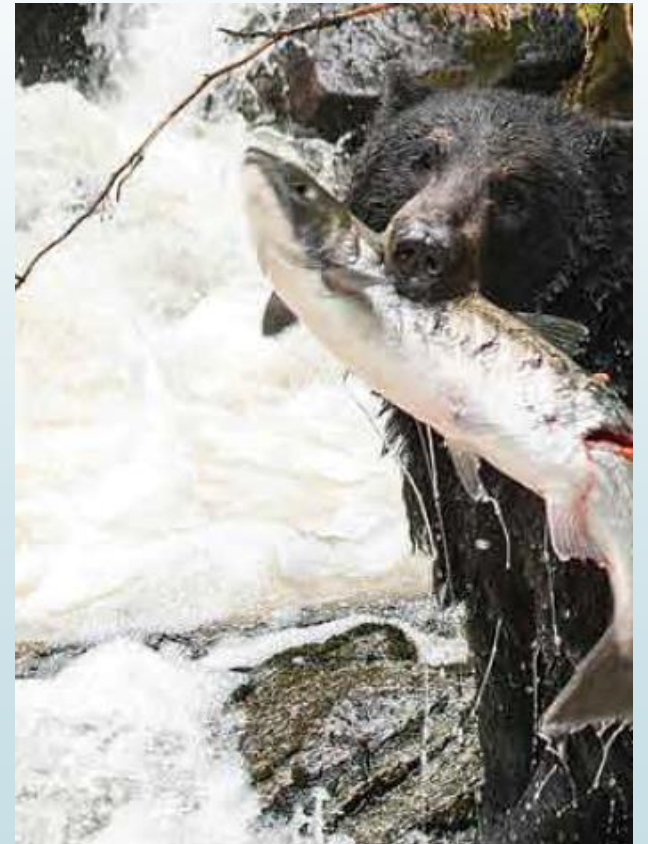


1-3: How can natural and artificial selection
1 influence changes in populations?

Topic 1.3: How can natural and artificial selection influence changes in populations?

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.



Concept 2: Natural selection favours traits that make an organism better suited to its environment.

- [Adaptations increase fitness](#)
- [Mutations cause genetic variation](#)
- Evolution is a change in frequency in traits in a population:
- [Evolution by artificial selection](#)
- Evolution by natural selection:
 - [Principles of Natural Selection](#)
 - [Process of Natural Selection](#)
- [\(miscellaneous other slides\)](#)



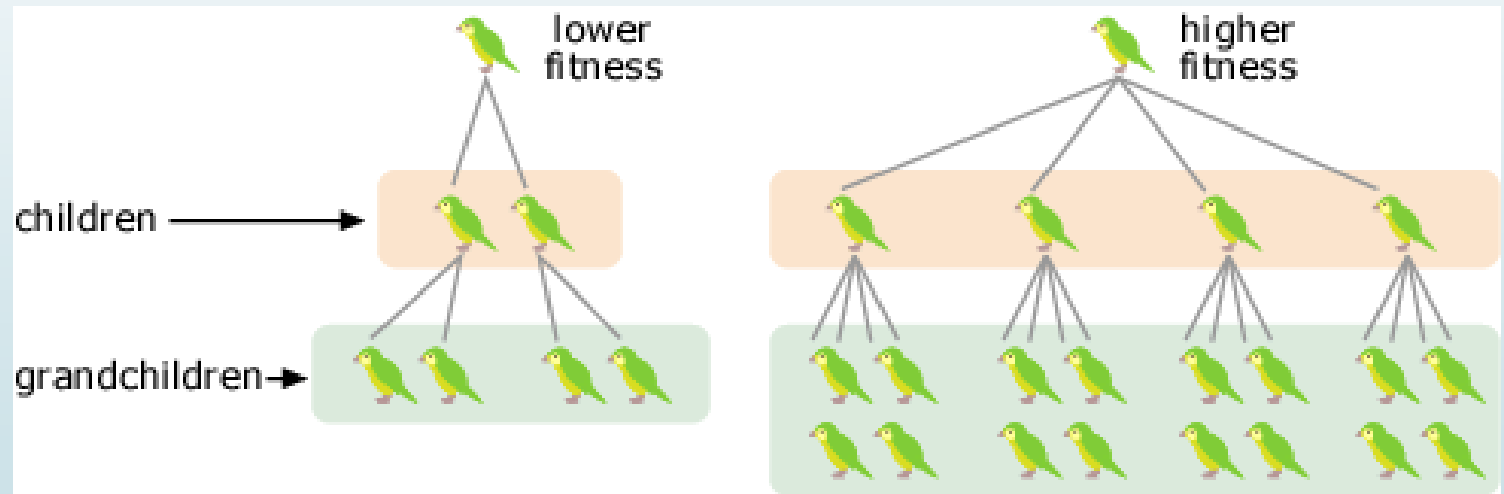
Adaptations Increase Fitness

*What are adaptations?
What is fitness?*

5

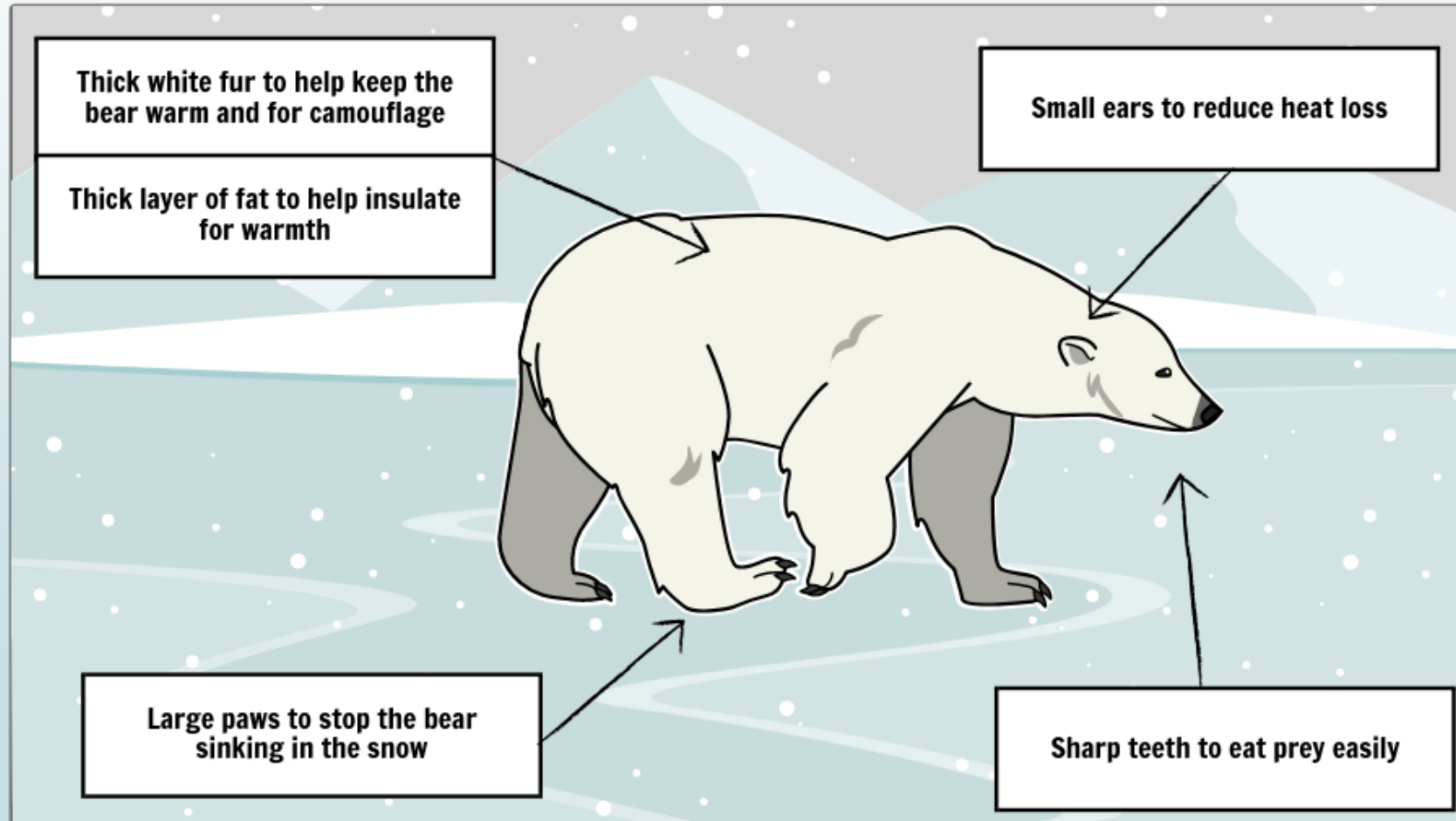
Adaptations Increase Fitness

Fitness: the ability of an individual to survive or reproduce



Adaptations Increase Fitness

Adaptation: heritable trait (trait you are born with) that improves an organism's fitness in its environment



Adaptations Increase Fitness

Overall, evolution results in organisms becoming well-adapted for the environments they live in.

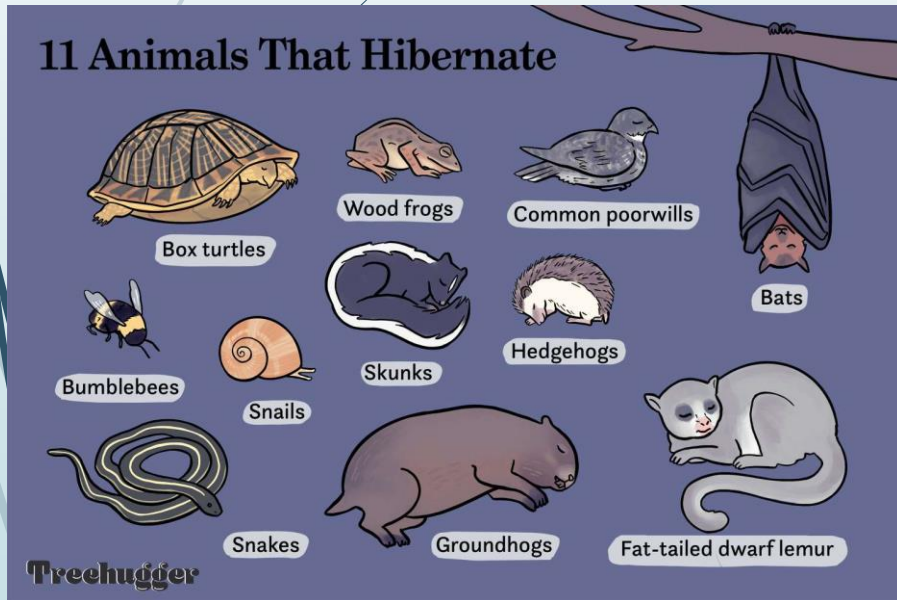
Types of Adaptations:

- **Structural:** body part or colouration (e.g. body armour, camouflage)
- **Behavioural** (e.g. mating rituals, migration)
- **Physiological:** internal functions that help with survival and reproduction including production of special chemicals or hormones (e.g. snake venom, plant nectar, being cold-blooded)

Adaptations Increase Fitness

Practice. Which of the following are adaptations? Explain how they increase fitness. Classify them as structural, behavioural, or physiological.

Hibernation



Adaptations Increase Fitness

Practice. Which of the following are adaptations? Explain how they increase fitness. Classify them as structural, behavioural, or physiological.

Moulting



Adaptations Increase Fitness

Practice. Which of the following are adaptations? Explain how they increase fitness. Classify them as structural, behavioural, or physiological.

Vampire bats share blood meals with 'friends'



Adaptations Increase Fitness

Practice. Which of the following are adaptations? Explain how they increase fitness. Classify them as structural, behavioural, or physiological.

Leaves changing colour



Adaptations Increase Fitness

Practice. Which of the following are adaptations? Explain how they increase fitness. Classify them as structural, behavioural, or physiological.

Peacock feather colours in male (left) and female (right)



Adaptations Increase Fitness

Practice. Which of the following are adaptations? Explain how they increase fitness. Classify them as structural, behavioural, or physiological.

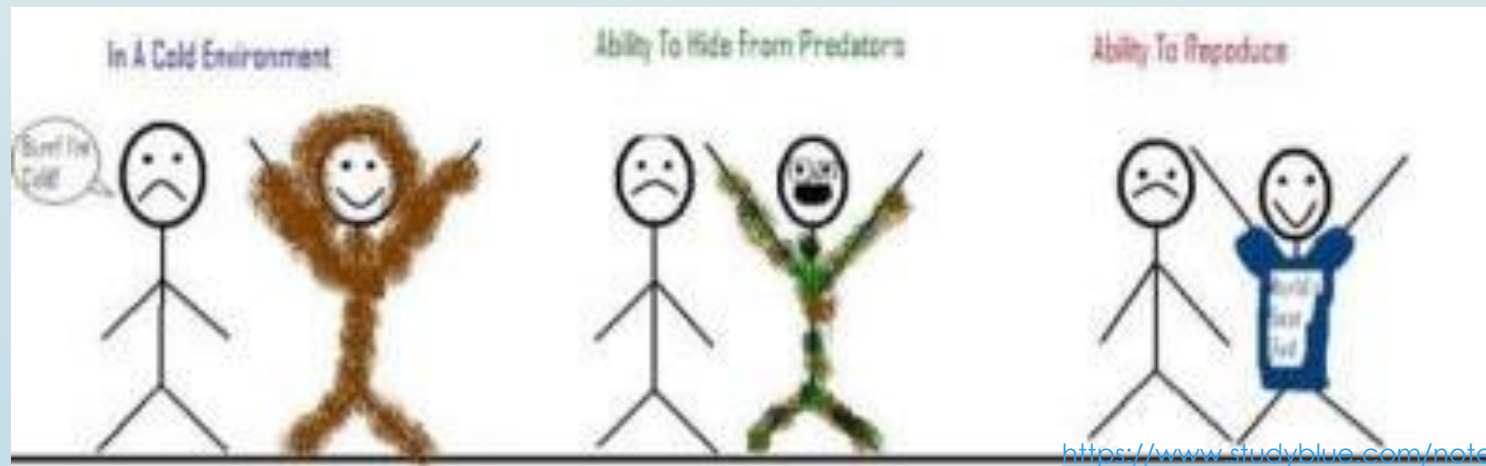
Red-winged blackbird male (left) and female (right)



Adaptations Increase Fitness

Organisms often have adaptations for:

- Tolerating environment (climate)
- Finding food
- Avoiding predation
- Movement (locomotion)
- Attracting mates
- ...and more!



Adapting to Climate

Can you maintain a 'healthy' body temperature? Can you get enough water? Can you handle harsh weather?

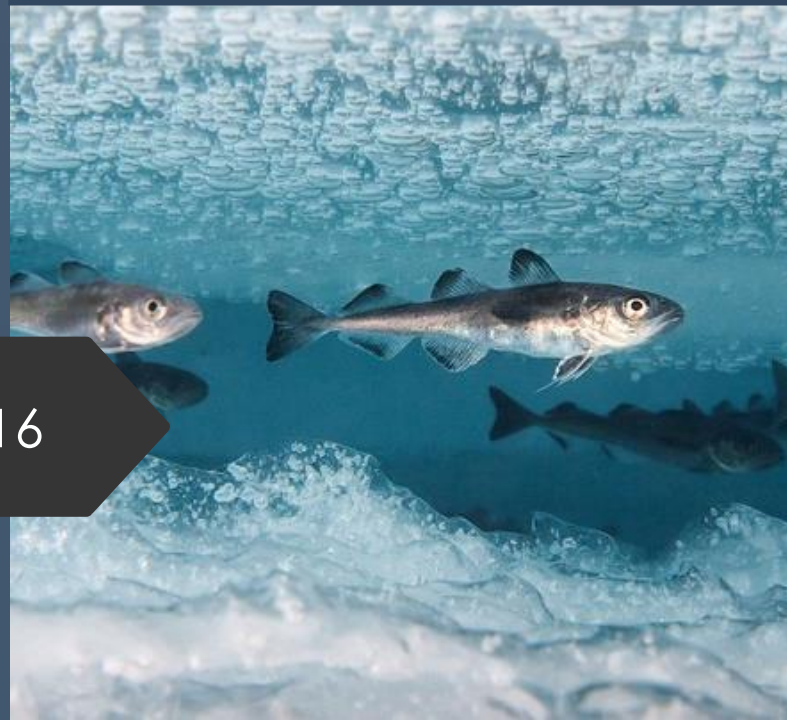
15



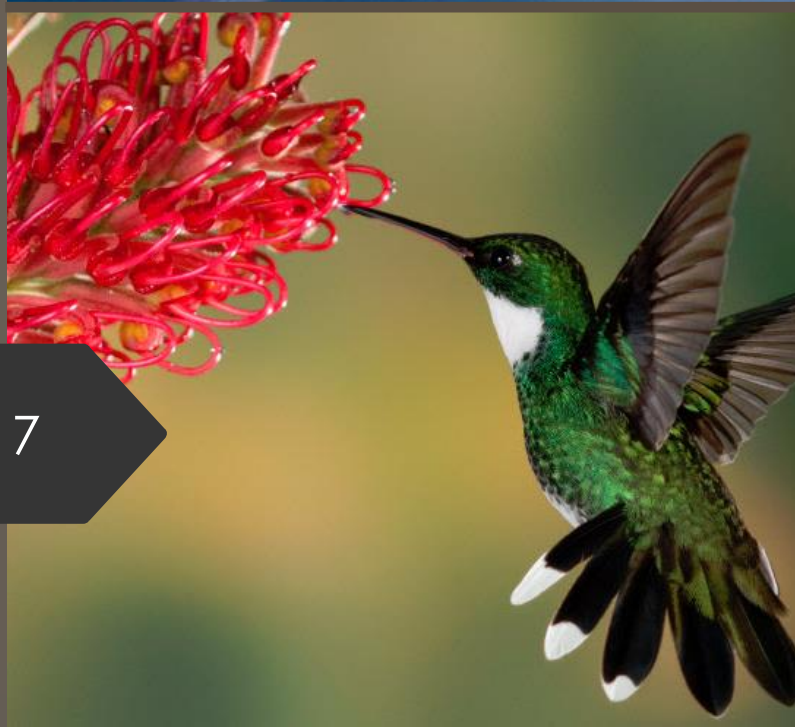
Adapting to Climate

Can you maintain a 'healthy' body temperature? Can you get enough water? Can you handle harsh weather?

16

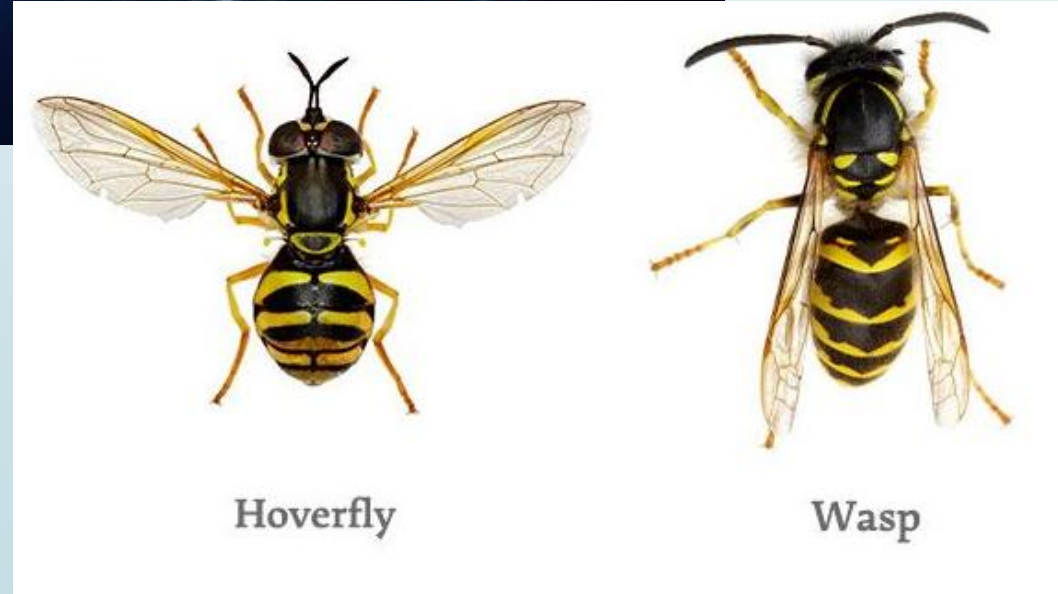


Finding Food



Avoiding Predation

Can they run away, hide, or fight back? Do they taste bad? Do they look like a species that tastes bad?



Movement (Locomotion)

*How do they move around
efficiently in their environment?*

19

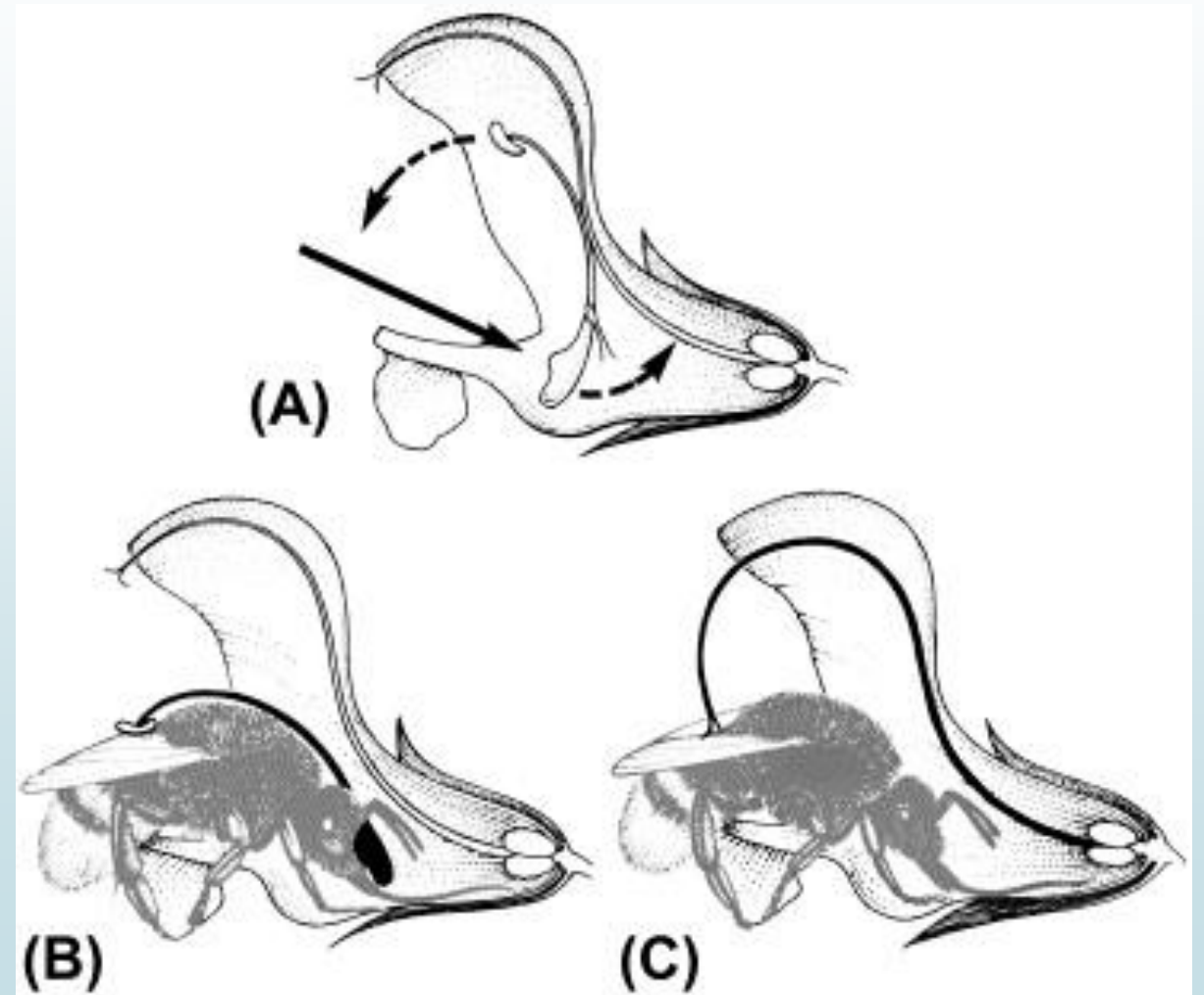




https://www.youtube.com/watch?v=CAQuoH_fOWM&ab_channel=BBCEarth

Attracting Mates

Are you 'attractive' to members of the opposite sex? Can you fight off competitors?



Attracting Mates

Are you 'attractive' to members of the opposite sex? Can you fight off competitors?



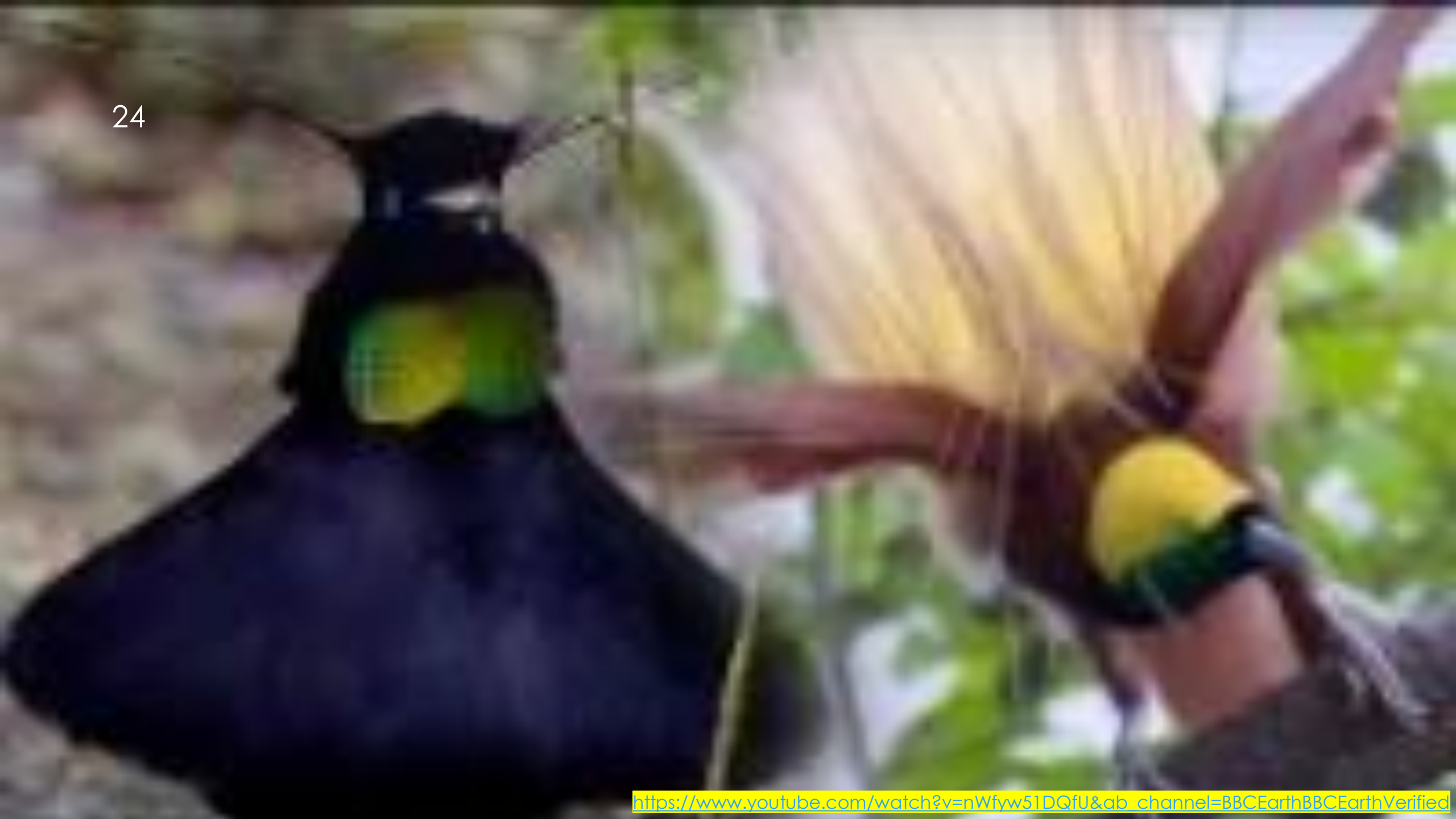
https://www.allaboutbirds.org/guide/Black-capped_Chickadee/sounds

Attracting Mates

Are you 'attractive' to members of the opposite sex? Can you fight off competitors?



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Adaptations Increase Fitness

Activity:

Research and record 3 examples of adaptations. For each adaptation:

- Describe the adaptation.
- Classify the adaptation as structural, behavioural, or physiological.
- Explain how the adaptation increases the organism's fitness in its natural environment.

Examples of Adaptations:

<https://www.thoughtco.com/adaptation-definition-2291692>

<http://www.animalplanet.com/wild-animals/animal-adaptations/>

<https://www.nationalgeographic.org/encyclopedia/adaptation/>

Adaptations Increase Fitness

“Mice with brown fur have low fitness. They adapt to their environment by changing to white fur.”

Can't change what you are born with!



“When the forest burned down, the owls lost their home. So they adapted to their situation by learning to dig holes in the ground to live in.”

Learning isn't that easy! By the same logic:

- Mice would learn to avoid mousetraps
- Squirrels would never be hit by cars
- Birds would never fly into windows

Adaptations Increase Fitness

Most living things are **not** intelligent.

They do not adapt to their environments on purpose during their lifetimes. They are born with an adaptation or they are not.

“Elephants’ large ears are an adaptation that helps them to dissipate heat from their bodies.”



“Many fish exhibit counter-shading, an adaptation to help with camouflage.”
(counter-shading: dark on top, light on bottom)

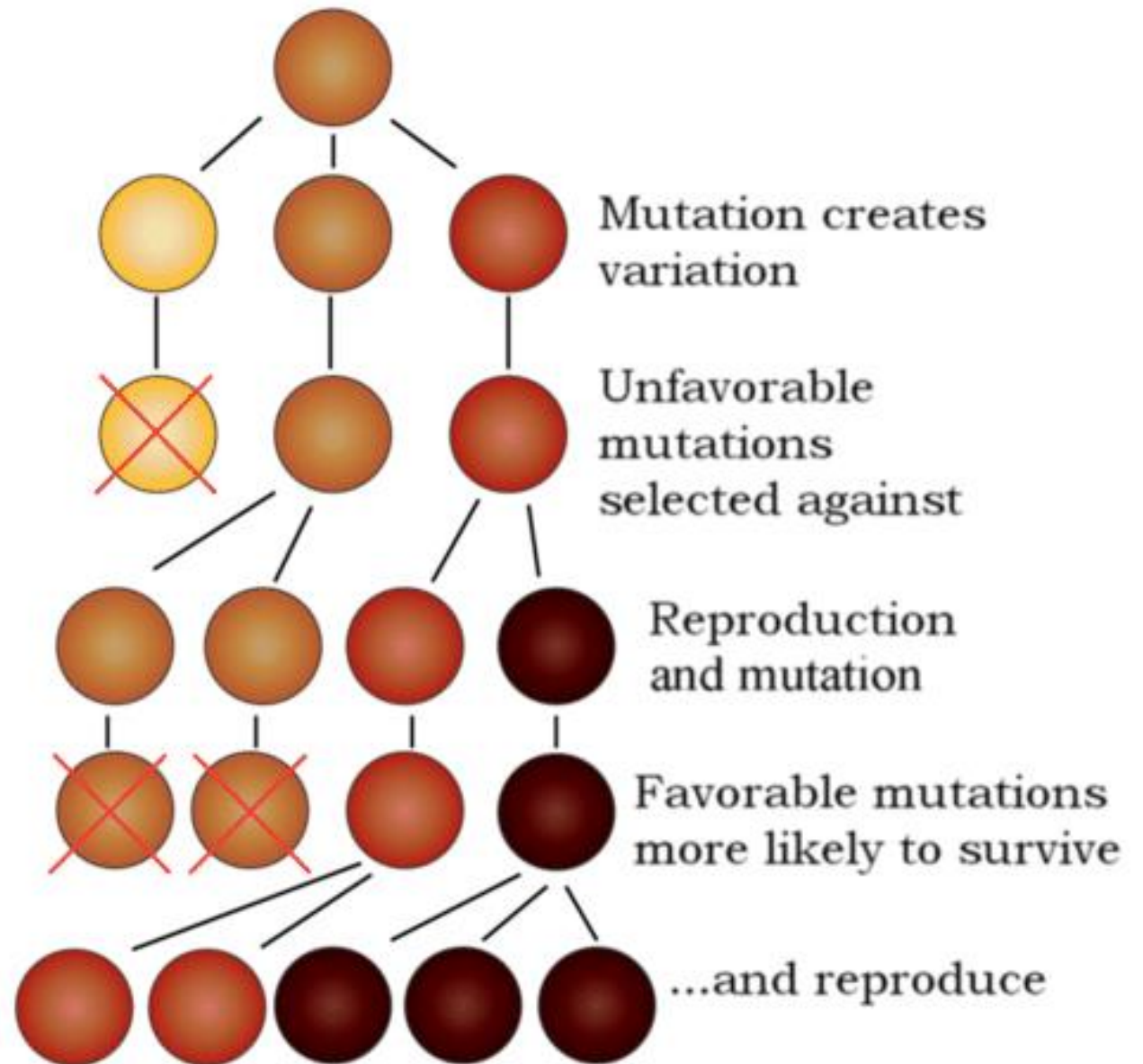


But how do adaptations evolve, if there is no intelligent plan? What happens if the environment changes? How do they adapt?

Mutations Provide the Variation Required for Adaptations to Evolve

What is evolution?
Where does variation come from?

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Mutations

Mutations: a permanent change in the genetic material of an organism

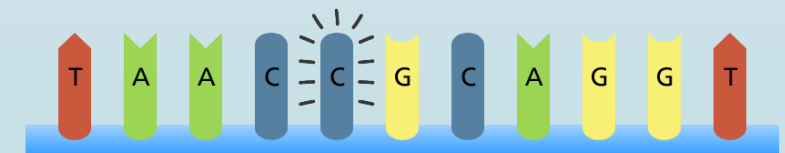
- Errors occur randomly during DNA replication
- Mutations can be good, bad, or have no effect

Whether a mutation is good, bad, or neutral depends on **selection**...more on this later!

Original sequence



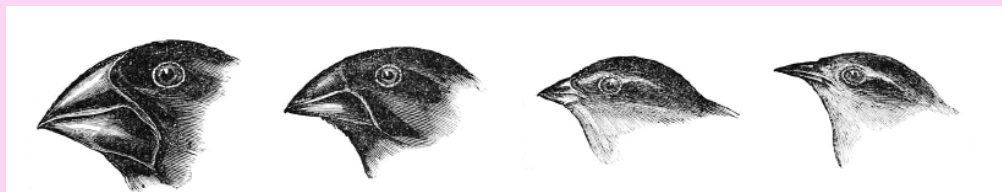
Point mutation



Review: What is Variation?

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.

Programming Analogy

32

You are a computer programmer for Microsoft. You have been asked to make Microsoft Word more modern and more 'useful'. Every time you change the code, one of several things happens:

Your whole code breaks. The program doesn't work anymore.

Undo your changes.

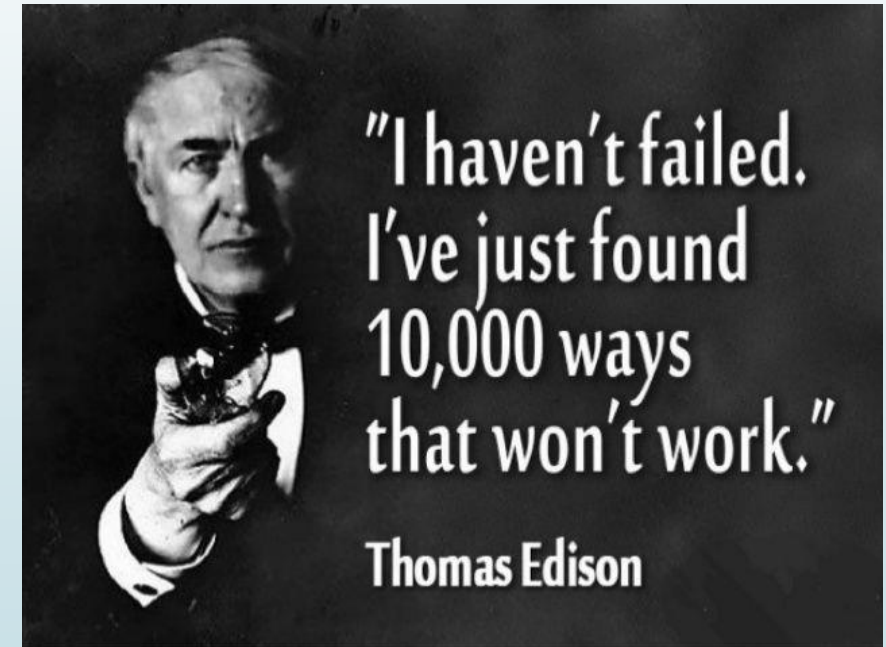
Nothing happens.

Keep or undo changes; it doesn't matter. (Or does it?)

Your program changes a little.

Keep the changes. (Hopefully you didn't accidentally mess something else up.)

Your change improves the program!



In biology, adaptations ('improvements') arise through random trial and error. Mutations (changes to DNA) regularly occur; then, bad changes are weeded out naturally, while good changes persist.

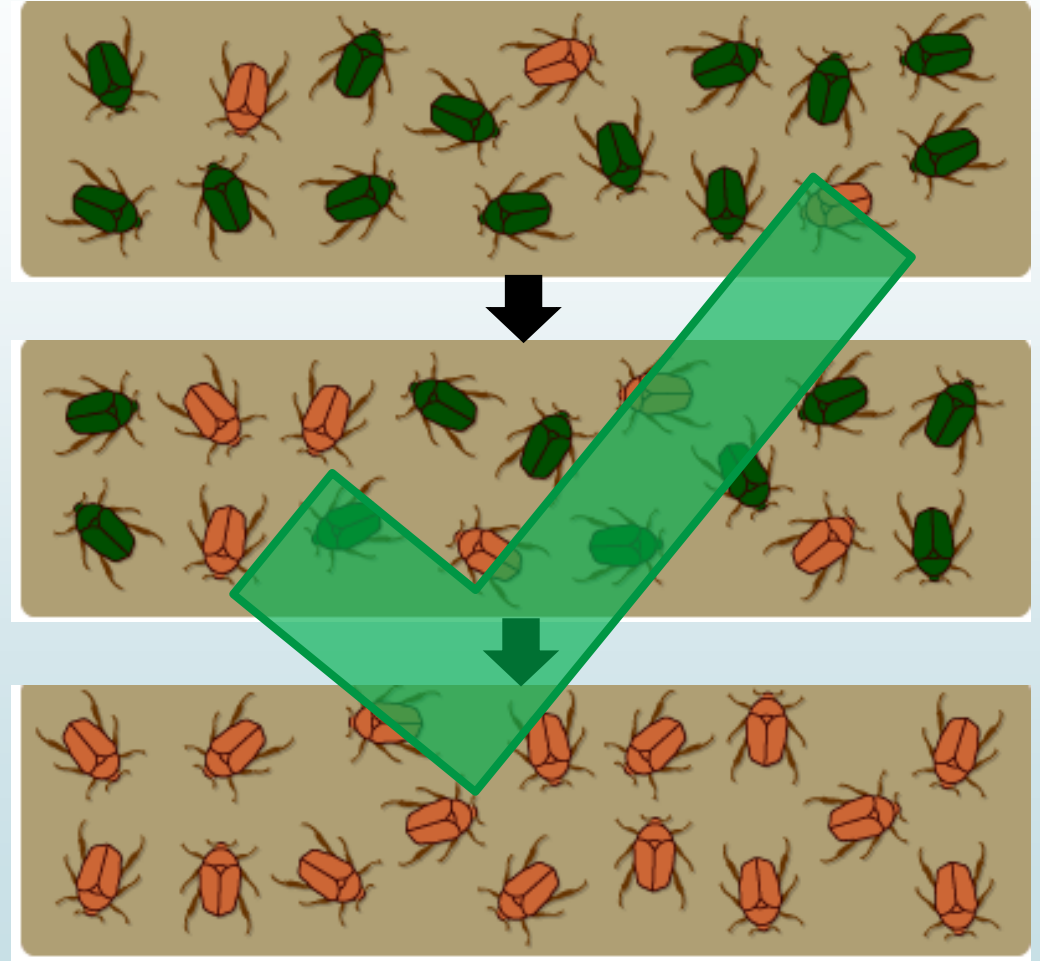
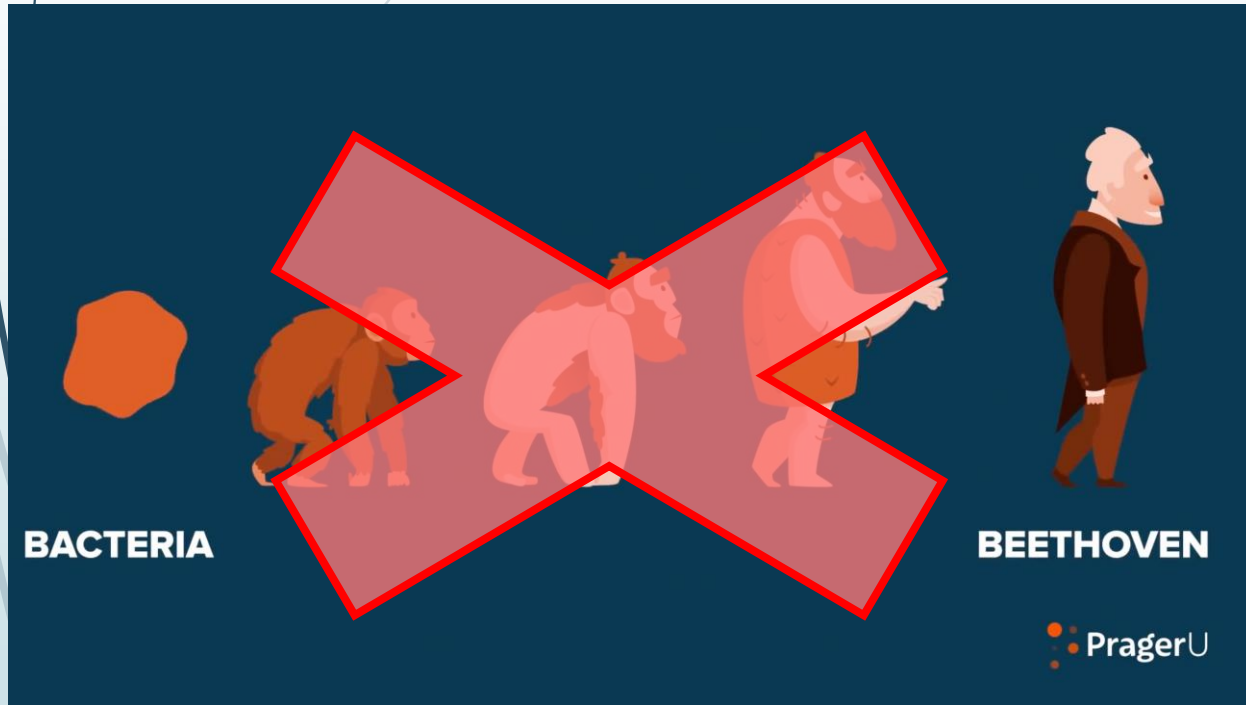
What is Evolution?

Warm-Up Discussion

What is evolution?

What are some images, examples, and ideas that come to mind?

What is Evolution?



What is Evolution?

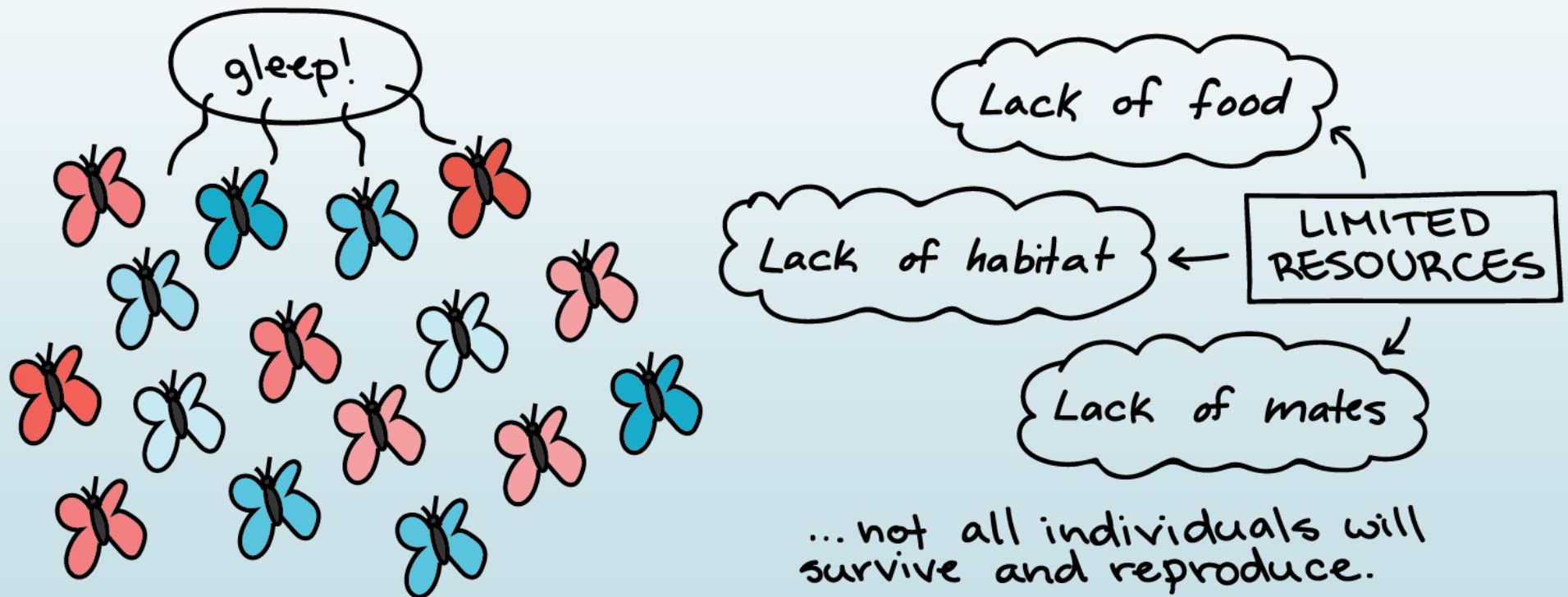
The several requirements for evolution:

1. Overproduction
2. Variation
3. Selection

...Evolution!

Requirement 1: Overproduction

More offspring are produced than survive and reproduce.



Requirement 1: Overproduction

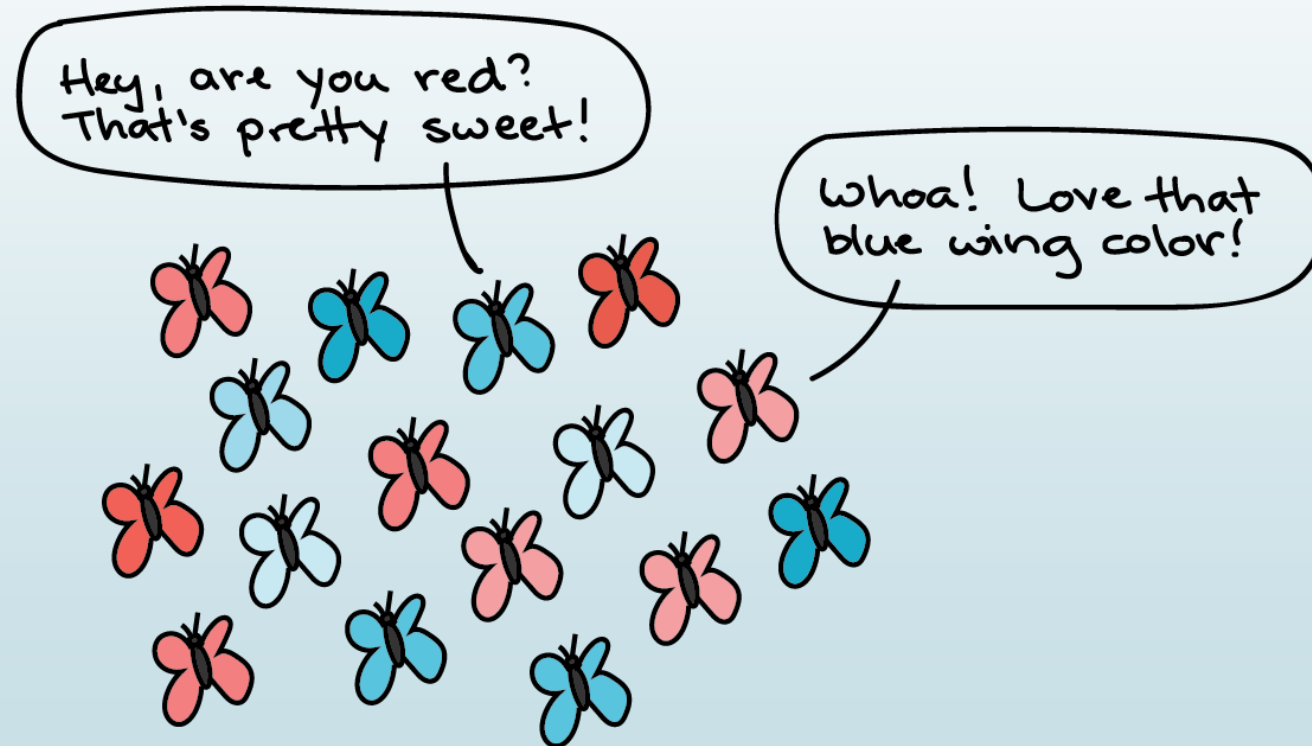
More offspring are produced than survive and reproduce.

The environment has a limited number of resources. Each generation has too many offspring for the environment to support. The individuals compete for limited resources, with some being more successful than others at survival and/or reproduction.



Requirement 2: Variation

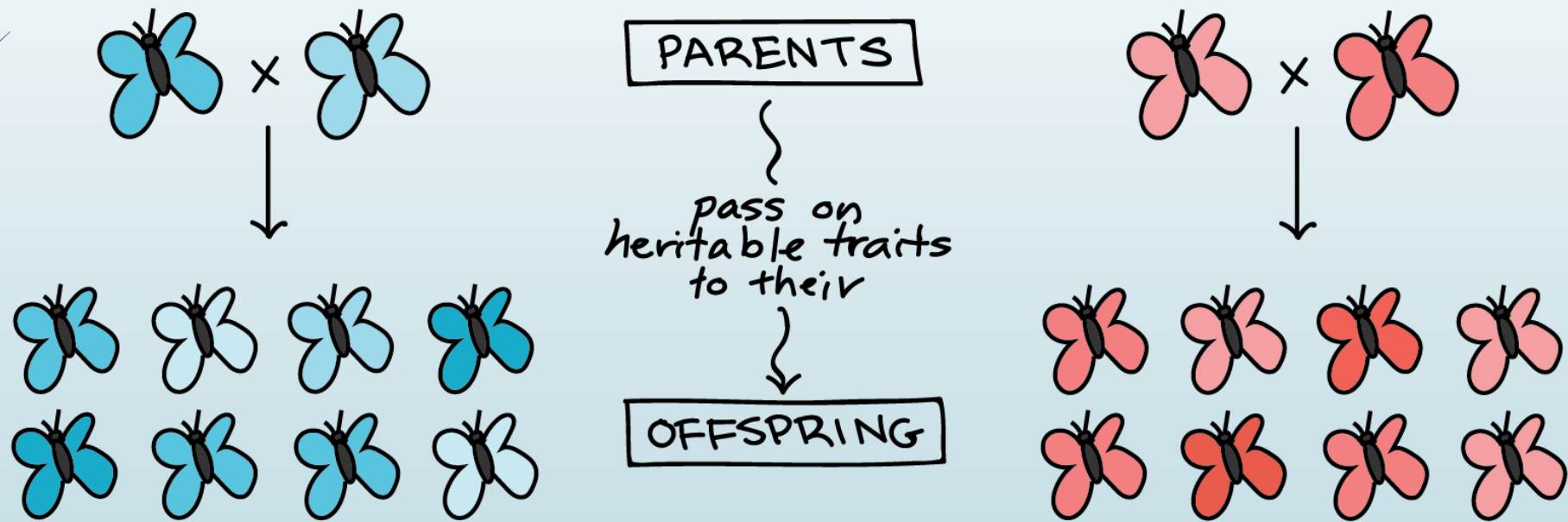
There is natural variation of heritable traits in the population.



* Butterflies do not actually talk! cartoon for cute illustration purposes only 😊

Requirement 2: Variation

There is natural variation of heritable traits in the population.



Requirement 2: Variation

There is natural variation of heritable traits in the population.

Examples:

- Appearance
- Intelligence
- Tolerance to heat, cold, dehydration
- Resistance to disease
- Ability to find and digest food
- Attractiveness to potential mates
- Locomotion efficiency/speed
- Social behaviour
- Communication (voice, song)
- ...etc.



Requirement 2: Variation

There is natural variation of heritable traits in the population.



Zebra finch
(*Taeniopygia guttata*)

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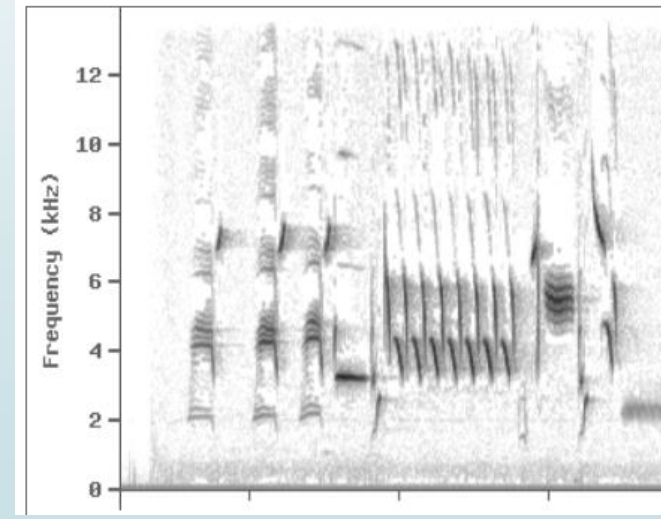
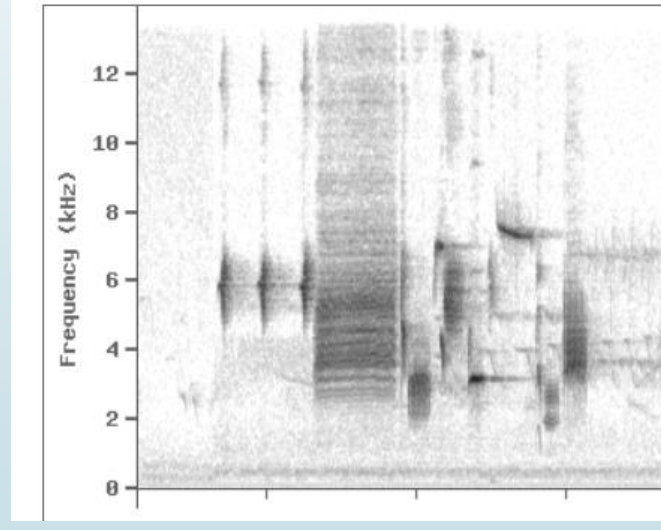
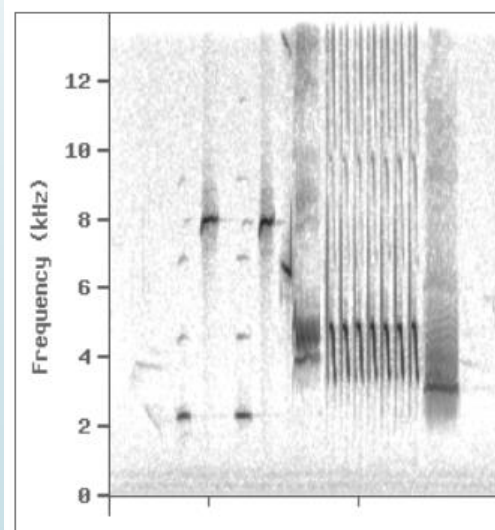
Requirement 2: Variation

There is natural variation of heritable traits in the population.

Song sparrow
(*Melospiza melodia*)



Audio: <https://www.natureinstruct.org/dendroica/spec.php/Canada>



Requirement 2: Variation

Variation = differences between individuals

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



Requirement 3: Selection

Selection determines which members will be more successful at surviving and reproducing than others.

The most successful pass on their genes more; their traits are most common in the next generation.

Types of selection:

- Artificial Selection (humans choose)
- Natural Selection (nature/environment chooses)

Runaway Selection (FYI only)

“Why can't penguins and horses fly? Why aren't humans' brains bigger?”

Most traits have drawbacks or physical constraints. This keeps biological systems in check.

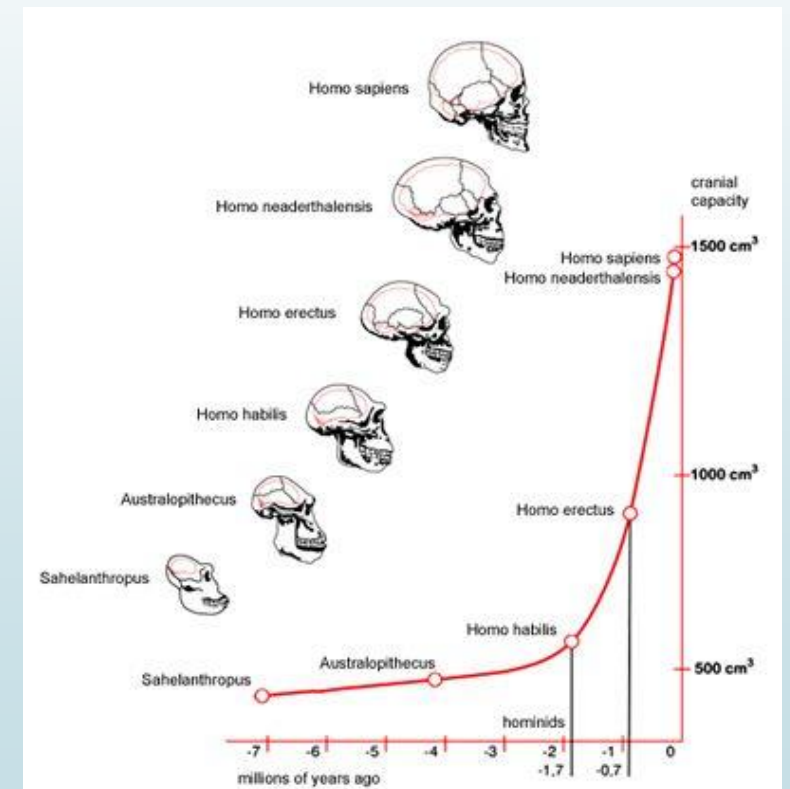


Figure 2. The growth rate of hominid cranial capacity began to rapidly increase starting around two million years ago. Figure adapted from Le Journal du Net (2010).

Runaway Selection (FYI only)

“Tenchi Souzou Design-bu”



Giraffe Excerpt

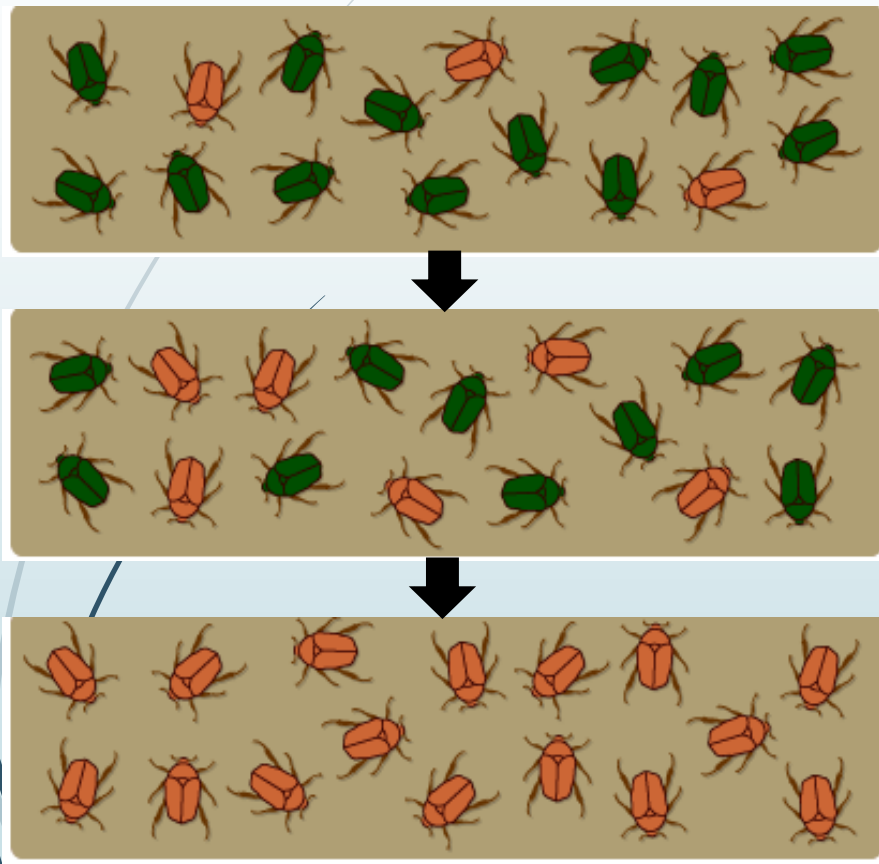
https://www.youtube.com/watch?v=jl85dL3ooVU&ab_channel=CrunchyrollCollection



Unicorn Excerpt

https://www.youtube.com/watch?v=6SHQoFgZYYI&ab_channel=CrunchyrollCollectionCrunchyrollCollectionVerified

What is Evolution?



Evolution:

- Evolution is a change in frequency of heritable traits in a population over many generations*
- Evolution can produce adaptations

*In simpler terms, evolution is when some traits become more or less common over time



Evolution by Artificial Selection

Humans can be the driving force of evolution when they choose which individuals to reproduce



What do you think the sausage dog was selectively bred for?



- Hunting lions
- Guard dog
- For aristocracy to rest their feet on
- Chasing rabbits down their holes

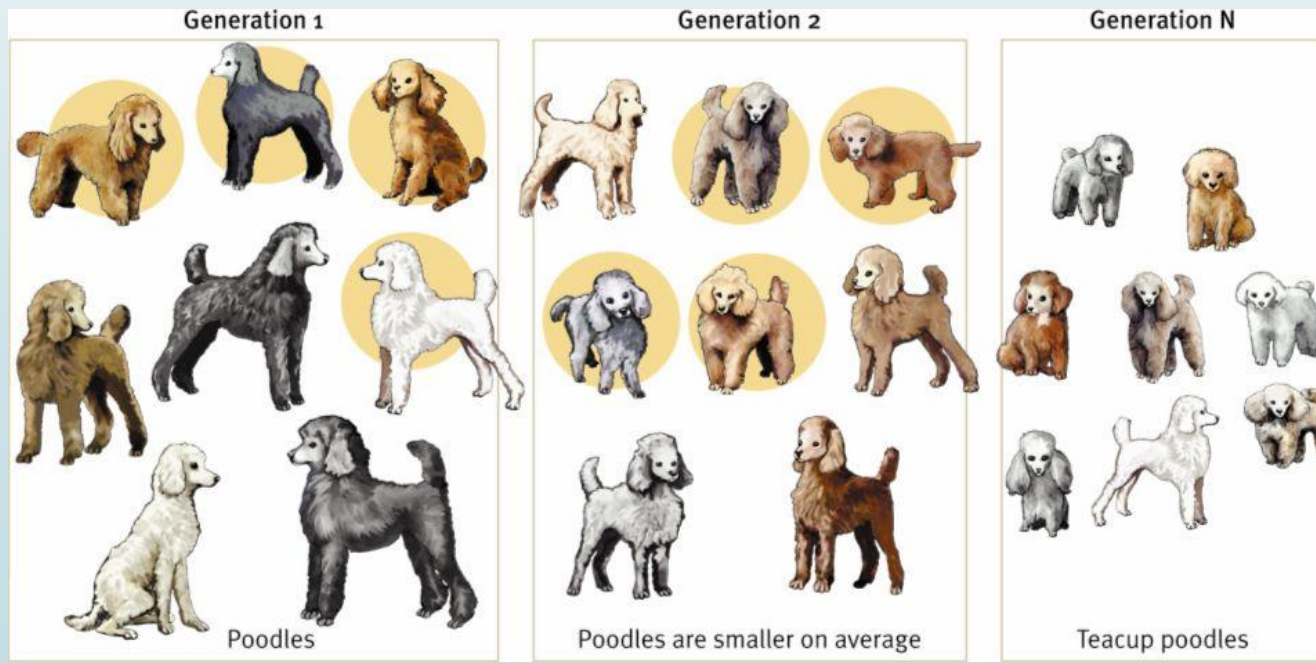
Evolution by Artificial Selection: Case Study 1

You are a dog breeder. Teacup (very small) dogs are in high demand and are worth a lot. How can you raise the smallest dogs possible?



Evolution by Artificial Selection: Case Study 1

1. You pick which dogs are allowed to breed (**overproduction**).
2. Your dogs differ in size (**variation**).
3. Pick the smallest ones to breed and pass on their traits. (**artificial selection**). Repeat for multiple generations.
4. Voila! You have very small dogs. (**evolution**).



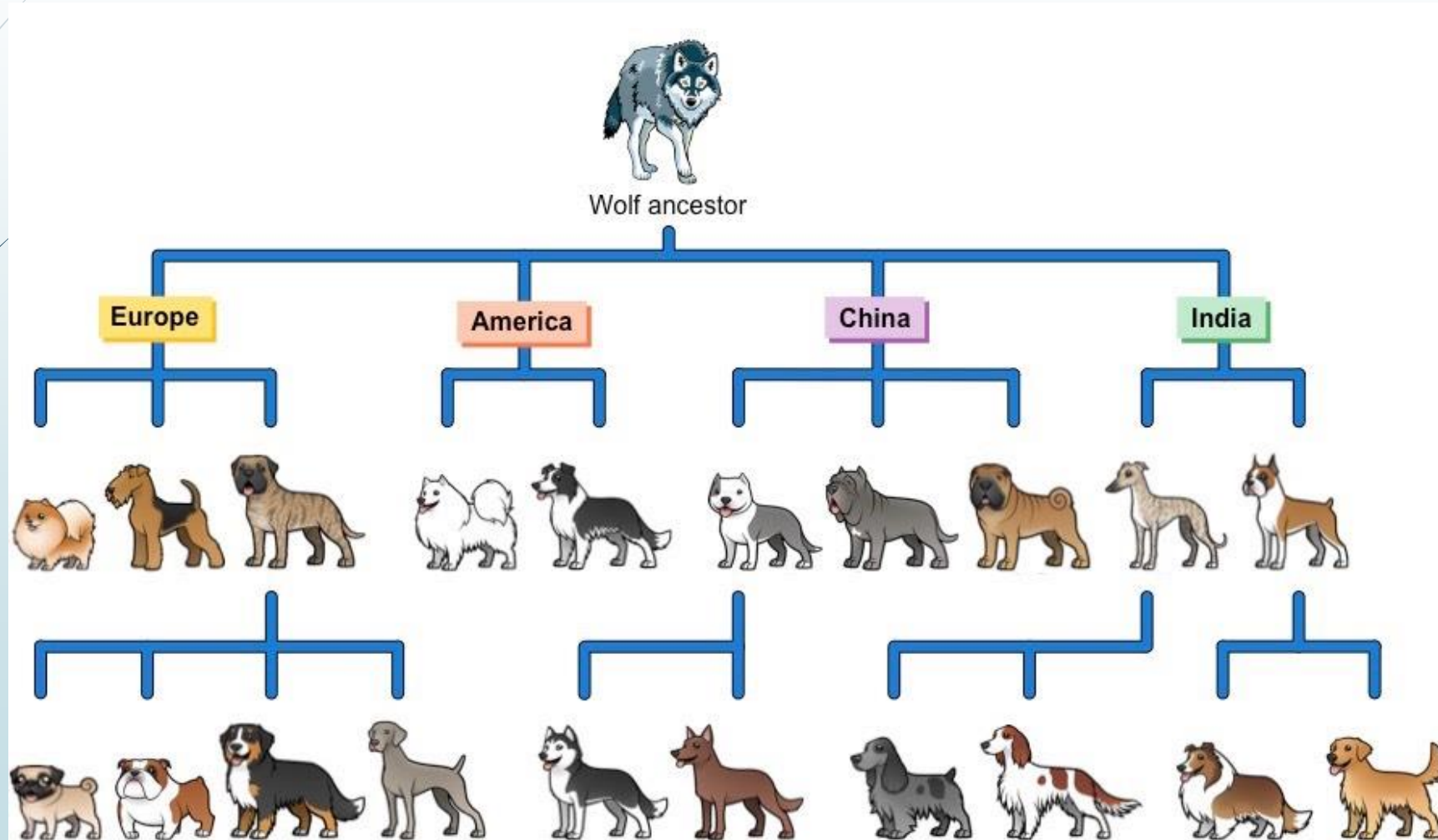
Evolution by Artificial Selection: Case Study 2

You are a farmer growing beans. You have noticed that the climate is changing and growing warmer. Tall bean plants do best in warm weather. How do you maximize your profits and ensure that your farm succeeds?

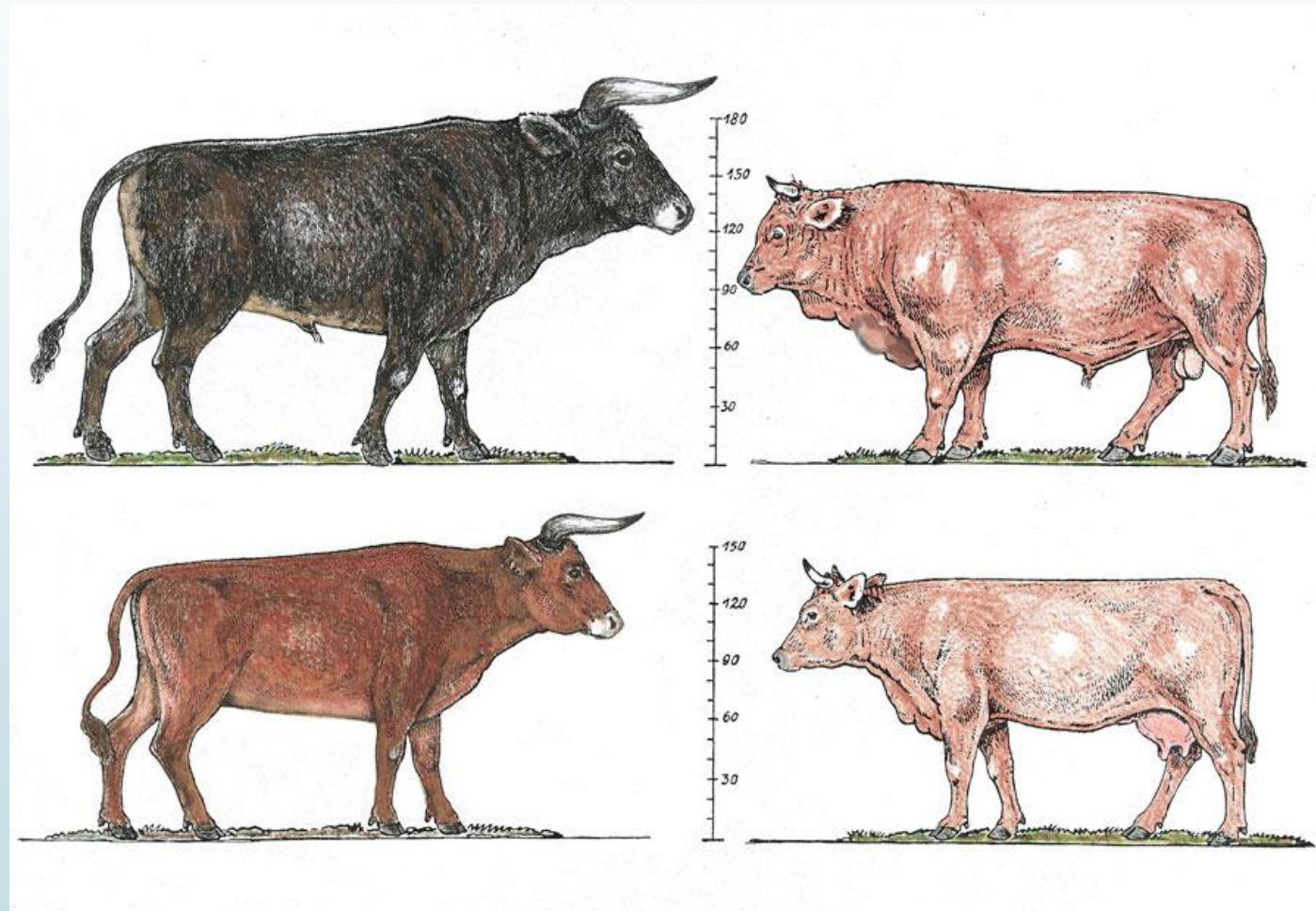
Evolution by Artificial Selection: Case Study 2

1. Not all plants will survive and reproduce: you will pick seeds from the 'best' (**overproduction**).
2. Look at the plants you have. Some are taller than others (**variation**).
3. Pick the tallest plants and collect seeds from them (**artificial selection**). Plant those seeds but destroy the rest. Repeat for multiple generations.
4. Voila! Your plants will, on average, be taller (and more heat-resistant) than before (**evolution**).

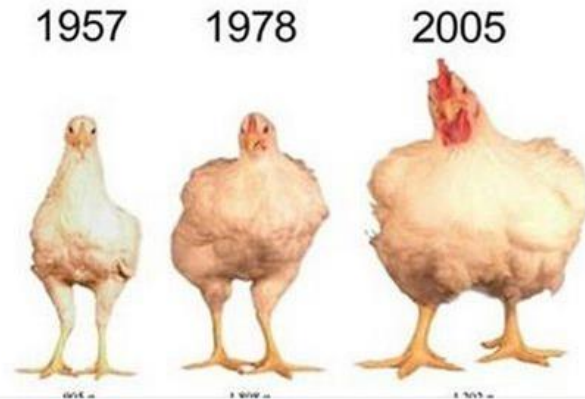
Evolution by Artificial Selection: Other Examples



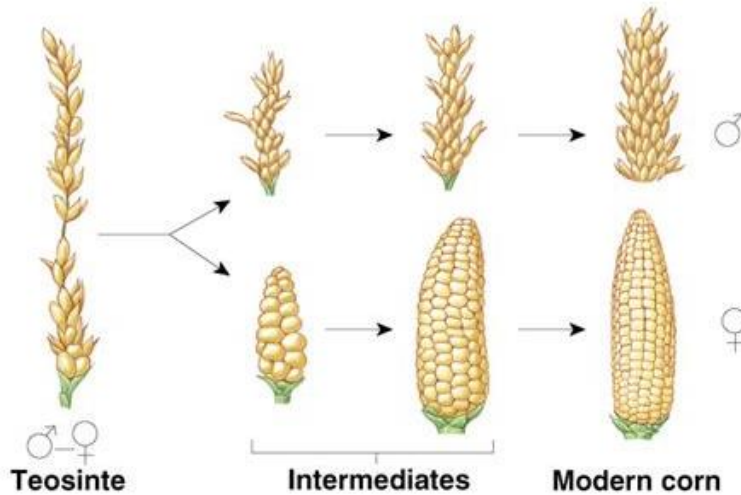
Evolution by Artificial Selection: Other Examples



Evolution by Artificial Selection: Other Examples



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Evolution by Artificial Selection

Artificial selection: humans choose individuals with certain desirable characteristics survive and reproduce the most

1. Overproduction
2. Variation
3. Artificial selection: survival and reproduction of individuals with desirable traits
4. Evolution and Adaptation

Artificial Selection vs Natural Selection

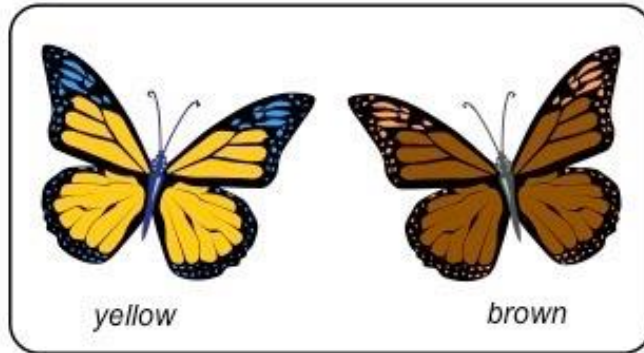
- Caused by humans
 - Has a goal/purpose in mind
 - Usually shorter time scale
 - Result: breeding goal achieved, sometimes at the cost of the ecosystem or health of the species
- Caused by environmental factors
 - Has no goal/purpose; occurs naturally as a result of variation and fitness differences
 - Time scale depends on strength of selective pressure
 - Result: adaptation OR extinction



Evolution by Natural Selection

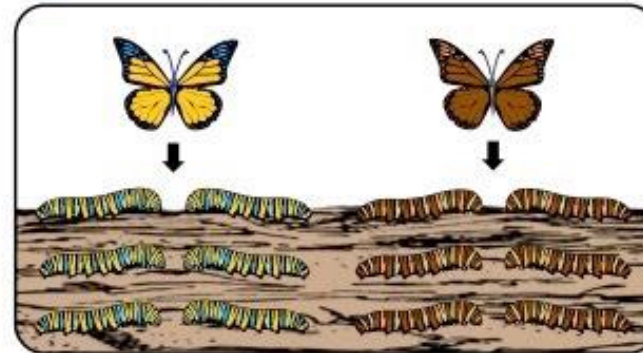
Evolution by Natural Selection

1 Variation



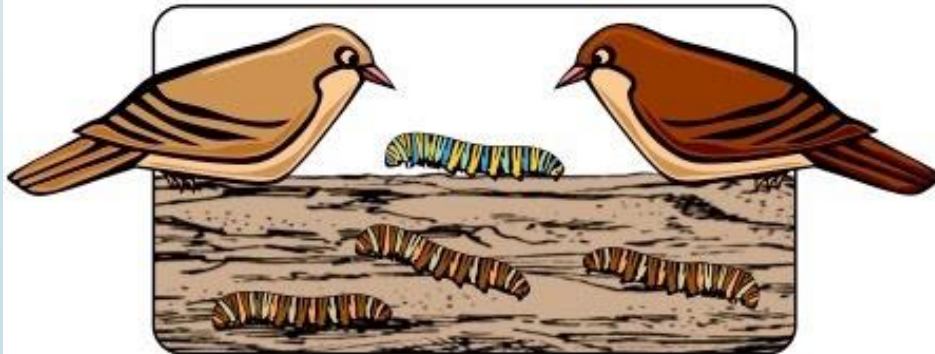
There is genetic variation within a population which can be inherited

2 Competition



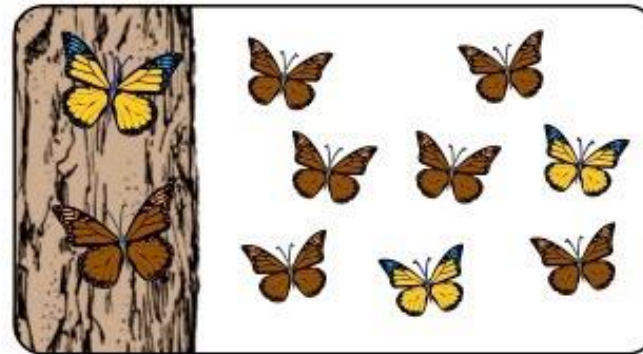
Overproduction of offspring leads to competition for survival

3 Adaptations



Individuals with beneficial adaptations are more likely to survive to pass on their genes

4 Selection



Over many generations, there is a change in allele frequency (evolution)

Evolution by Natural Selection

Natural selection: the 'most fit' individuals (i.e. those with adaptive traits) survive and reproduce the most

1. Overproduction
2. Variation
3. Natural selection: survival and reproduction of the fittest
4. Evolution and Adaptation

Survival and Reproduction of the Fittest

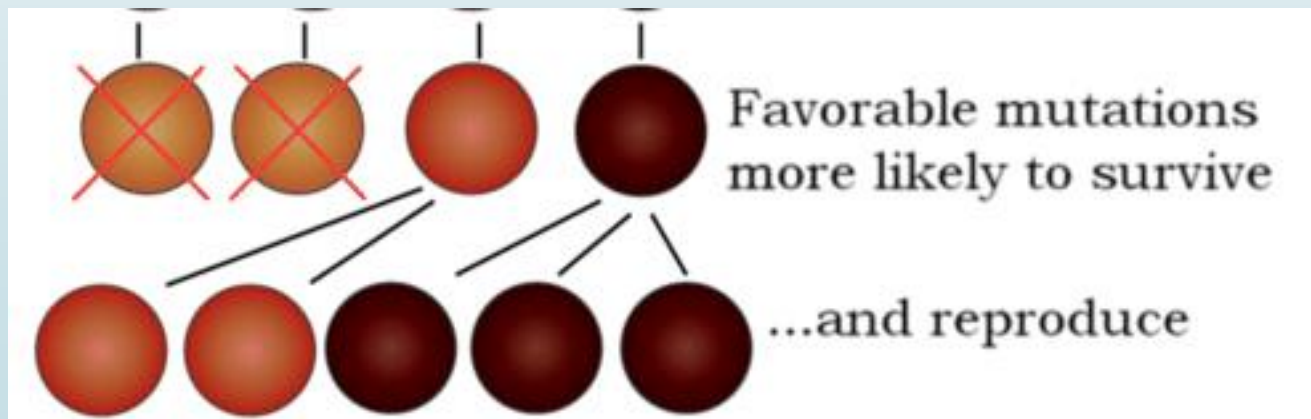
Selective pressures:

- Aspects of a specific habitat/environment that affect fitness (e.g. disease, climate, competition for food or mates)
- Some individuals are favoured over others (***selective advantage***), depending on their traits.

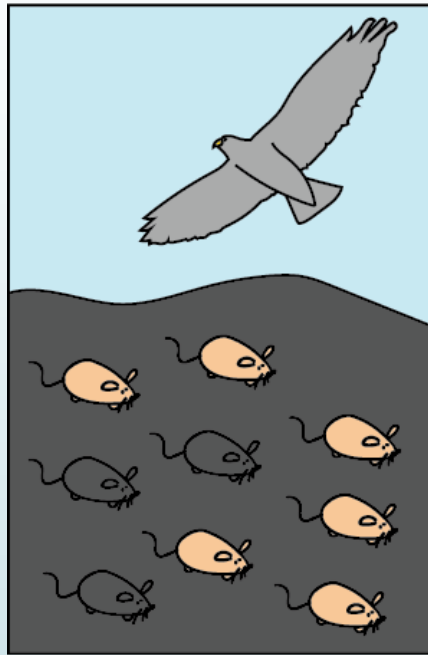
Survival and Reproduction of the Fittest

Individuals with a selective advantage reproduce and pass on their traits the most.

Over time, traits that increase fitness (adaptations) become more common.

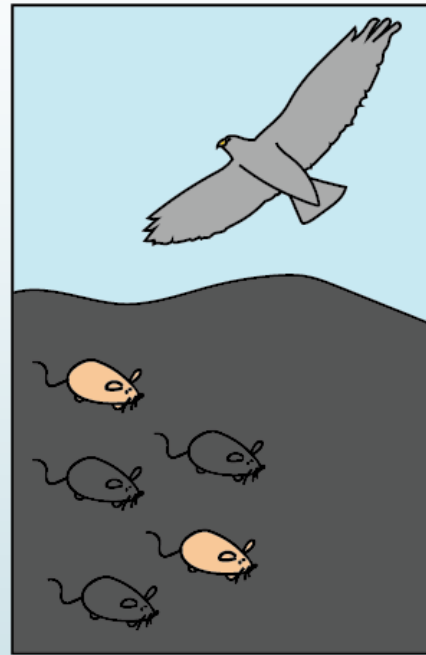
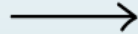


Survival and Reproduction of the Fittest



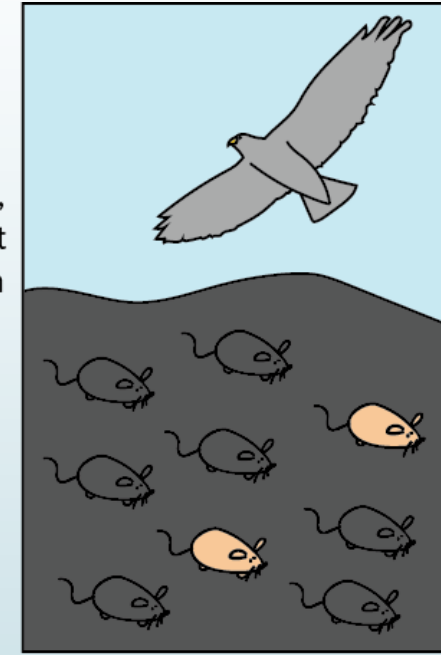
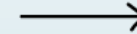
A population of mice has moved into a new area where the rocks are very dark. Due to natural genetic variation, some mice are black, while others are tan.

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

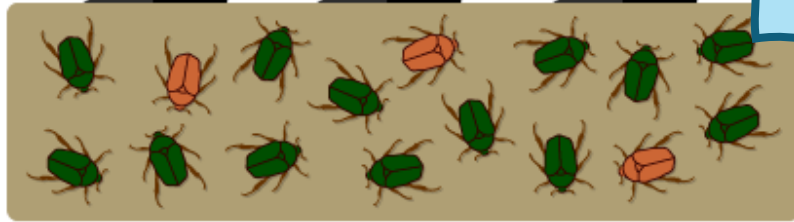


Because black mice had a higher chance of leaving offspring than tan mice, the next generation contains a higher fraction of black mice than the previous generation.

Survival and Reproduction of the Fittest

Natural selection, in a nutshell:

Yum! Green beetles! Our favorite!



...generations later...

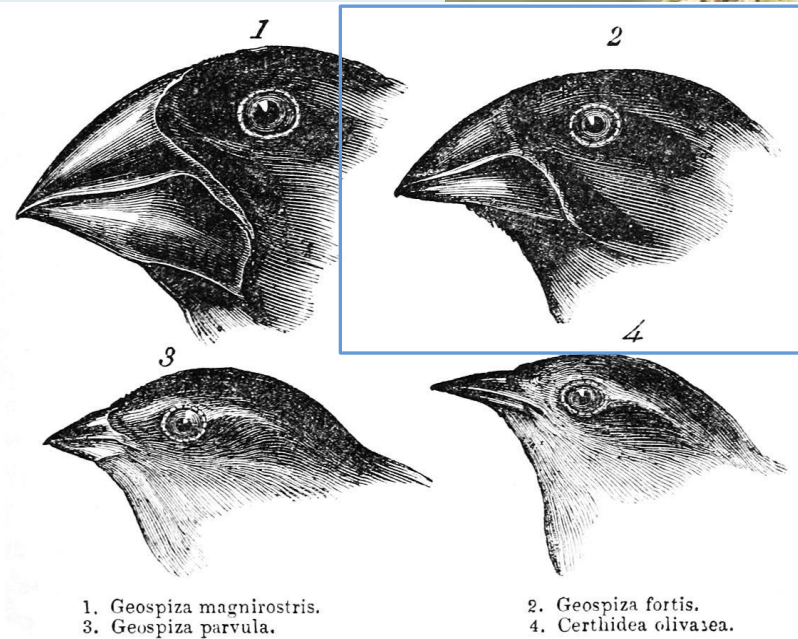


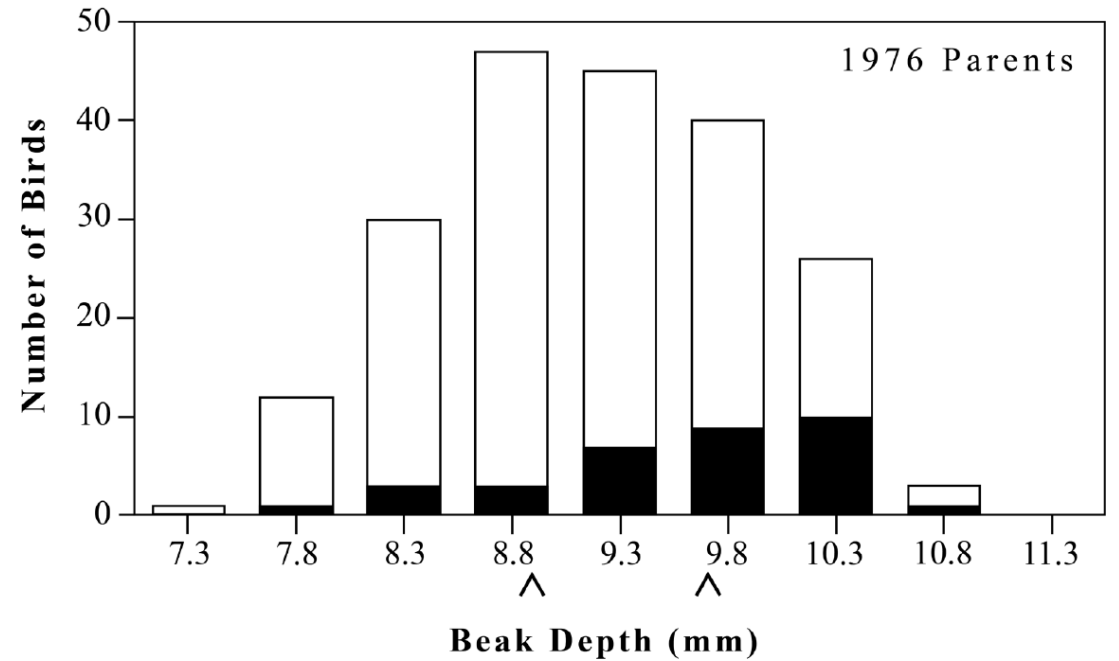
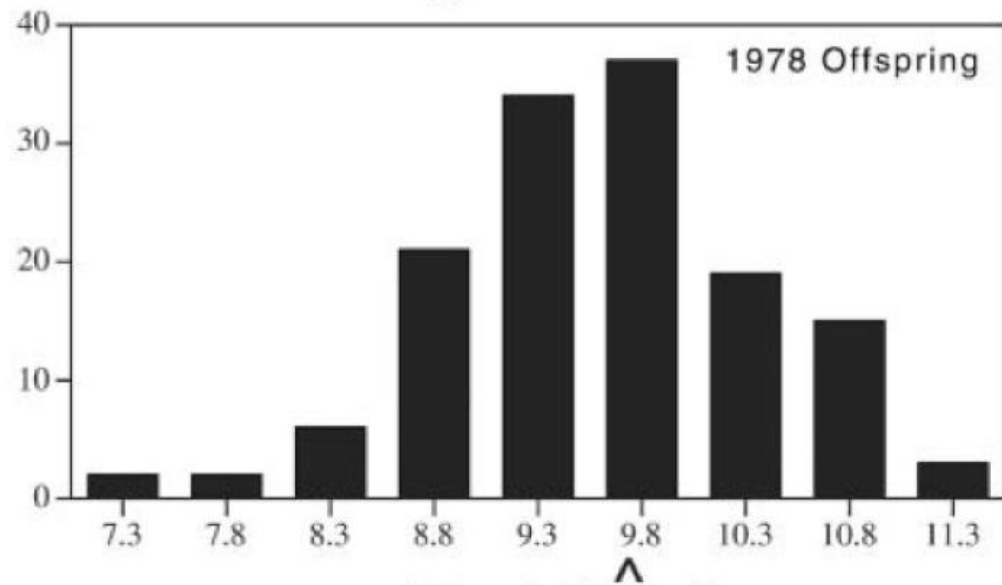
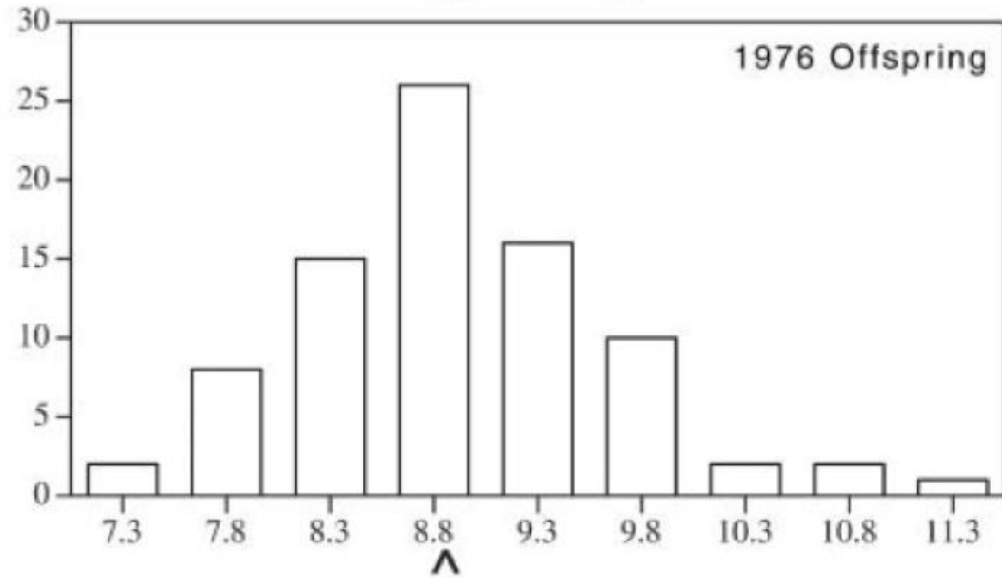
...generations later...



Green beetles have been selected against, and brown beetles have flourished.

Case Study: Finches in the Galapagos





Severe drought in 1977 (selective pressure):
small seeds scarce

Big beaks = good for eating large seeds
Small beaks = good for eating small seeds

Finches with bigger beaks had a higher fitness.

Evolution happened in just two years! How!?

Populations Evolve and Adapt by Natural Selection

- Over many generations, adaptive traits becomes more and more common. Non-adaptive traits become rare. The population becomes better adapted to their environment.
- **Remember: evolution** is the change in the heritable traits of a population over many generations.

Peppered Moth Case Study

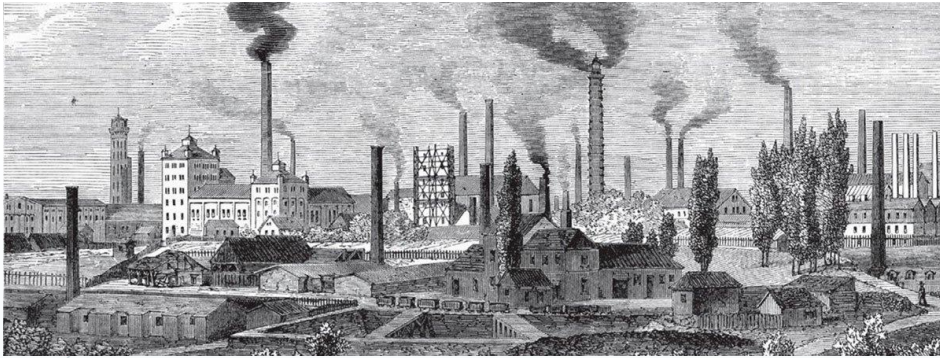
1. Overproduction:

Birds eat moths. Not all moths survive.

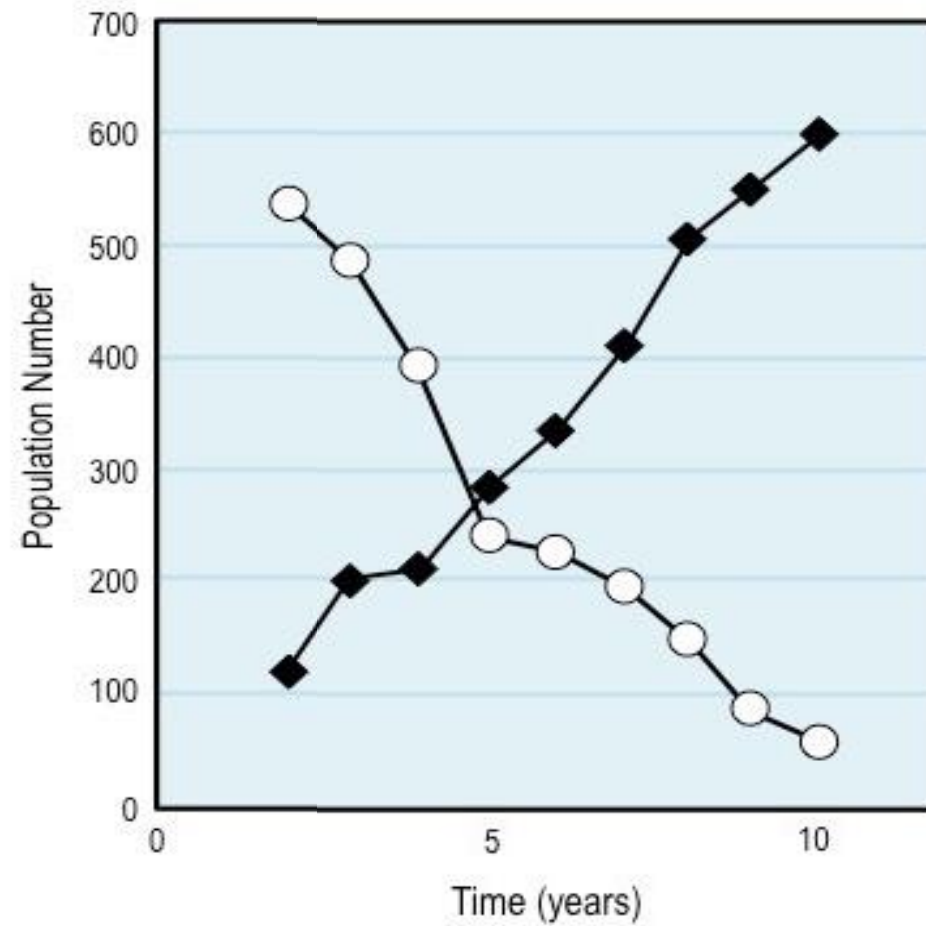
2. Variation:

Some moths are black. Most moths are white.





**Pre-Industrial
Revolution**



**Post-Industrial
Revolution**

Evolution by Natural Selection

3. **Selective Pressure:** 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.
4. **Adaptation/Evolution:** over time, the proportion of black moths in the population increased. Evolution had occurred.

Why do you suppose the non-favoured variants were never completely wiped out from the population?

Evolution of Antibiotic Resistance



Natural Selection Rabbit Simulation

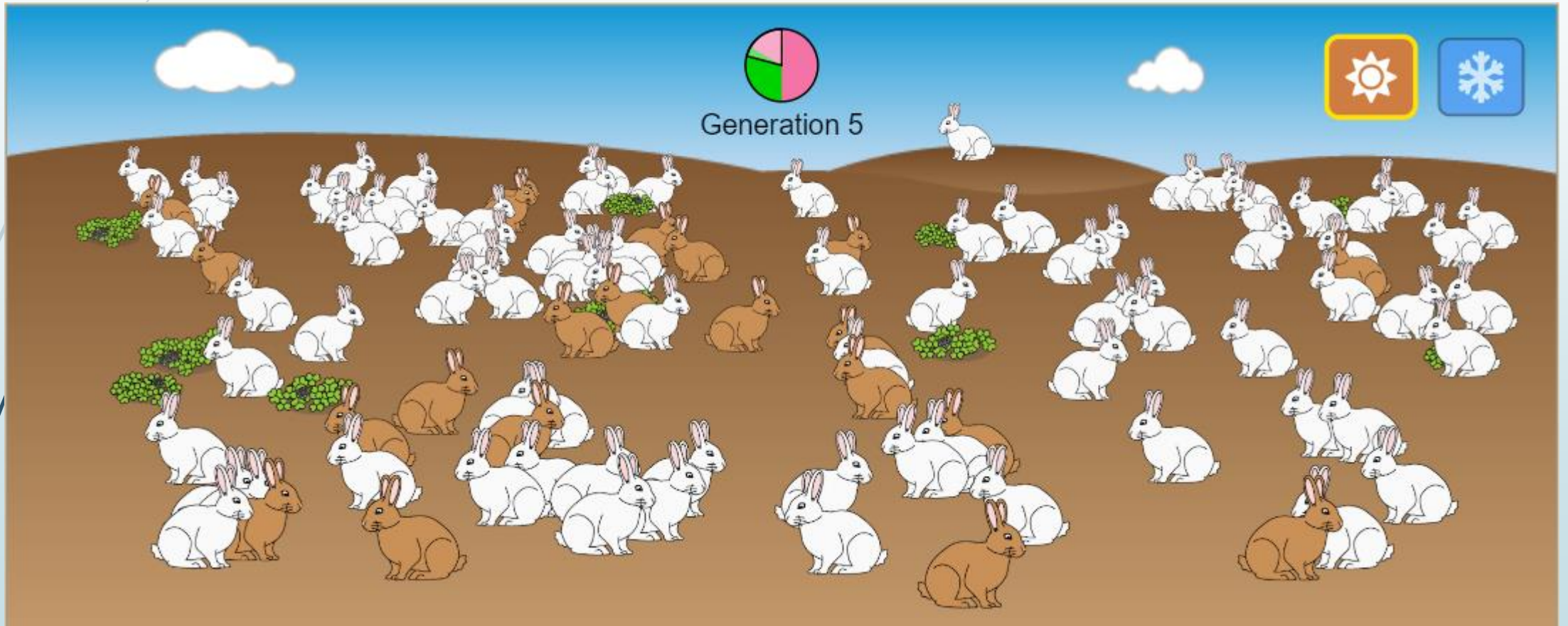
https://phet.colorado.edu/sims/html/natural-selection/latest/natural-selection_en.html

Discussion:

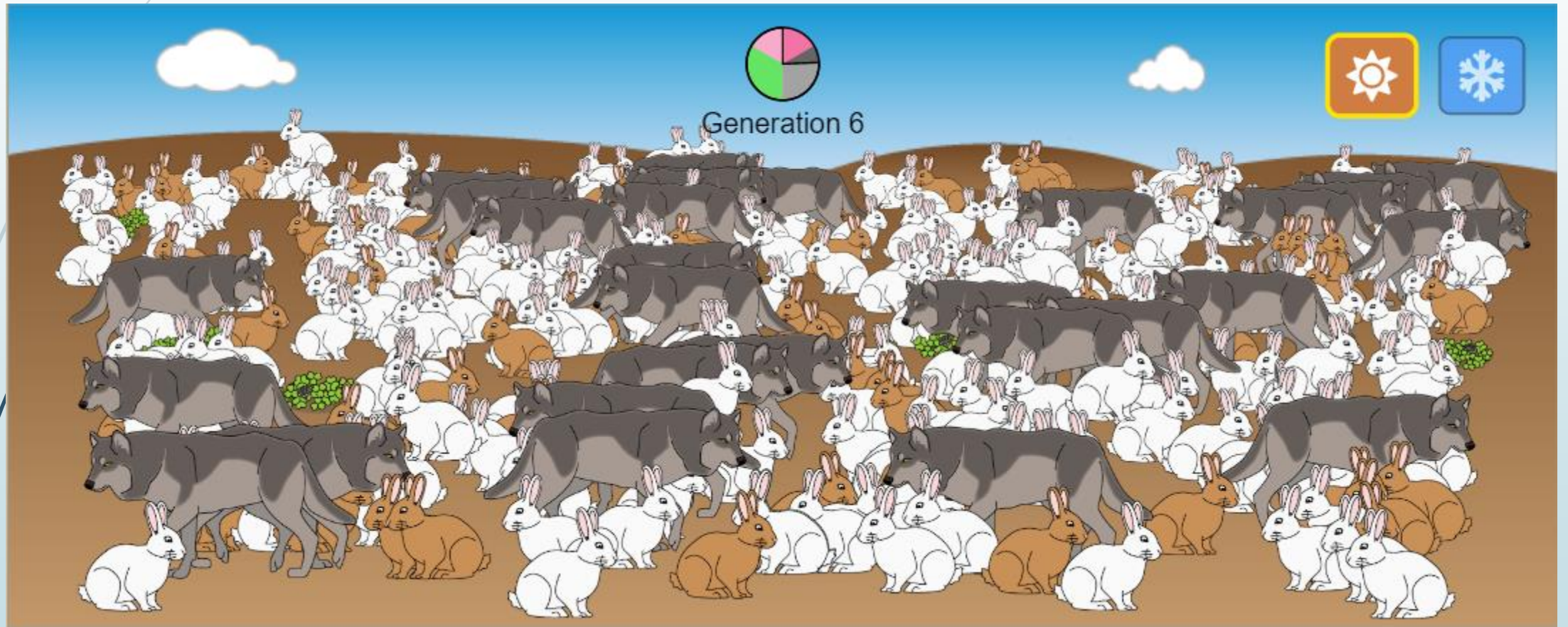
- 1) Play with the intro simulation. Which patterns do you see?
- 2) In which scenarios does evolution occur?
When does it not?
- 3) Why haven't bunnies taken over planet Earth, nor gone extinct?

1. Overproduction

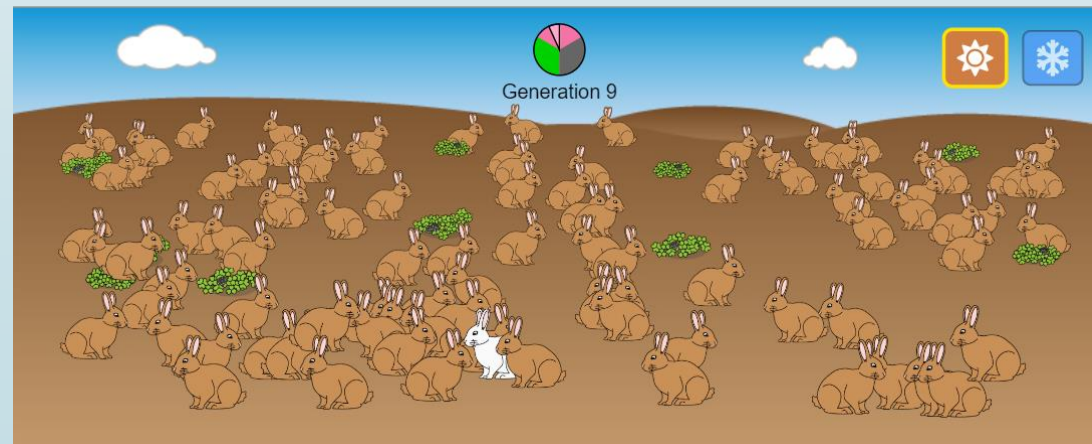
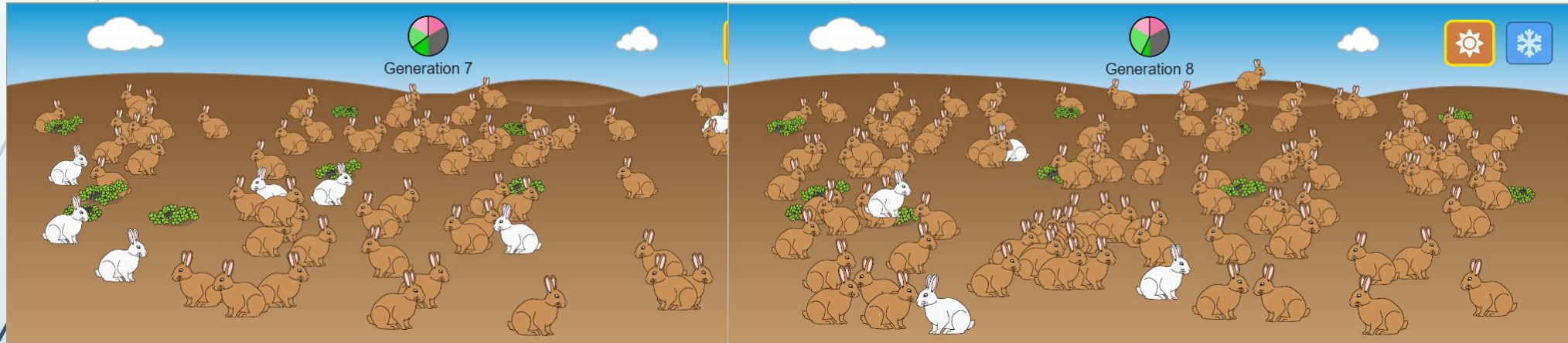
2. Variation

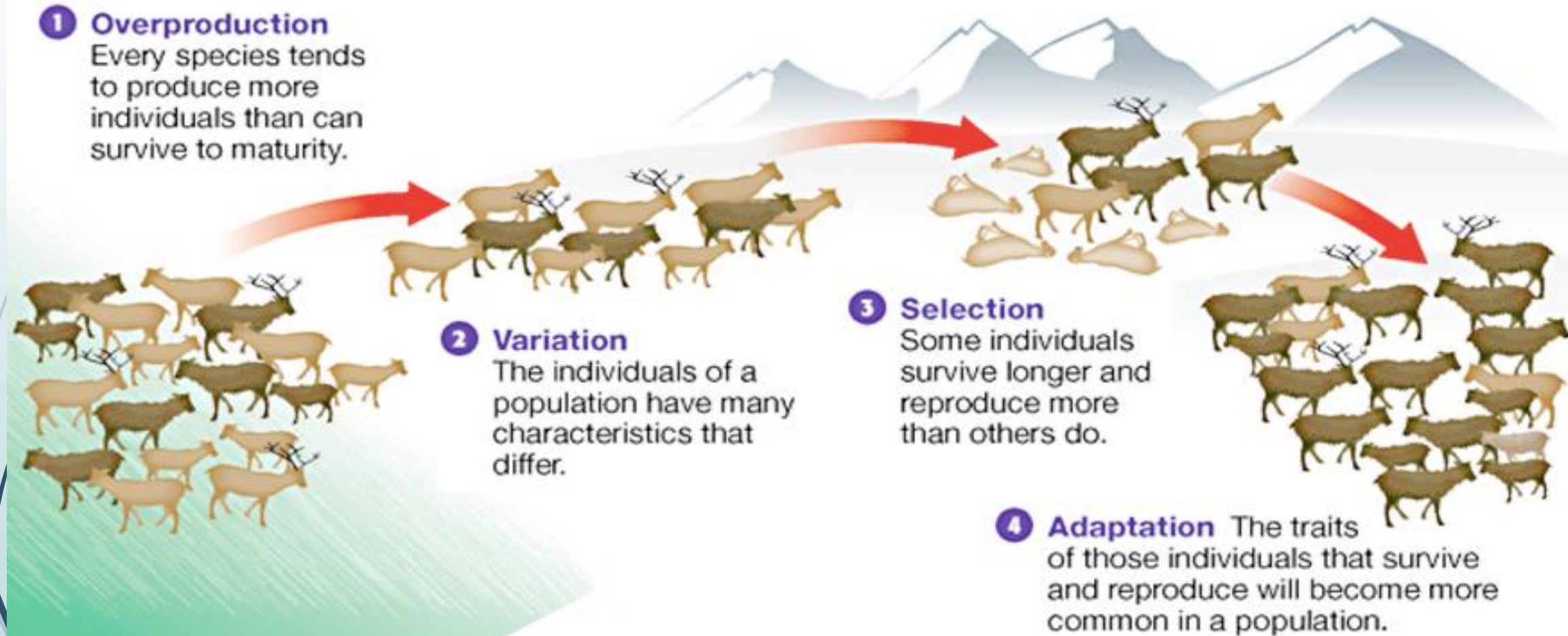


3. Selection (by selective pressure)



4. Evolution/Adaptation







Natural Selection Explained



Organisms vary with respects to their genetic constitution and traits (e.g., gut size, skin color, metabolic capabilities). Heritable traits that are beneficial in the context of survival and reproduction under the existing environmental conditions naturally tend to become more common over time/generations, whereas traits that are disadvantageous are "weeded out".

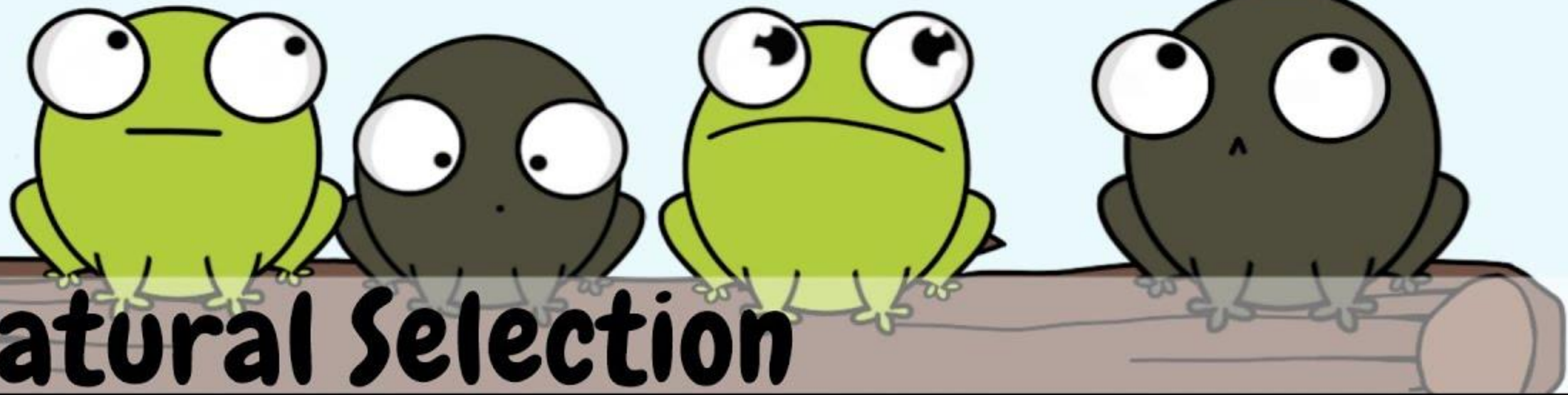
In this scenario, the focus is on a single trait: wing color. The color *blue* is now more common in the population of butterflies, which indicates that it is - or at least has been - beneficial, in a Darwinian sense, to have blue wings.

The population is now markedly dominated by blue butterflies. This implies that butterflies with blue wings have historically been at an advantage in the struggle for existence and experienced better reproductive success than red, purple, green, and yellow butterflies (on average). I.e., the trait 'blue wings' has become more common as a result of natural selection.



Why is this relevant to medicine...?

Every living thing on this planet is a product of evolution; hence, it's impossible to make sense of why organisms behave, look, and function the way they do if one doesn't know or consider how evolution works. Although it's organismal reproductive success that ultimately "matters" in biological evolution, organismal health ends up being a key factor, as it affects Darwinian fitness in a variety of ways.



Natural Selection

with the Amoeba Sisters

Discussion Questions

1. Why does genetic variation make it possible for changes in populations to occur through natural selection? Explain your answer.
2. Using the example shown in Figure 1.23, make a graphic organizer to show the steps by which natural selection favours a population of plants to grow in a shady environment.

Misconceptions about Evolution

What is Wrong Here?

Jimmy is a white rabbit who lives with his family in the Arctic. His parents and brothers and sisters are all white rabbits. They blend in well with the environment.

But climate change is causing all the snow to melt! Now, Jimmy and his family stand out.

Jimmy evolves brown fur to improve his survival in the environment.



What is Wrong Here?

Peanut is a dwarf hamster. Hamsters get eaten a lot because they are small and delicious.

Being small is bad for fitness. Peanut and his hamster tribe learn to fight their enemies by using spears. They die less. They have evolved.



Natural Selection Acts on Populations

- Natural selection is not about one individual organism. It is about a larger group of organisms, where there is variation among the members that cause some to have higher fitness than others.
- The environment exerts selective pressures that result from predators, parasites, and competition for limited resources.
- Over time, the *population* changes because individuals with favourable characteristics survive and reproduce.
- **Individuals cannot evolve, but populations or species can.**

Natural Selection Is Random

- Natural selection does not happen because the population “wants” to survive/reproduce better. **There is no goal or intelligent purpose in mind.**
- It is the product of statistics, probability, and logic...
 - If Phenotype A has 60% of survival and Phenotype B has 80% of survival, of course, over time, Phenotype B will become more common.
 - If there is no variant that can cope with new selective pressures (e.g. climate change!) then the entire population may decline and species may become extinct.

Heritable Traits Cannot be Learned

- Traits can only evolve through natural selection if
- E.g. thick hair good in cold but bad in heat
 - E.g. big human brains good now (intelligence, critical thinking, innovation) but bad in the past (used too much energy; diets couldn't keep up)

Natural Selection Is Situational

- A trait that decreases fitness in one environment may increase fitness in another environment or time. And vice versa.
 - E.g. thick hair good in cold but bad in heat
 - E.g. big human brains good now (intelligence, critical thinking, innovation) but bad in the past (used too much energy; diets couldn't keep up)

END OF TESTABLE CONTENT

Do not go past this point.

Concept 3: Natural selection can lead to the formation of new species.

- Individuals of the same **species** can interbreed to produce fertile offspring.
- Sometimes members of a population change so much that they are no longer able to produce fertile offspring with members of the original population.
- This leads to **speciation**, where new species are formed.

One Type of Speciation: Adaptive Radiation

- **Geographic barriers** can isolate a population, resulting in new species that are unable to interbreed.
- Examples of geographic barriers include a glacier, a lava flow, and an island.



Sciurus kaibabensis



Sciurus aberti



One Type of Speciation: Adaptive Radiation

- **Adaptive radiation:** the diversification of a common ancestral species into a variety of differently adapted species
- Finches on the Galapagos Islands have different beak shapes due to their diverse diets.

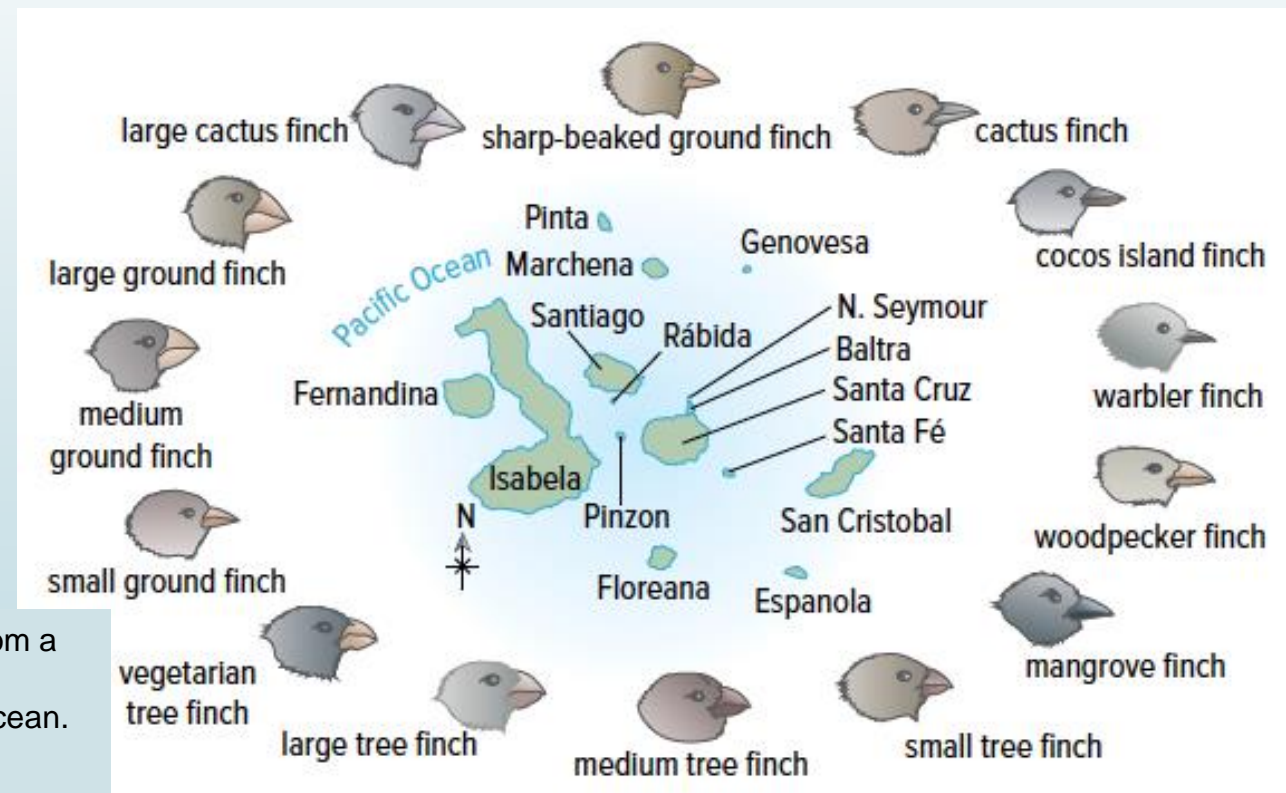


Figure 1.25: One common example of new species forming from a common ancestor are finches on the Galapagos Islands. The Galapagos Islands are located on the equator in the Pacific Ocean. The islands are volcanic in origin and contain a number of ecosystems, ranging from dry and desert-like to humid forests. Notice the difference in the shape and size of the birds' beaks.

Adaptive Radiation (Another Example)

- Tortoises on the Galapagos Islands are all different due to mutations, natural selection, and adaptive radiation.

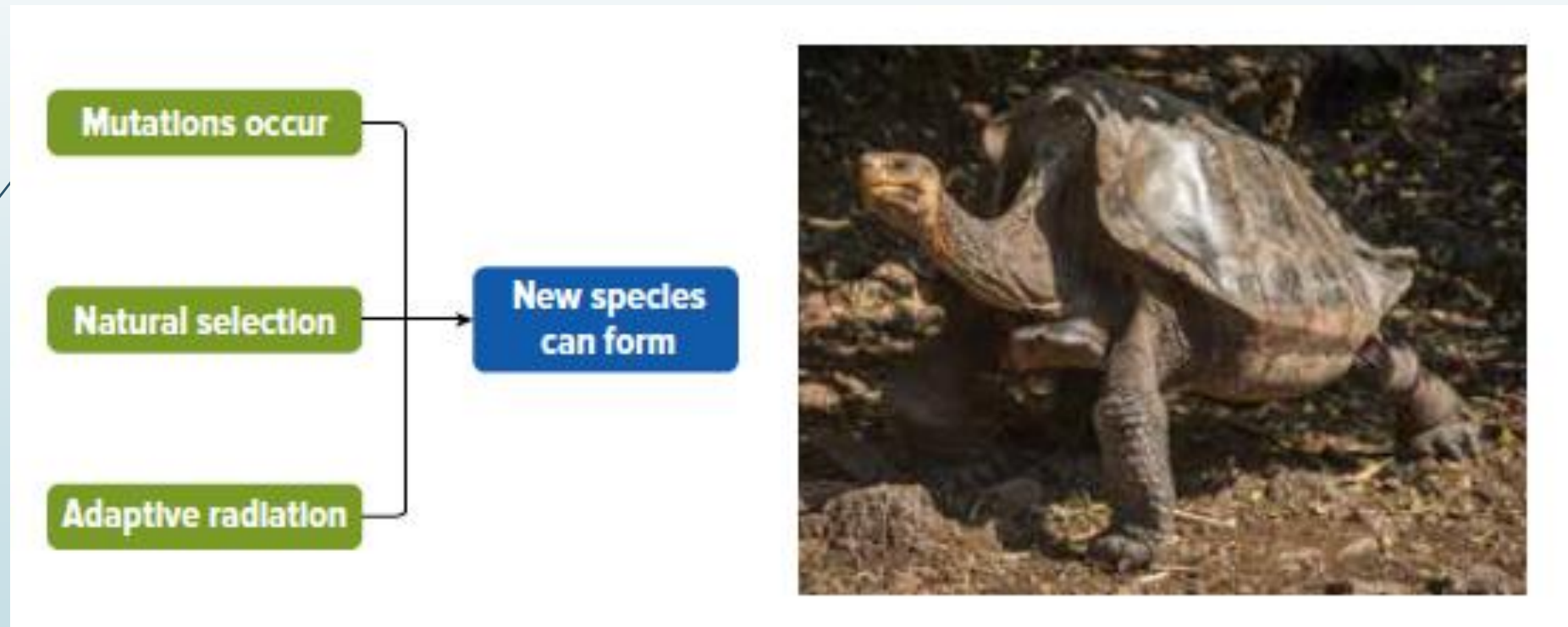


Figure 1.26: This figure illustrates how the various factors interact to form a new species.

Extinction and Selective Pressure

- **Extinction:** occurs when a species completely disappears from Earth
- Mass extinctions result in a decline in the number of species.

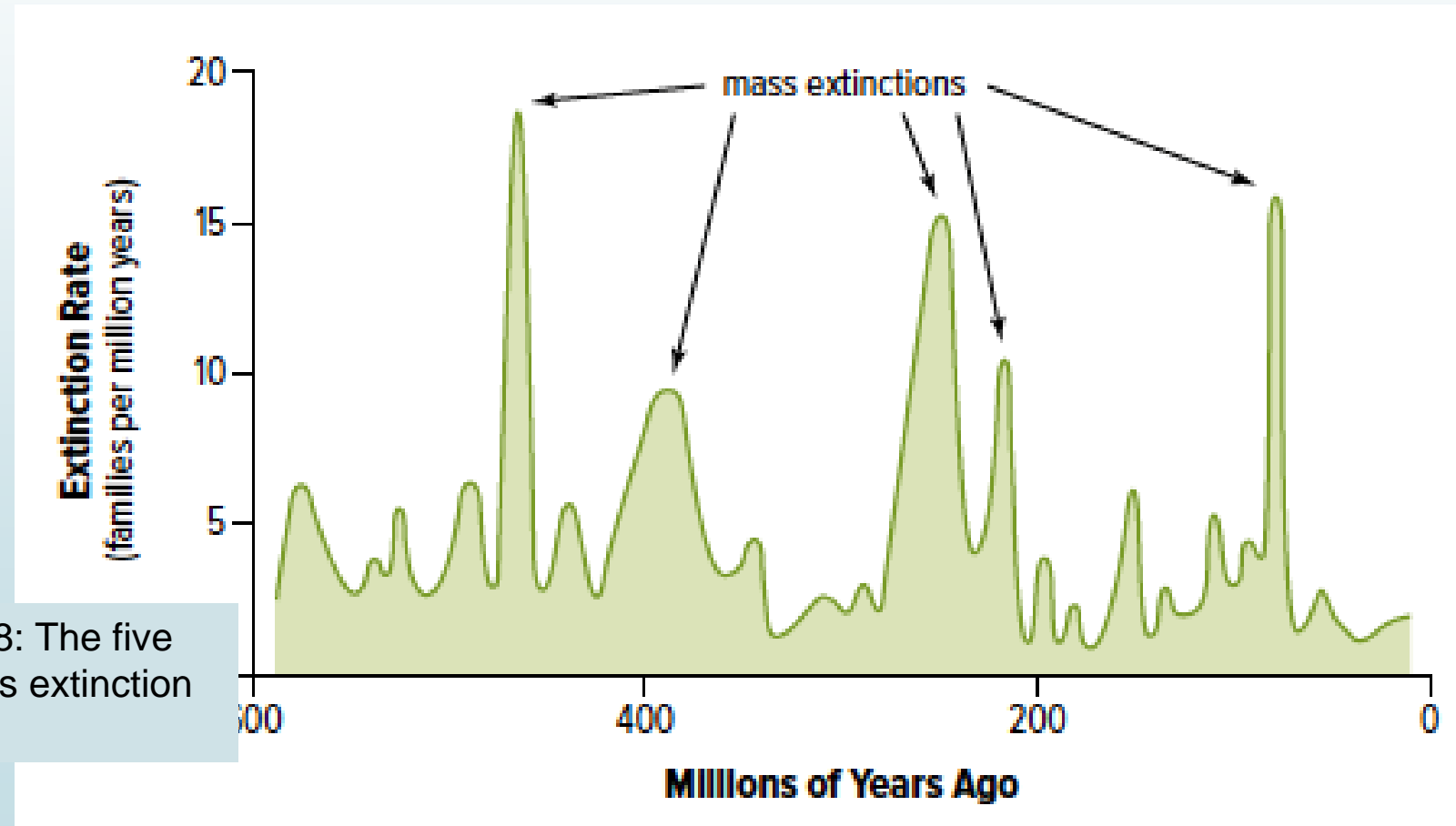


Figure 1.28: The five major mass extinction events.

Discussion Questions

1. What is adaptive radiation?
2. Explain why it would have been possible for an ancestral finch species, having arrived on one of the Galapagos Islands, to have diversified and evolved into other species over time.
3. How is extinction related to selective pressure?

Concept 4: Environmental factors can cause mutations.

- Mutations are important to natural selection and speciation.
- Mutations provide genetic variation.
- **Mutagen:** a substance or event that increases the rate of mutation
 - *Physical mutagens* cause physical changes in the DNA (i.e., X-rays and UV radiation).
 - *Chemical mutagens* can chemically react with DNA (i.e., nitrites and gas fumes).

Carcinogens

- **Carcinogen:** a substance or agent that causes cancer
- Some mutagens are carcinogenic.
 - Examples include UV radiation, cigarette smoke.
 - Wearing sunscreen, a hat, and sunglasses can reduce the exposure to UV radiation.



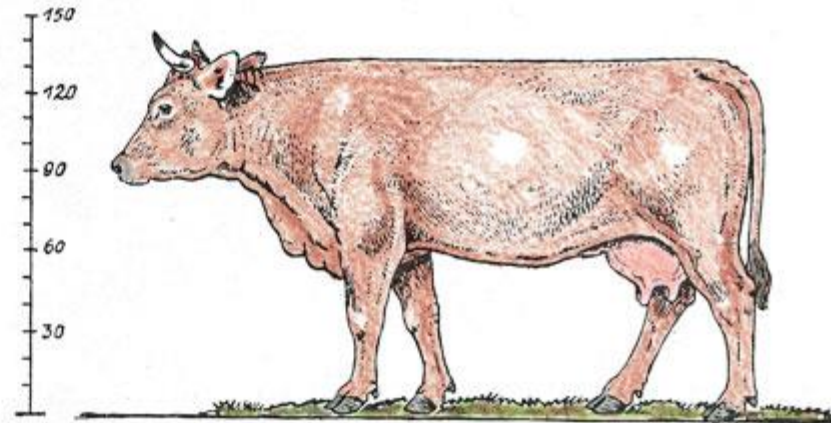
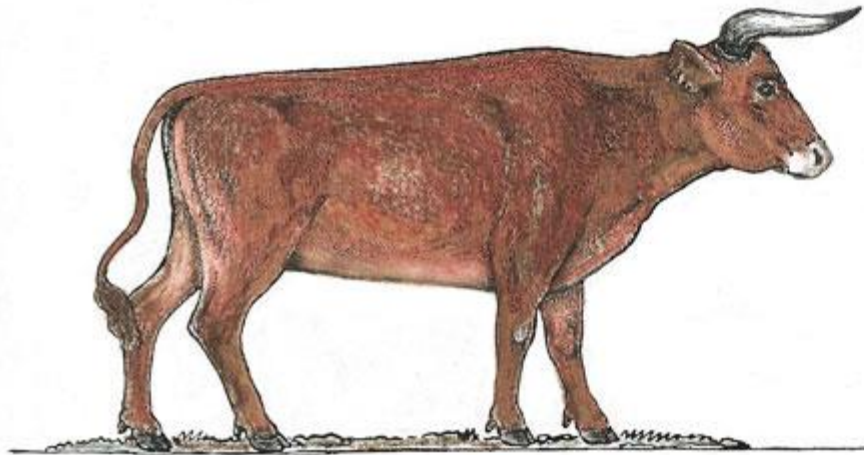
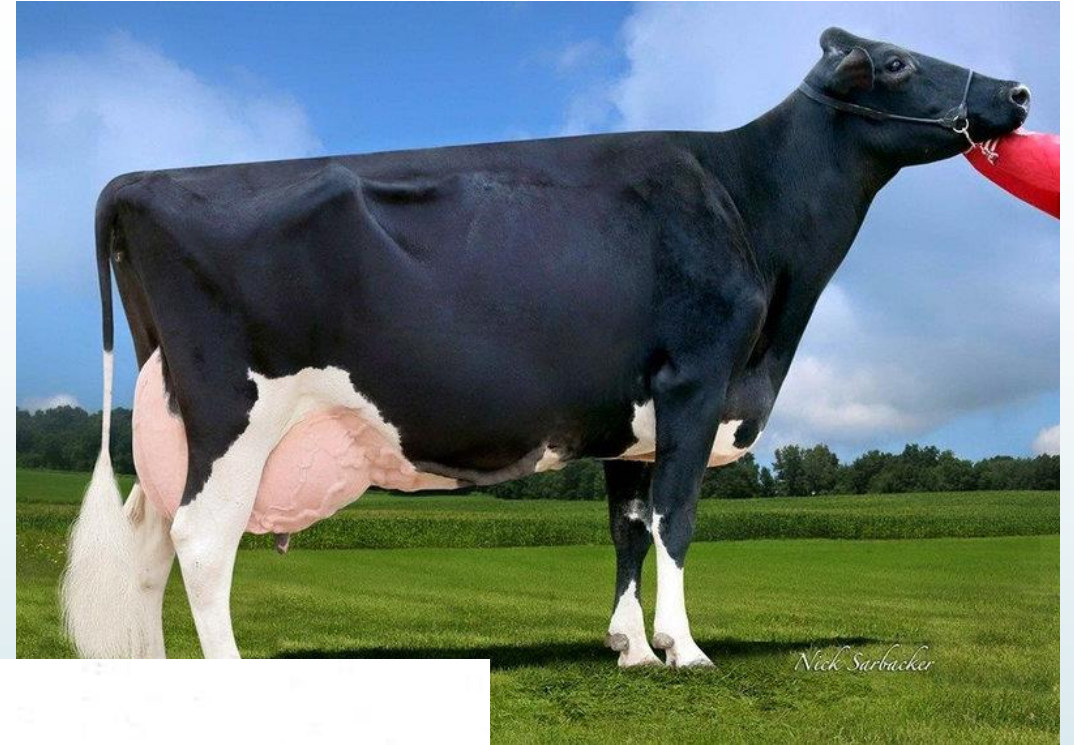
Figure 1.29: Applying sunscreen before going out in the sun can help reduce a person's exposure to ultraviolet radiation.

Discussion Questions

1. What is a mutagen?
2. Explain how mutagens and the production of proteins are related.

100

Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.



Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.



What do you think the sausage dog was selectively bred for?



- Hunting lions**
- Guard dog**
- For aristocracy to rest their feet on**
- Chasing rabbits down their holes**

Artificial Selection



Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.

- **Artificial selection:** selective pressure exerted by humans on populations in order to improve or modify desirable traits
- Humans breed cows that produce more milk, chickens that produce large numbers of eggs, and pigs with large muscles for meat.

Artificial Selection and Food Crops

- Humans breed crops to resist drought, disease, and insect infestations.
- Through selective breeding, the wild mustard plant is used to produce six other plants.

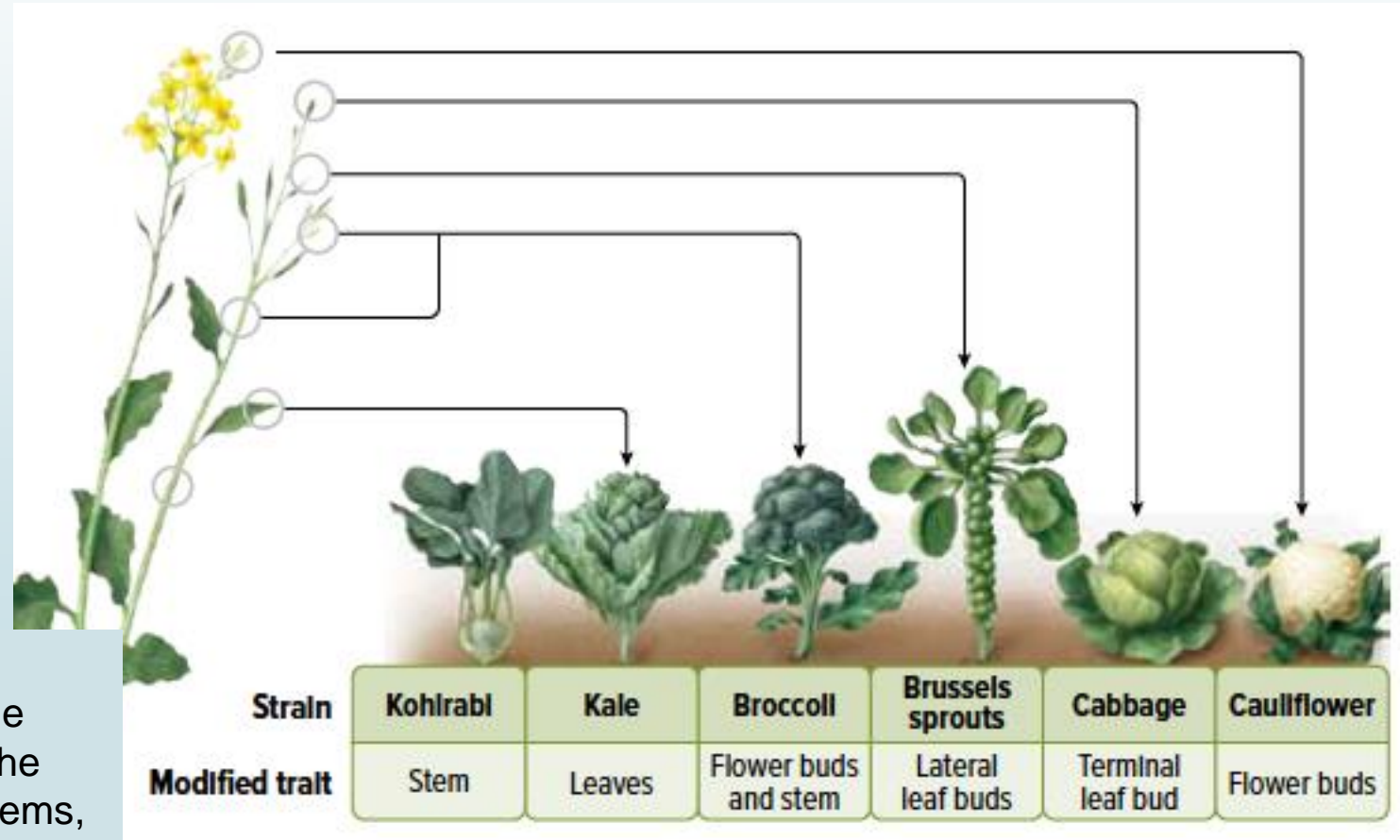


Figure 1.31: These six agricultural plants look very different from each other, but they carry much of the same genetic material as the wild mustard plant. The differences affect the formation of flowers, buds, stems, and leaves.

Consequences of Artificial Selection

- Some selectively bred animals have health problems (i.e., English bulldogs have respiratory problems and German shepherds have hip problems).
- Selectively bred plants lack genetic diversity because they are all similar.
- **Monoculture:** repeated planting of the same varieties of a species over large expanses of land
 - Decreased diversity → potential effects?

Discussion Questions

1. What is artificial selection?
2. What are some benefits and risks associated with artificial selection of agricultural crops?

Topic 1.3: How can natural and artificial selection influence changes in populations?

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.

