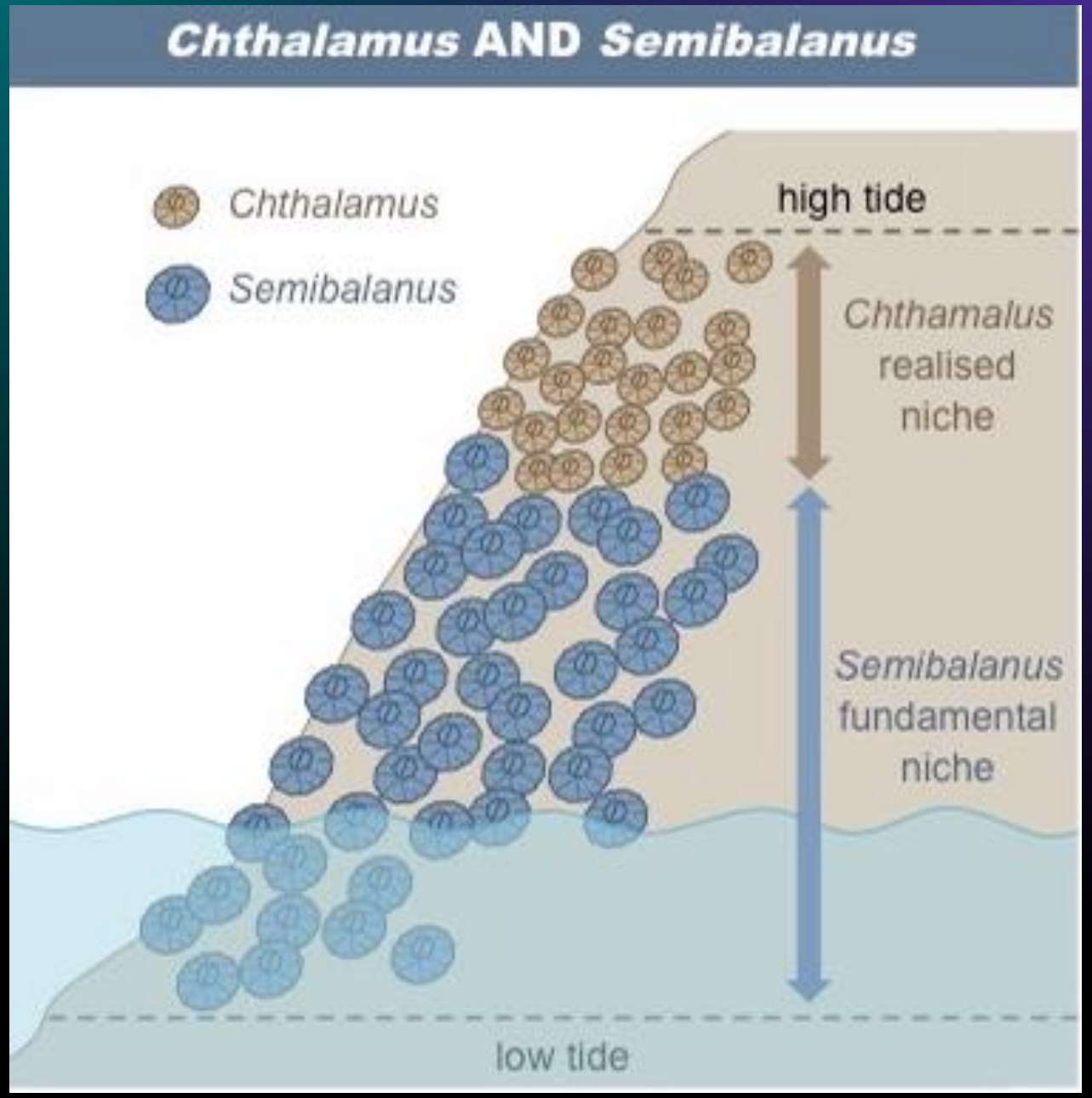
- Accounts for environmental conditions, food sources

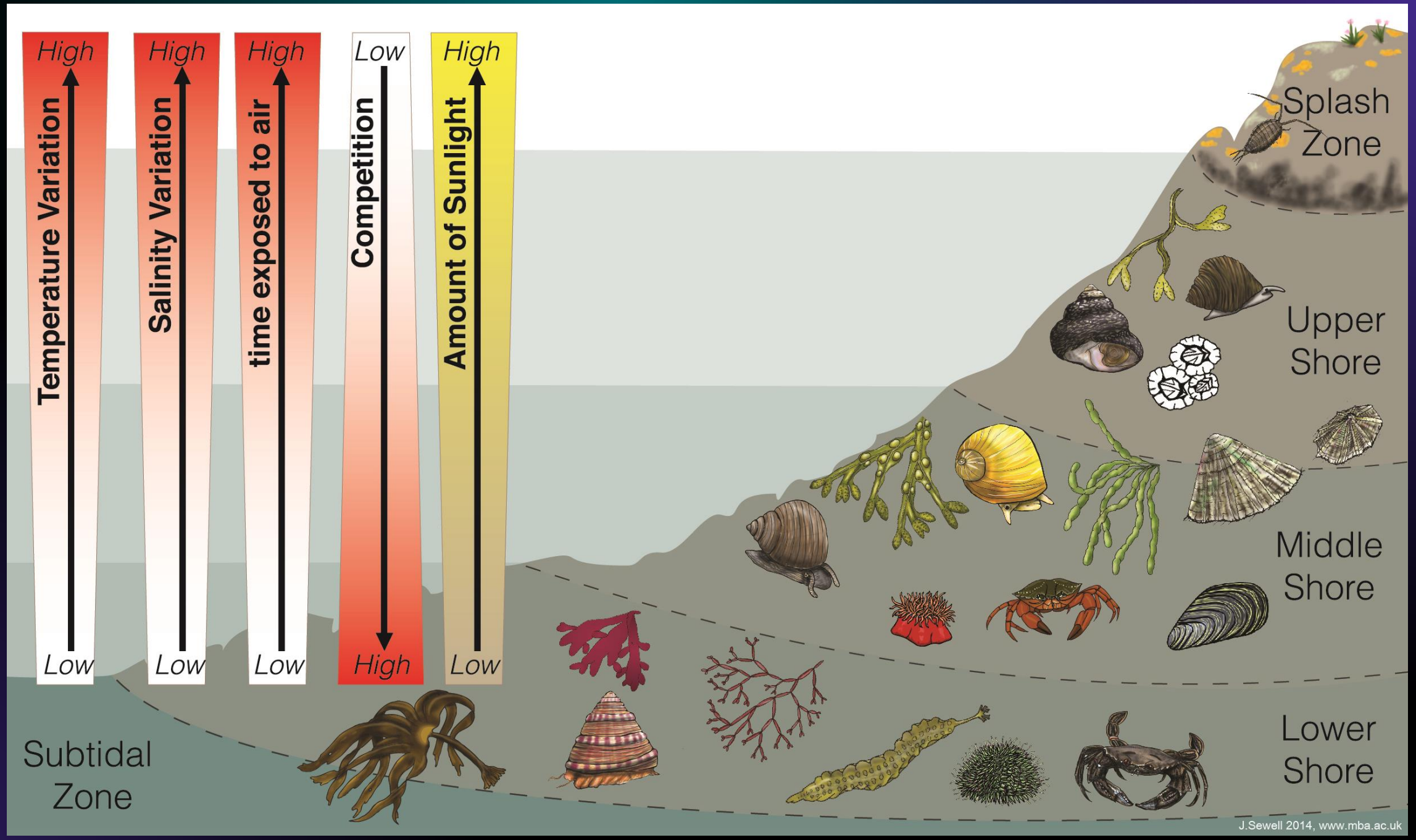


Niche

Realised niche: actual conditions used by organism (where it *does* live)

- Accounts for environmental conditions, food sources, *and* predators/competition
- Usually smaller than fundamental niche



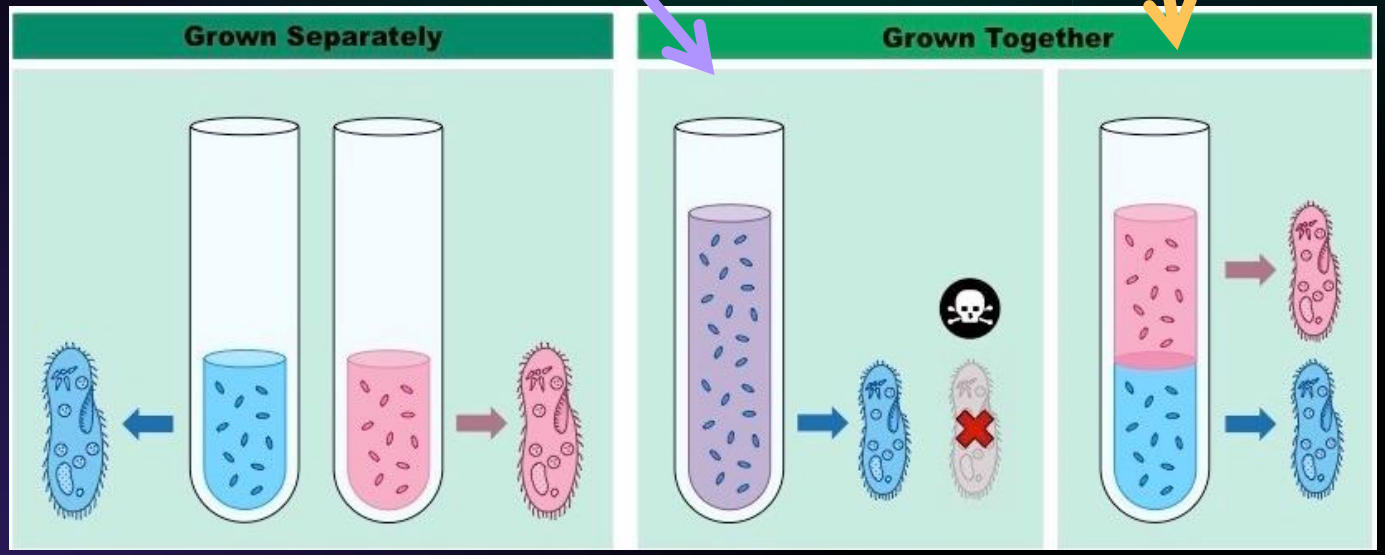

High
Temperature Variation
Low
High
Salinity Variation
Low
High
time exposed to air
Low
Low
Competition
High
High
Amount of Sunlight
Low
Splash Zone
Upper Shore
Middle Shore
Lower Shore
Subtidal Zone
J.Sewell 2014, www.mba.ac.uk

Niche

Possible effects of competition:

a) Narrowing of realised niche

b) Extinction



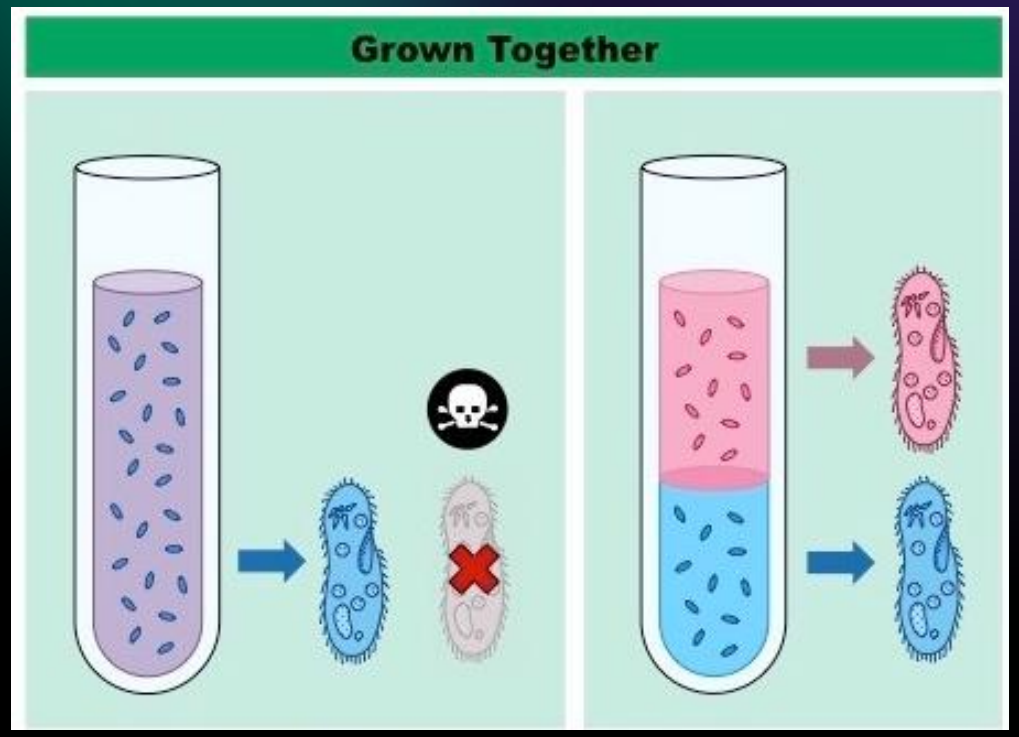
European starling (*Sturnus vulgaris*) is an invasive generalist which outcompetes native birds (e.g. woodpeckers, bluebirds)

Discussion/Research

1. Are all introduced species a problem? Why or why not?
2. Research one example of an introduced species that has become invasive. Explain why it is a threat to native populations, using your understanding of niches.

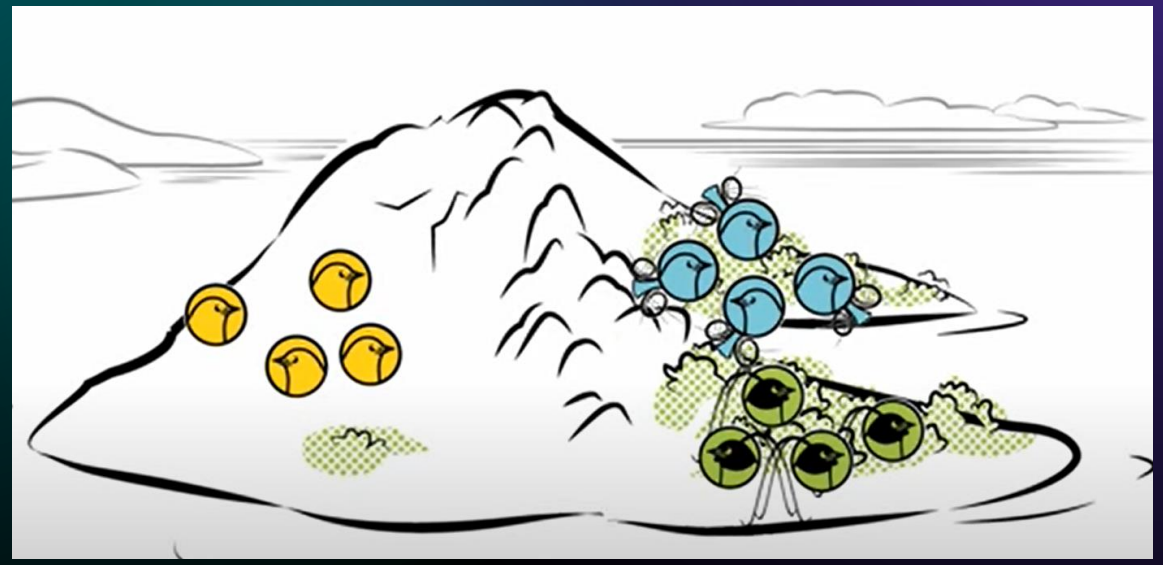
Species Formation

- Fact: No two species can occupy the same niche for a long period of time. The weaker competitor will go **extinct**.
- Therefore, species or populations that can ‘branch out’ and occupy new niches are more likely to survive. Over time, they will evolve adaptations that make them better suited for these niches.
- **Speciation**: the process by which new species evolve



Reproductive Isolation

- New species can form when two populations are separated for long periods of time.
- Isolated populations cannot interbreed. They evolve separately.



https://www.youtube.com/watch?v=8yvEDqrc3XE&ab_channel=CornellLabofOrnithology

- Even if mating occurs, if DNA is different enough, offspring will not develop properly or will be infertile.

Reproductive Isolation

Mechanisms for reproductive isolation:

- **Geographic isolation**
- **Temporal isolation**

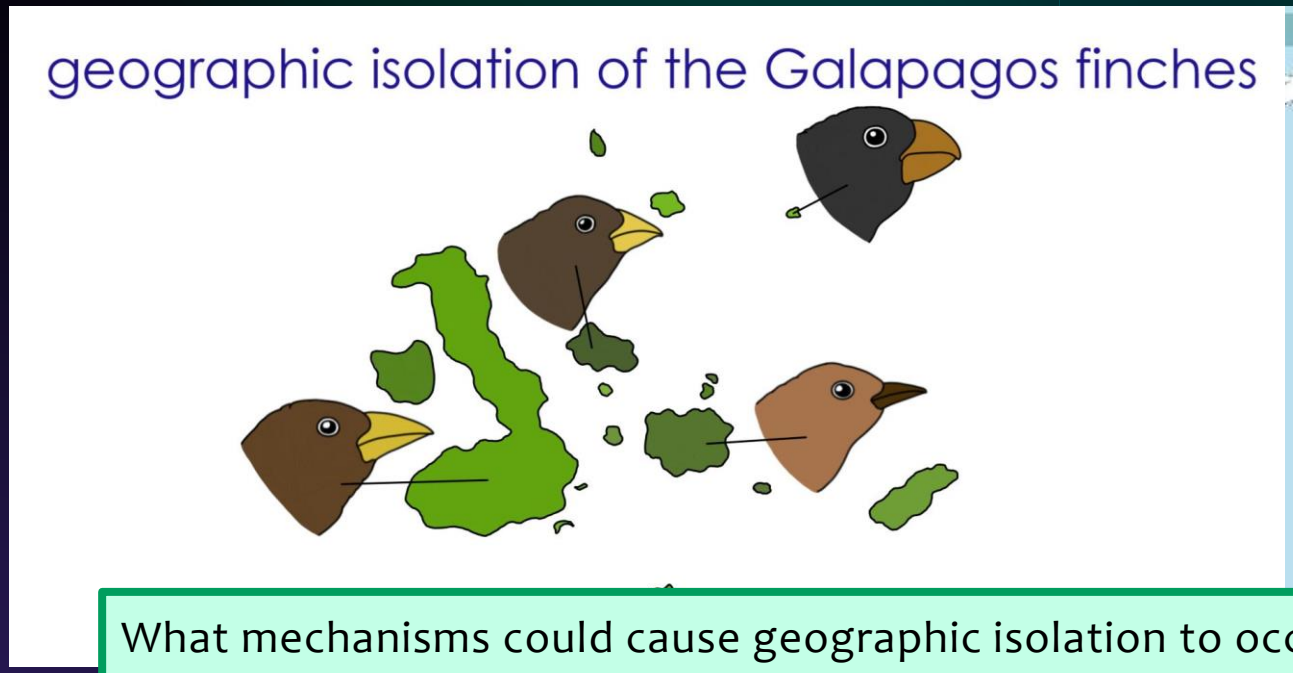
} populations evolve differently

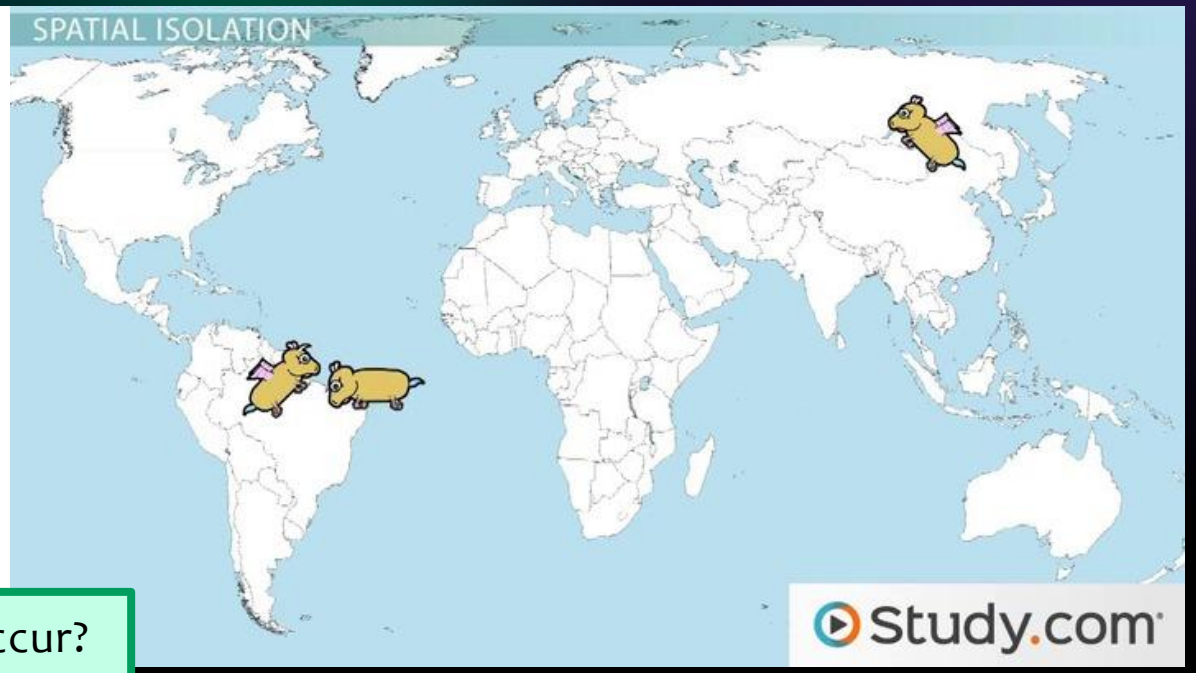
- **Gametic barriers**
- **Courtship barriers**

} maintains DNA differences

Geographic Isolation

- Geographic barriers (e.g. rivers, ocean, mountains, roads) can separate populations





What mechanisms could cause geographic isolation to occur?

Temporal Isolation

- Populations never meet (i.e. not alive at same time)
- Mating schedules do not match

American toad (*Anaxyrus americanus*)

Breeding season early summer

Magicicada: 7 species

13 or 17 year life cycles

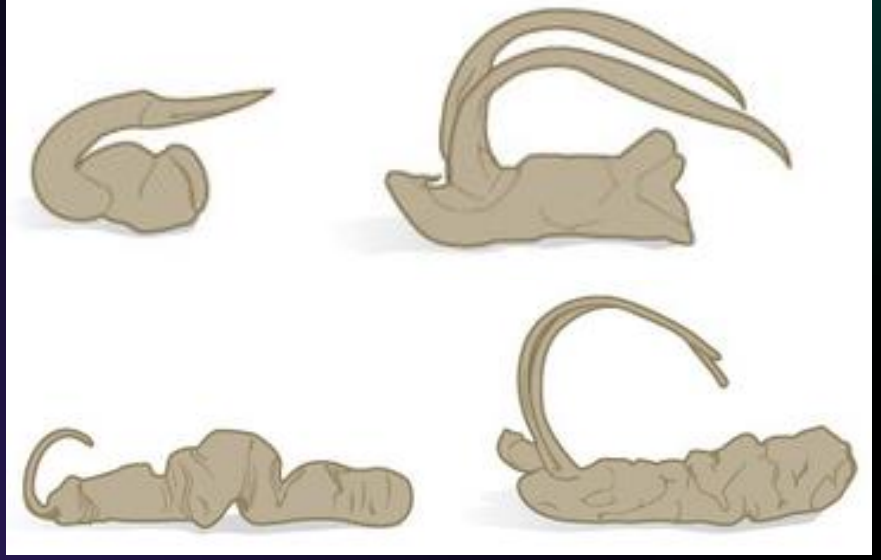
Fowler's toad (*Bufo fowleri*)

Breeding season late summer

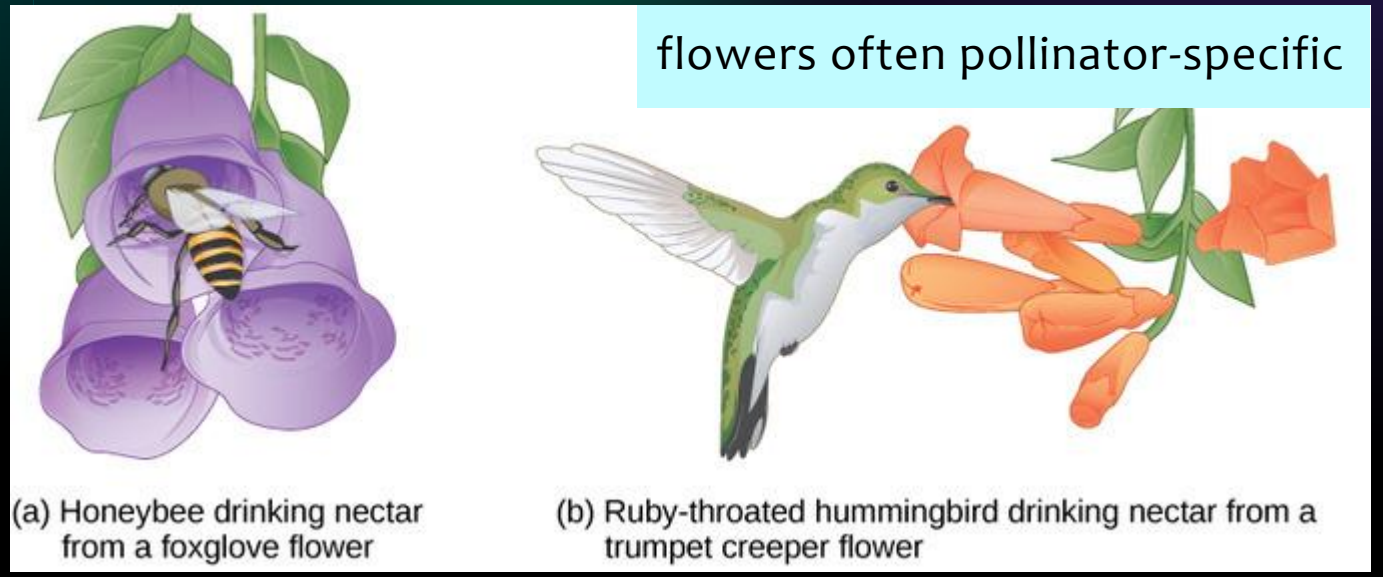
Gametic Barriers

Fertilization does not occur because gametes never meet: reproductive structures are too different

damselfly male genitalia only fits in female of same species



flowers often pollinator-specific



(a) Honeybee drinking nectar from a foxglove flower

(b) Ruby-throated hummingbird drinking nectar from a trumpet creeper flower

Courtship Barriers

The two populations find each other unattractive or courtship behaviours strange

https://www.youtube.com/watch?v=U89tw093s_Y&ab_channel=NatGeoWILD

Case Study: Sticklebacks Part 1

Article: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/species-ecosystems-at-risk/brochures/stickleback_species_pairs.pdf

Questions:

1. Why are stickleback pairs endangered? (at least 2 reasons)
2. Compare and contrast benthic and limnetic sticklebacks in terms of niche (role, habitat) and appearance.
3. In your own words, describe one way in which stickleback pairs are thought to have evolved.
4. Describe one key takeaway from this article.

Case Study: Sticklebacks Part 2

Article: https://science.ubc.ca/news/newly-introduced-species-fish-speeds-evolution-bc-lake

Questions:

1. What is reverse speciation?
2. Use your understanding of the word ‘niche’ to explain why the introduction of an invasive species caused reverse speciation.

Discussion/Review

1. Explain the concept of ‘niche’ to a neighbour. What is the difference between realized niche and fundamental niche? Use examples.
2. The four ways that reproductive isolation can arise are: geographic isolation, temporal isolation, gametic barriers, courtship barriers. Explain what these mean to a neighbour, using examples if possible.

Patterns of Speciation

- **Convergent evolution**
- **Divergent evolution**
- **Co-evolution**

Convergent Evolution

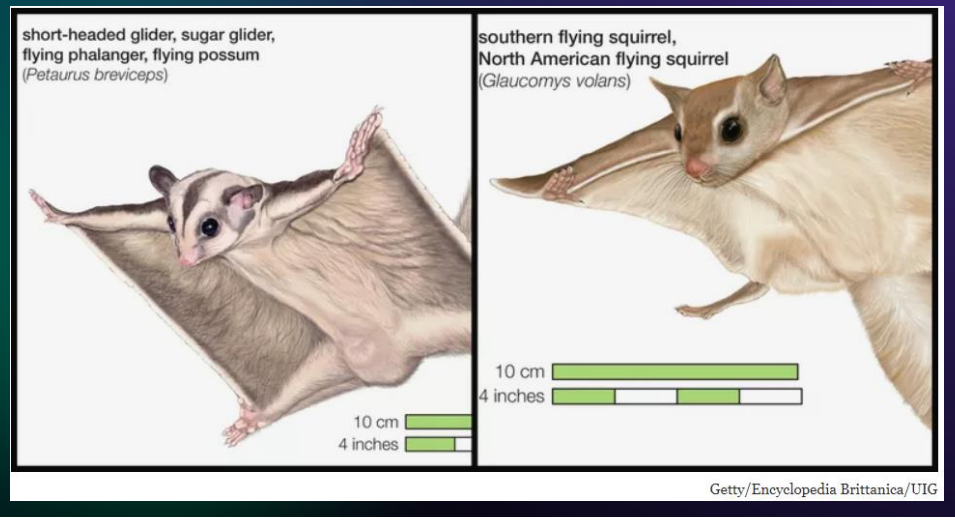
- **Convergent evolution**: pattern in evolution that produces many species that are similar in appearance and behaviour
- **Analogous structures**: structures that are similar in appearance and function but are not homologous; arise through convergent evolution

Convergent Evolution

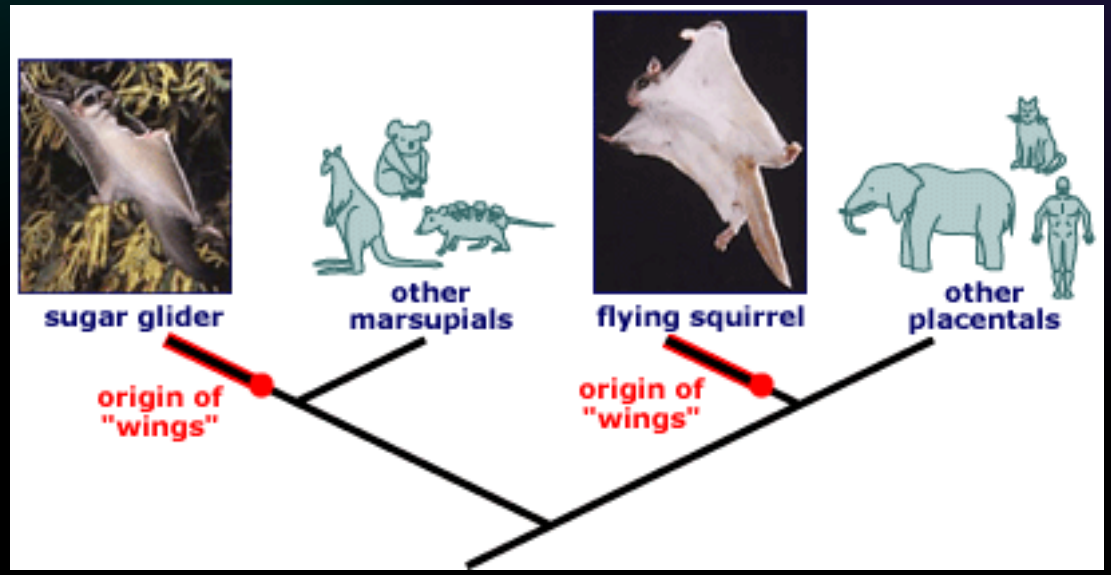
(a) Bat wing

(b) Bird wing

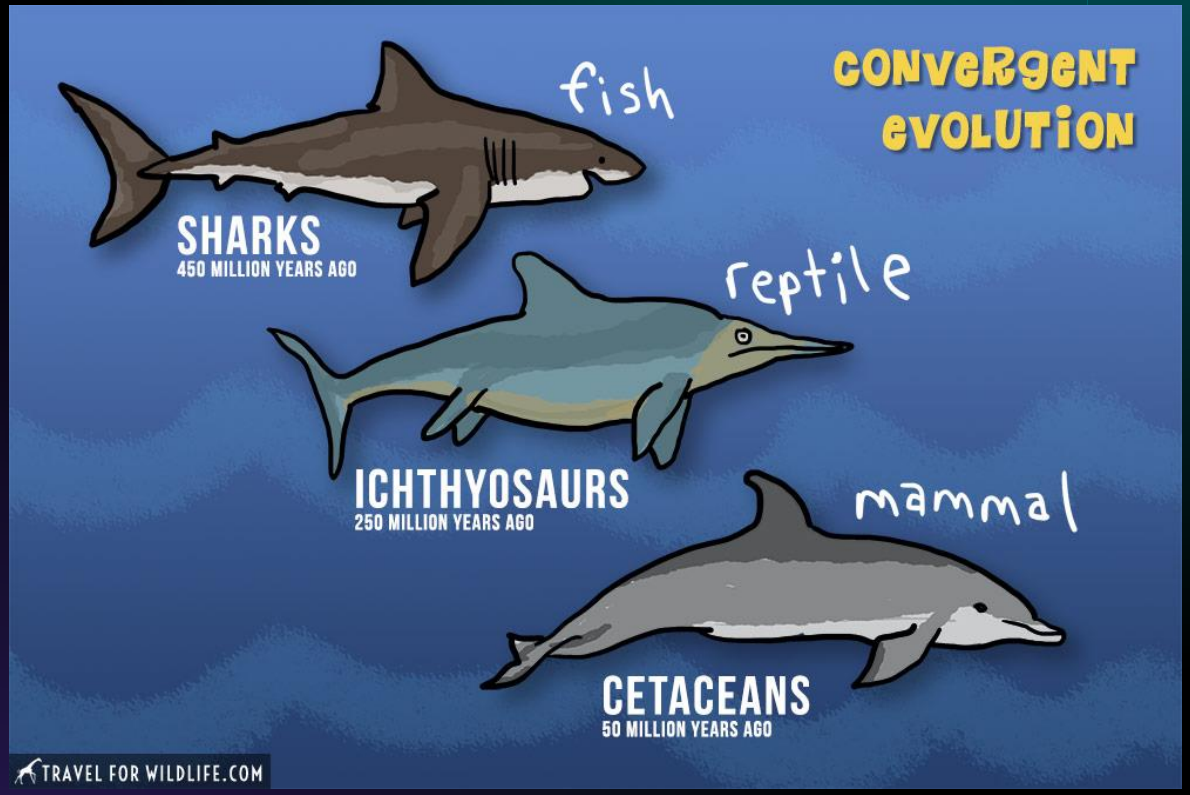
(c) Insect wing

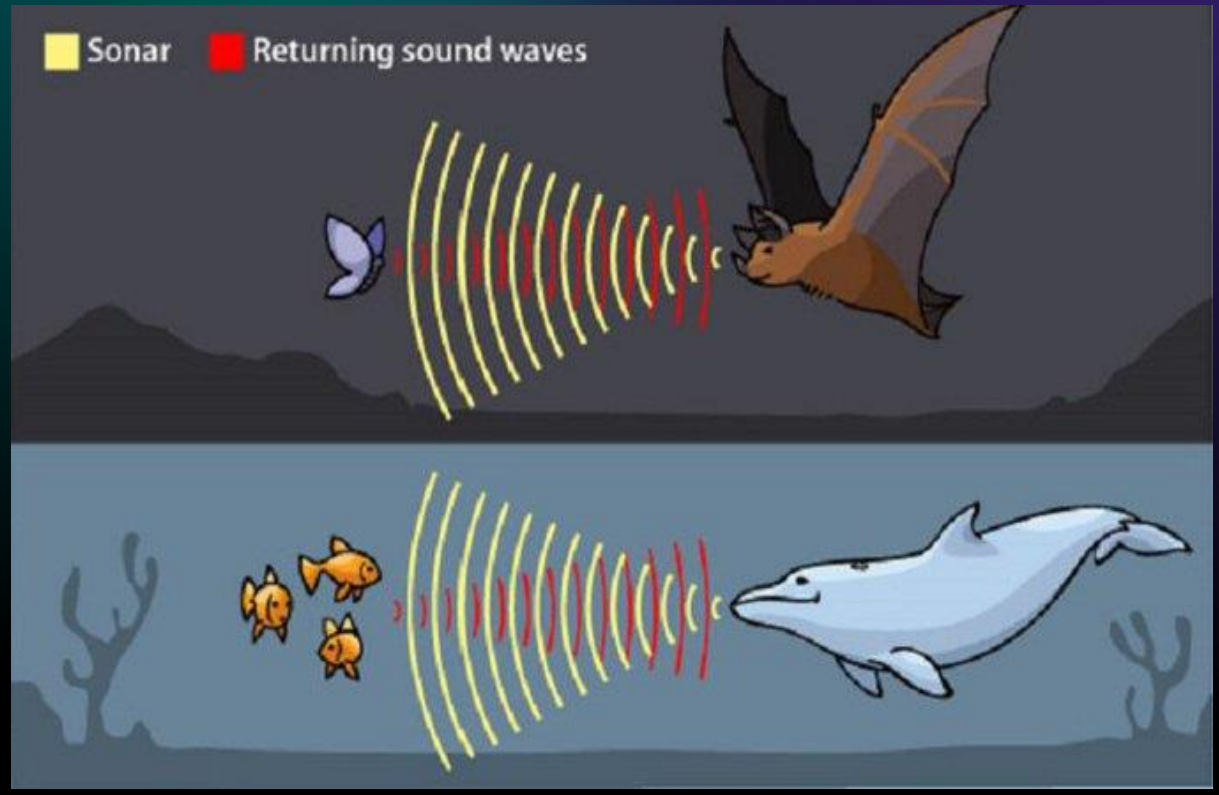


Getty/Encyclopedia Brittanica/UIG



Convergent Evolution

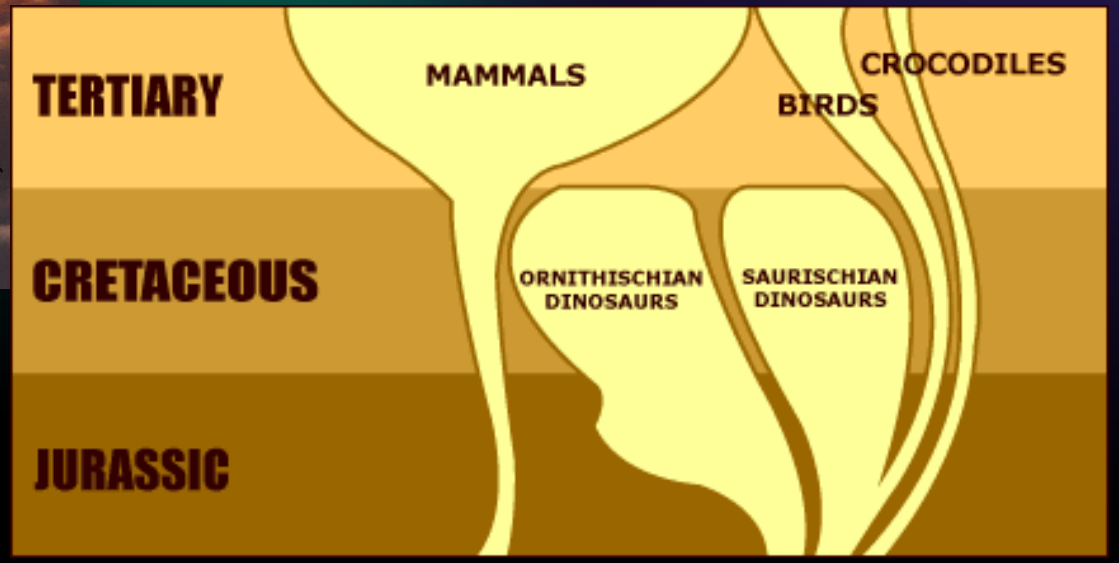




Divergent Evolution

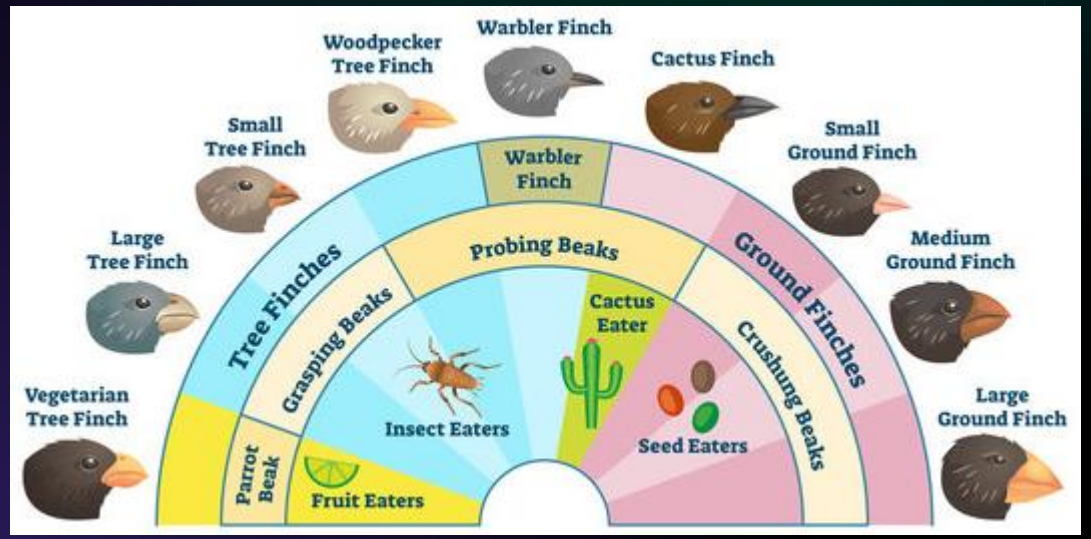
- **Divergent evolution:** When **niches** are 'open', existing species will diverge to fill those niches
- **Homologous structures**: body structures (e.g. bones, organs) inherited from a common ancestor, that have become adapted to serve different functions
- Best examples occur:
  - After mass extinctions
  - Colonization of new lands and habitats

The Rise of Mammals and Birds



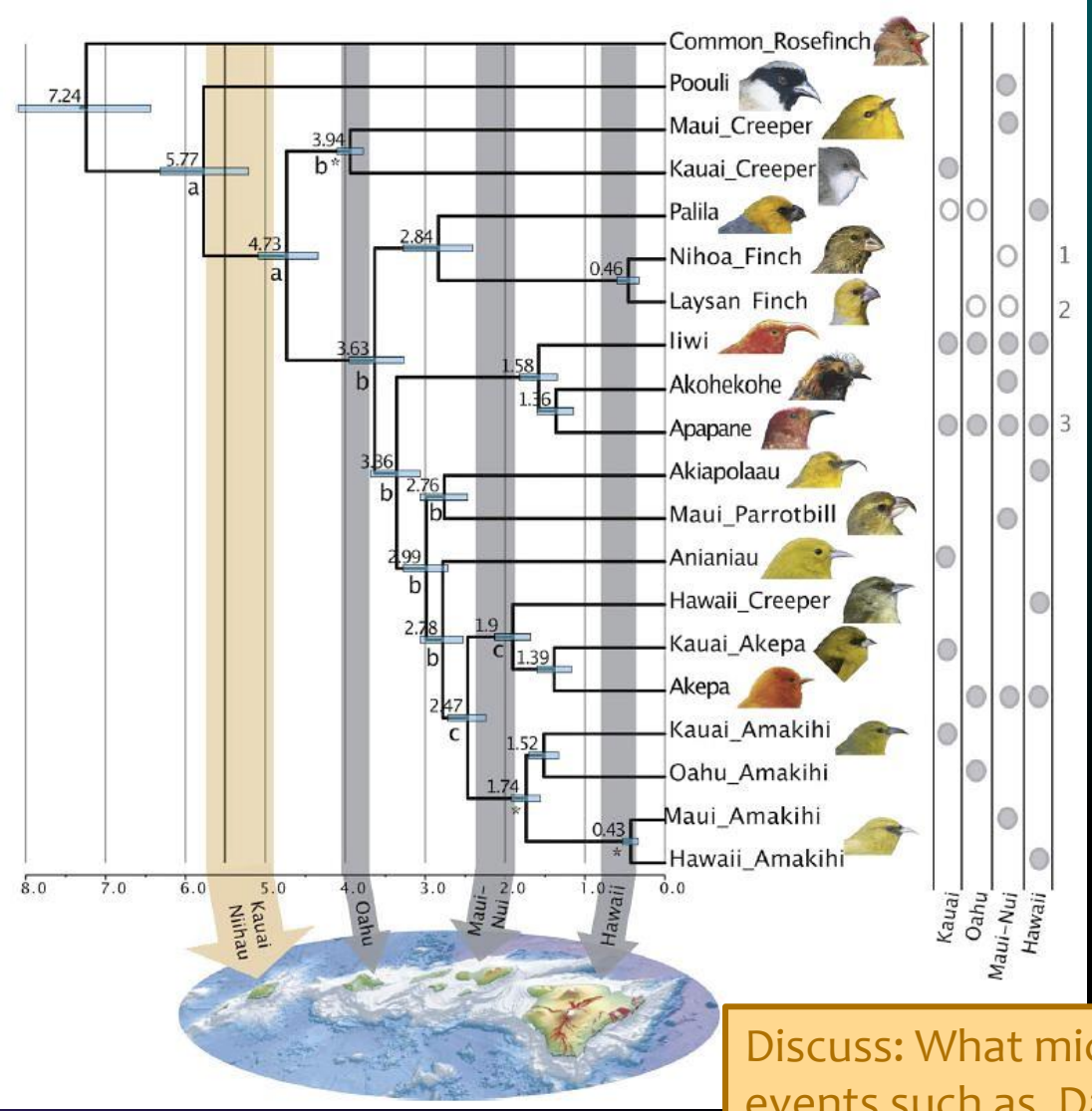
Darwin's Finches

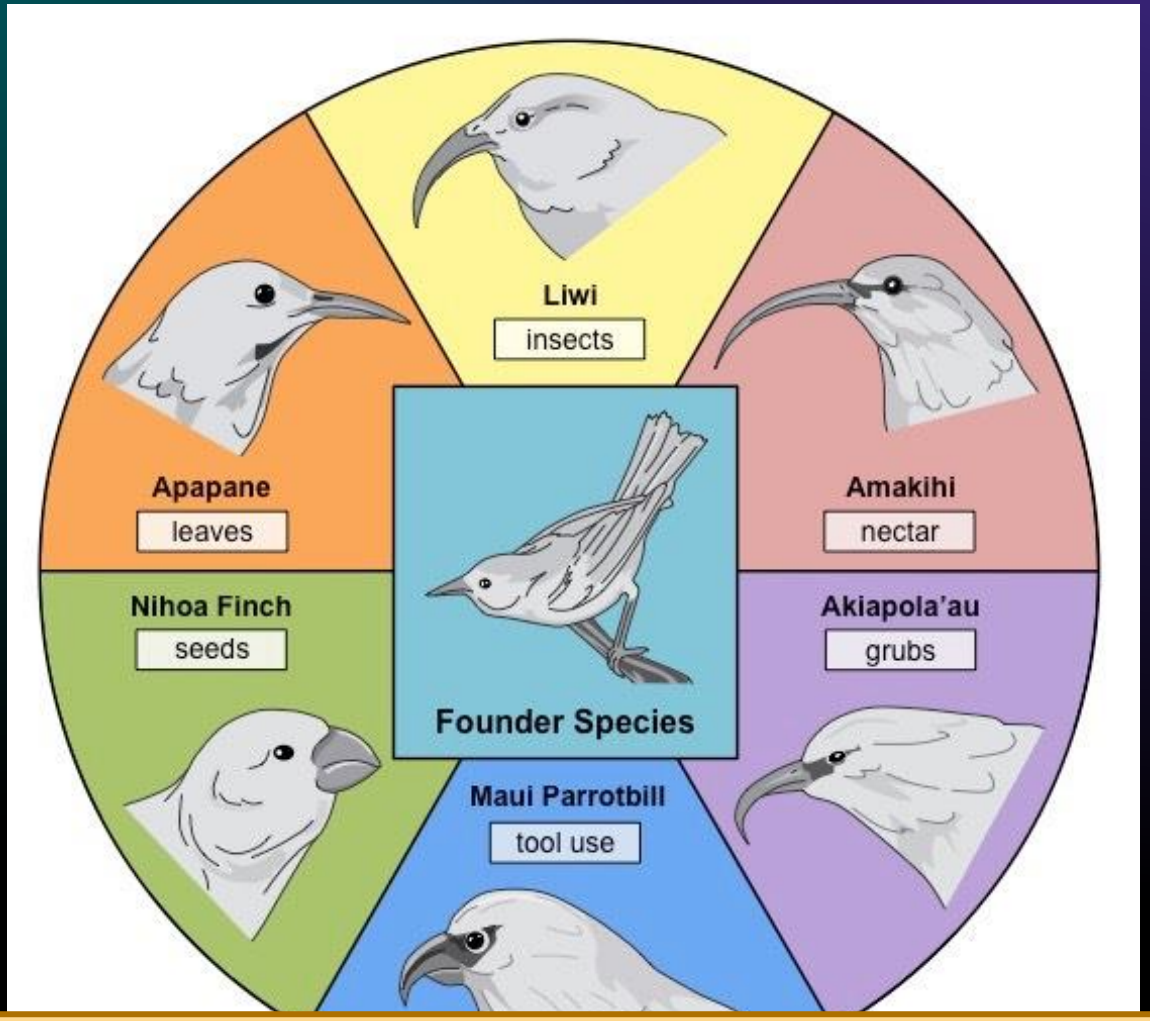
- Ancestral finches blown over from South American mainland
- Finches do not like to fly over open water: islands reproductively isolated from each other
- No other birds on islands: many available niches to exploit
- Result: finches diversified into many different finch species (at least 13)



more details: pg 306-308 in textbook

Hawaiian Honeycreepers



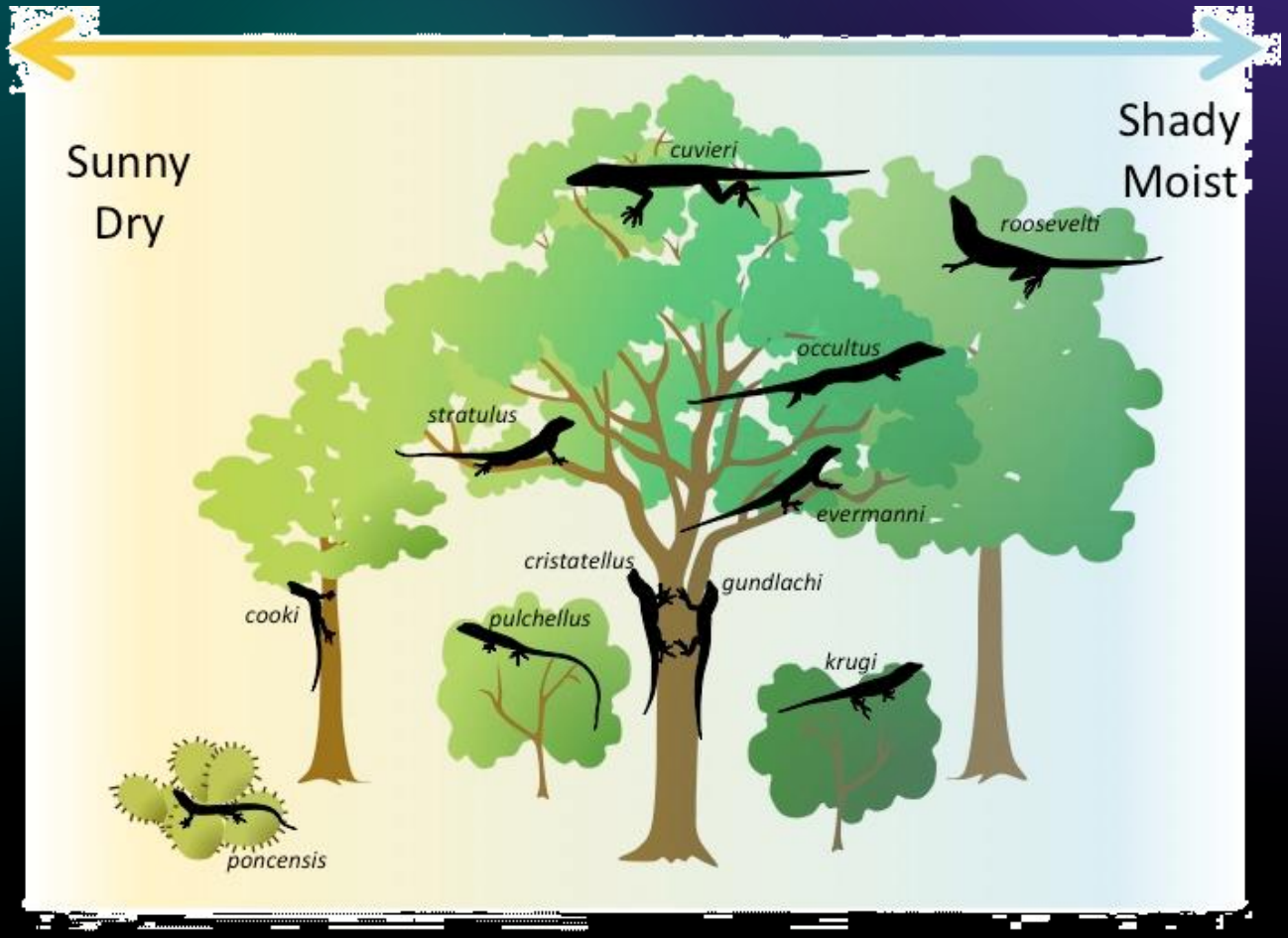


Discuss: What microevolutionary process would we expect to see in colonization events such as Darwin's Finches and the Hawaiian Honeycreepers?

Case Study: Anole Lizards

Consider the anole lizards from the HHMI biointeractive video.
(https://www.youtube.com/watch?v=rdZOwyDbyLo&t=782s&ab_channel=biointeractive)

Discuss: How was this an example of divergent evolution? convergent evolution?



Co-Evolution

- Many species are connected and affect each other (e.g. predator/prey, parasite/host, pollinator/plant, symbiotic relationships)
- **Co-evolution:** two (or more) ecologically connected species evolve together

Excellent resources:
https://biologos.org/series/evolution-basics/articles/coevolution
https://www.thoughtco.com/what-is-coevolution-4685678

Co-Evolution - Pollinators

Pollinators have evolved alongside the plants they pollinate.

Plants give specific rewards to their pollinators; pollinators efficiently extract those rewards.

Co-Evolution - Pollinators

- *Angraecum sesquipedale* orchid has nectar at the bottom of a foot-long tube: Darwin predicted existence of moth with extremely long proboscis
- Pollinator (*Xanthopan morganii praedicta* hawk moth) was not discovered until after Darwin had died

Co-Evolution – Bats and Moths

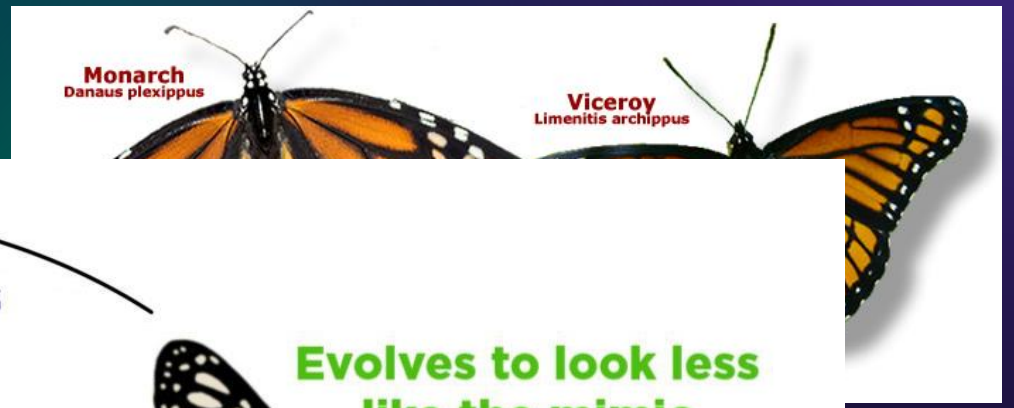
https://www.youtube.com/watch?v=NeCmSL_N65A&ab_channel=biointeractive

Co-Evolution – Bats and Moths

- Evolved ultrasonic echolocation to detect and hunt moths → Evolved ears that can detect bat echolocation
- Evolved echolocation at different frequencies (that moths cannot hear) → Toxic moths click at bats as a warning; other moths produce jamming signals to confuse the bats

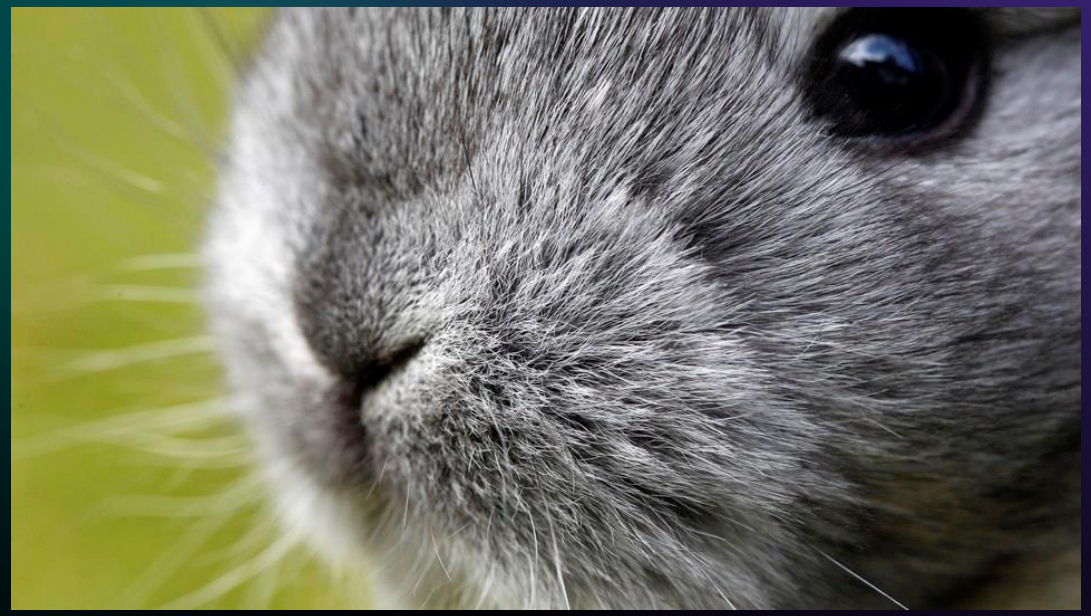
Read more at https://theconversation.com/explainer-the-evolutionary-arms-race-between-bats-and-moths-43675

A Co-evolutionary 'Triangle' (not testable)



Co-Evolution – Rabbits and Viruses

- 1950s: lethal myxoma virus was intentionally released to Australian rabbit population; reduced population by 99%



- A decade passed → rabbit population started recovering
- Rabbits had evolved resistance to myxoma AND virus evolved to become less deadly

Review: Patterns of Speciation

- Compare and contrast divergent evolution, convergent evolution, and

Resources

- Niche - https://www.khanacademy.org/science/ap-biology/ecology-ap/community-ecology/a/niches-competition