
BIODIVERSITY
&
EVOLUTION

THE INTRODUCTION

Have you ever wondered why giraffes have long necks, why some animals can blend into their surroundings, or how new species appear in the world? That's what this unit is all about—evolution and biodiversity, which is just a fancy word for all the different kinds of life on Earth (and even life that used to be here, like dinosaurs!).

In this unit, you'll learn how life changes over time. You'll explore the idea that living things pass traits (like fur color or beak shape) to their babies. Sometimes, small changes in traits help animals survive better. Those animals are more likely to have babies, and over many generations, the helpful traits become more common. This is called natural selection, and it's one way that evolution happens.

You'll also learn about things like:

- Fossils, which are clues from the past that show how creatures have changed.
- Homologies, which are body parts that are similar in different animals because they came from a shared ancestor.
- Mutations, which are changes in DNA that can create new traits.

- Speciation, which is how brand-new species form over time when groups of animals become separated.

There are also different ways evolution can happen. Sometimes it's super slow and steady (gradualism), and other times it happens in big bursts with long quiet periods in between (punctuated equilibrium). You'll see how the environment plays a big role—when the environment changes, animals and plants must change too, or they might not survive.

By the end of this unit, you'll be able to:

- Use evidence to explain how animals are related
- Describe how species change over time
- Understand what helps a species survive or go extinct
- Recognize how new species can form

Get ready to think like a scientist, ask questions about the past, and understand how the amazing variety of life on Earth came to be!

VOCABULARY

Vocabulary Word	Definition
Adaptation	
anatomical homology	
biogeography	
Bottleneck Effect	
Competition for Resources	
Differential Reproductive Success	
Directional Selection	
Disruptive Selection	

Vocabulary Word	Definition
Environmental Conditions	
Evolution	
Fossil Record	
Gene Flow	
Genetic Drift	
Genetic Recombination	
Gradualism	
Inherited Variation	

Vocabulary Word	Definition
Mutation	
Natural Selection	
Overproduction of Offspring	
Punctuated Equilibrium	
Speciation	
Stabilizing Selection	
Stasis	
Survival of the Fittest	

Echoes in the Dust

PHENOMENON

- Mission Log – Sol 121
- Location: Mars Surface – Sector Theta-9 Excavation Zone

The wind had barely settled when your team uncovered the first one.

A strange imprint, etched deep into the ancient red rock—a fossil. Long, fin-like limbs curled around a smooth stone. At first, it looked like the fossilized skeleton of an extinct Earth sea creature—maybe an ancient fish or early amphibian—but... different.

The bone structure was too dense, the limb positioning too angled. And there was something else.

Fifty meters deeper, you uncovered a second specimen: a massive hind limb with a three-toed claw, and beside it, a set of fossilized ribs the size of solar panels. The shape and spacing suggested something upright—possibly bipedal, possibly a predator. The resemblance to Earth's theropod dinosaurs was impossible to ignore.

But how could that be?

Mars was never believed to have supported complex life. Now, the fossil record is telling a different story. One that feels strangely familiar.
You and your team begin comparing fossil layers using the Law of Superposition, mapping the depth and locations of each discovery.

As you study the anatomical structures, you start seeing connections—bone layouts that match creatures from Earth's past. You check for homologies, looking at shapes of limbs, skulls, and spine positions. Even stranger? The sediment nearby shows signs of long-dried lakes and possibly even ancient coastlines.

Could these Martian fossils share common ancestry with life on Earth? Or are these simply examples of convergent evolution, where different species evolve similar features in similar environments?

Now, you're tasked with uncovering what these fossils reveal about life's origin and evolution—not just on Earth, but possibly on Mars.

Your investigation will focus on:

- Analyzing fossil evidence for evolution and species change
- Identifying anatomical homologies that suggest common ancestry
- Exploring how environmental change impacts survival, extinction, or adaptation

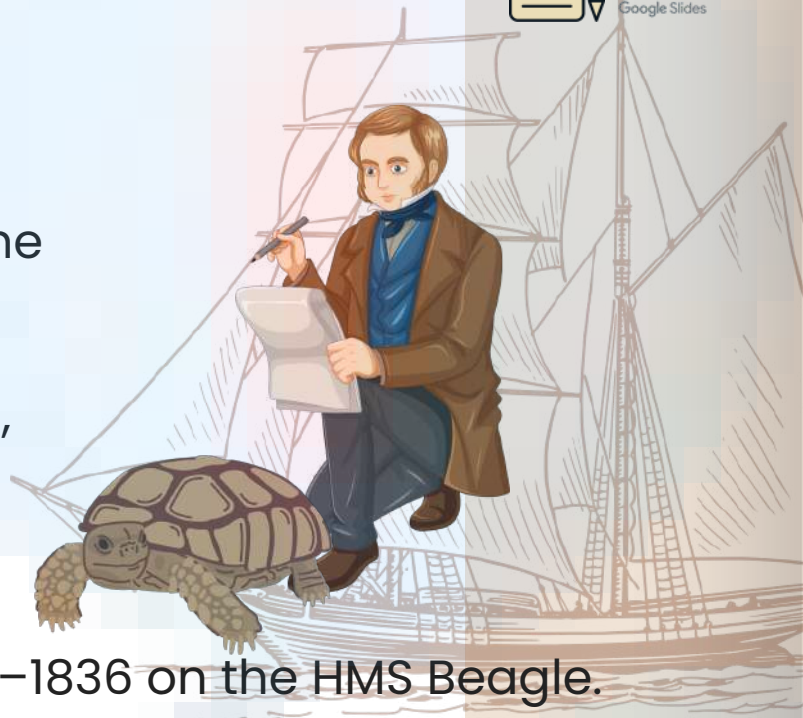
Comparing gradualism and punctuated equilibrium as patterns of change

- Evaluating whether these species show signs of adaptive radiation or speciation
- Considering if genetic mechanisms like mutation, gene flow, or genetic drift could have shaped life on Mars

Something lived here.

And the story written in stone is waiting for you to decode it.

THE " FATHER" OF EVOLUTION

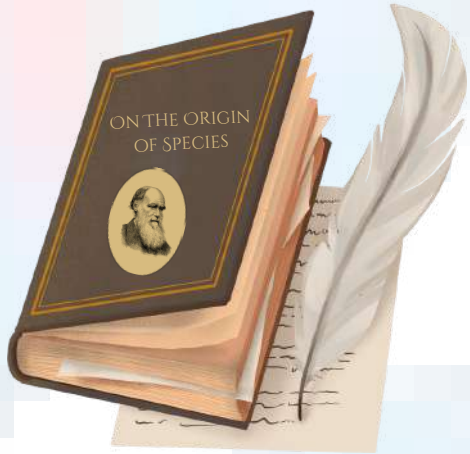


Charles Darwin and the Origin of Species

- Who Was **Charles Darwin**?
  - A naturalist and biologist who developed the theory of evolution by natural selection.
  - Published "**On the Origin of Species**" in 1859, explaining how species change over time.
- **The Journey on the HMS Beagle**
  - Darwin traveled around the world from 1831–1836 on the HMS Beagle.
  - Visited places like the **Galápagos** Islands, South America, and Australia.
  - Observed and collected plants, animals, and fossils.
- **Key Discoveries**
  - **Adaptations**: **Traits** that help organisms **survive** in their **environment**.
    - **Finches** on the Galápagos Islands: **Beak shapes** varied depending on the type of **food** available.

- **Tortoises**: **Shell** shapes were **different** based on the island's **environment**.

- **Fossil Evidence**: **Fossils** of **extinct** animals resembled **living** species.
- **Early Theories**
  - **Common Descent:** All species share a **common ancestor**.
  - **Natural Selection:** Organisms with traits that help them **survive reproduce** more, passing those traits to their **offspring**.

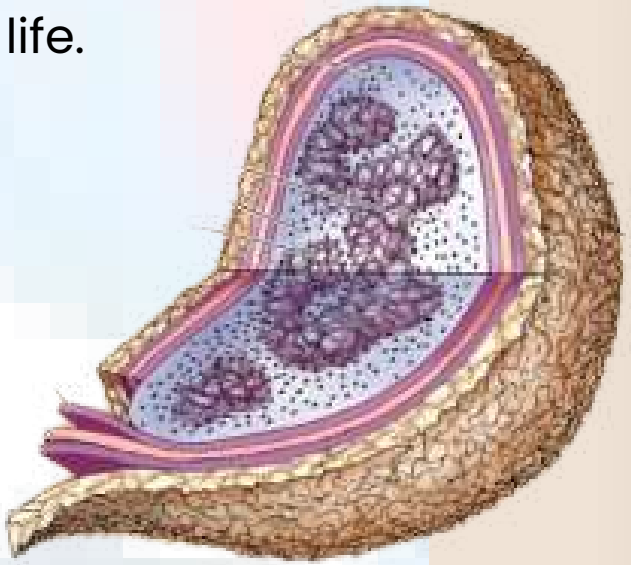


- What inspired Charles Darwin to study plants and animals in new places?
- How did Darwin use his observations of the finches to explain his ideas about nature?
- Why do you think the Galápagos Islands were important for Darwin's discoveries?
- What does "natural selection" mean, and how does it help animals survive?
- If you could ask Darwin one question about his journey, what would it be?

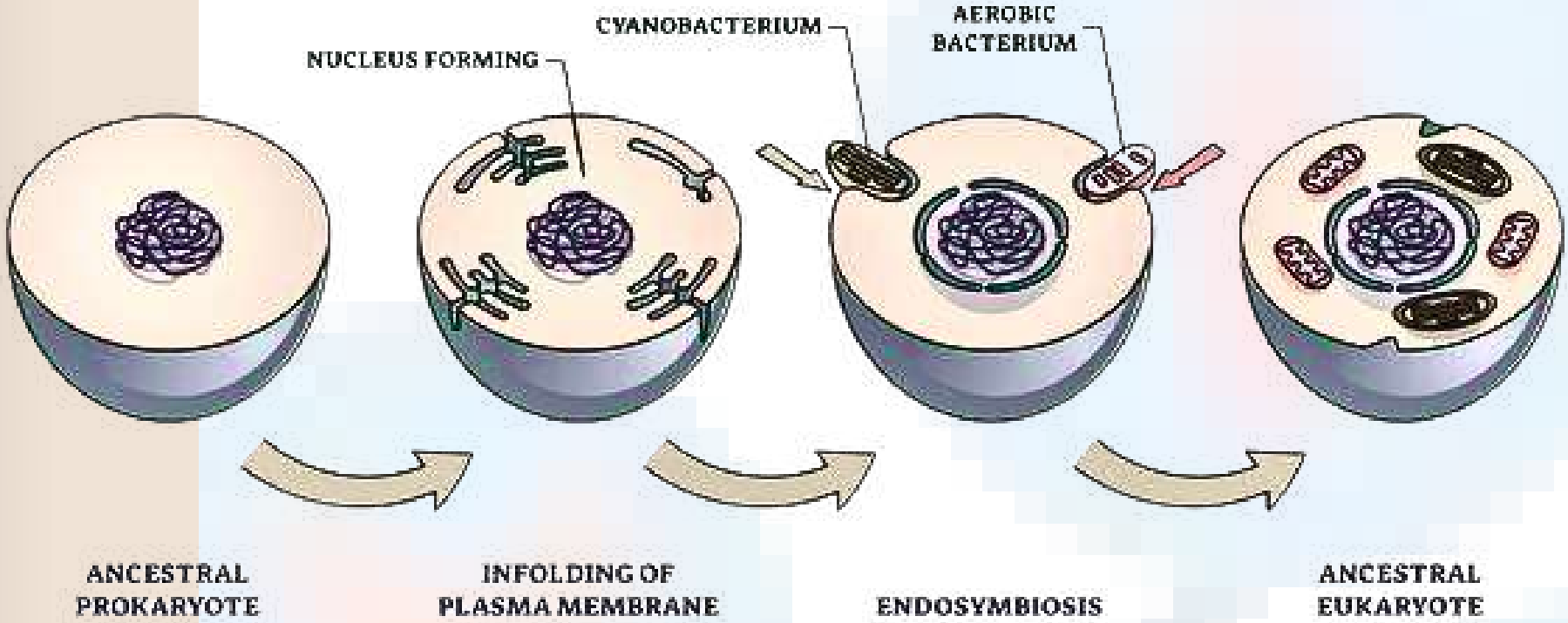
THE BEGINNING...

Abiogenesis (Origins of Life)

- Life arose from non-living matter over 3.5 billion years ago.
  - **Miller-Urey Experiment** (1953): Simulated early Earth conditions and produced **amino acids**, key building blocks of life.



- **Endosymbiotic Theory**
  - Explains how complex cells (**eukaryotes**) **evolved** from simple cells (**prokaryotes**).
- **Key Idea**: **Larger** cells engulfed **smaller** ones, which became **organelles** like **mitochondria** and **chloroplasts**.
  - Evidence:
    - **Mitochondria** and **chloroplasts** have their own **DNA**, similar to bacteria.
    - They reproduce **independently** within cells.

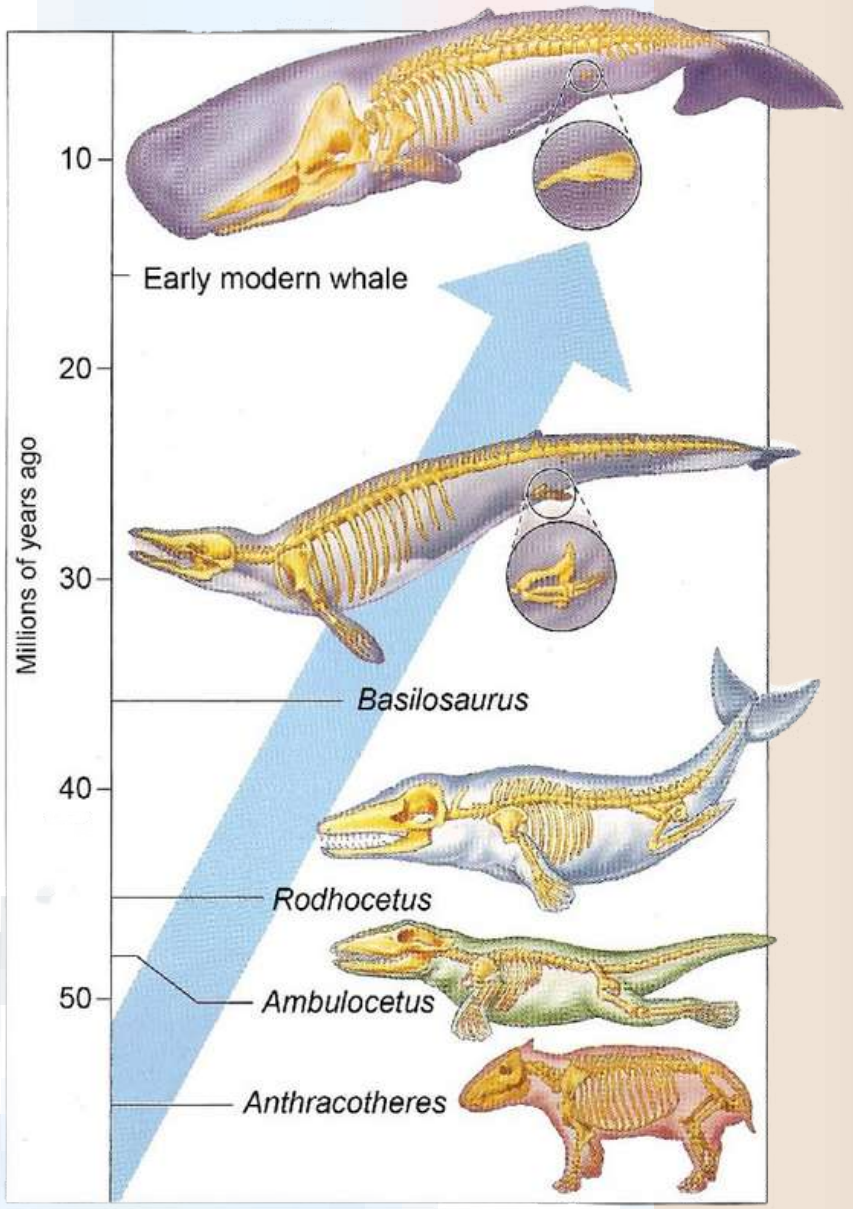


- What is the endosymbiotic theory, and how does it explain where mitochondria and chloroplasts came from?
- Why do scientists think mitochondria and chloroplasts were once free-living organisms?
- What evidence supports the idea that mitochondria and chloroplasts were part of a symbiotic relationship?
- How do mitochondria and chloroplasts help cells survive today?
- Why is it important to learn about how cells may have evolved in the past?

THE EVIDENCE

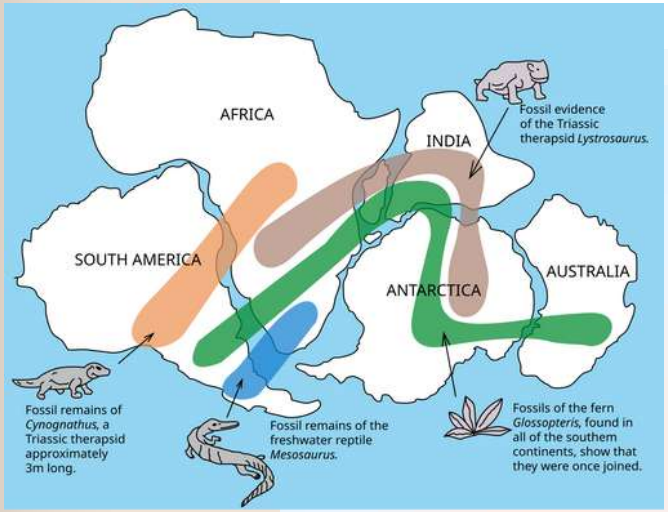
FOSSIL RECORD

- **Fossils show how species have changed over time.**
  - **Fossils** in older rocks look very different from modern species.
  - **Intermediate Fossils:** Show **links** between major groups, like Tiktaalik, which connects fish and amphibians.



- **Law of Superposition: Older** fossils are **deeper** in the earth while **younger fossils appear near the surface**

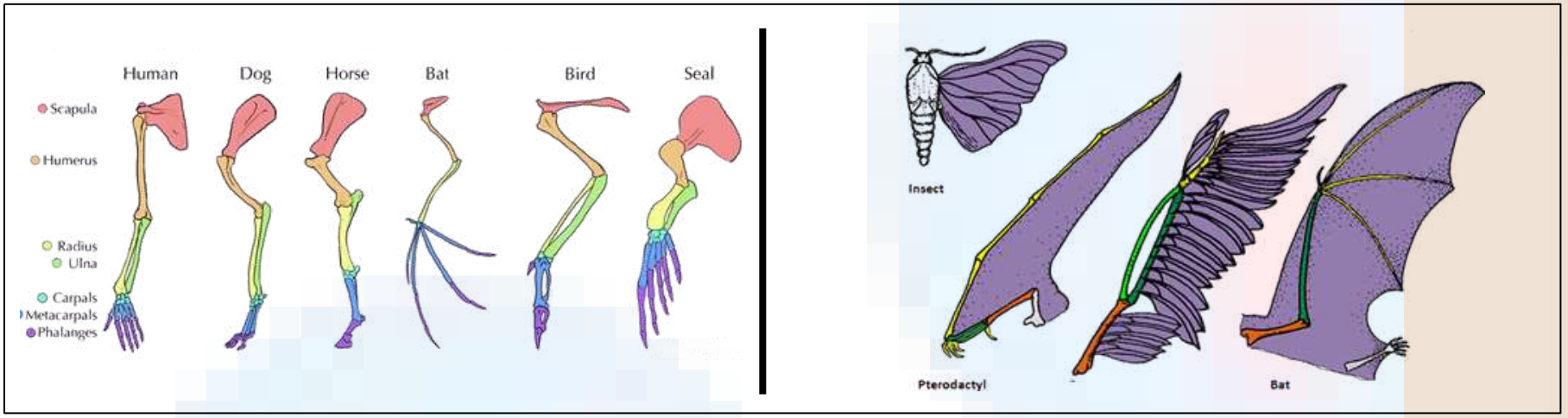
BioGEoGRAPHY



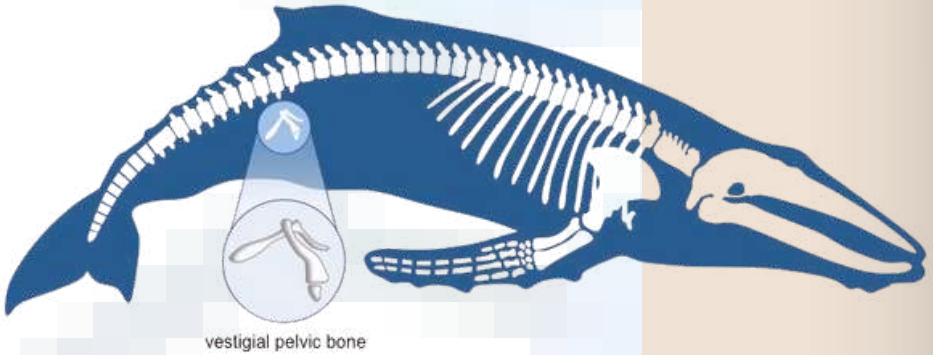
- Study of where species **live** and **how** they got there**.**
  - **Example:** Marsupials like kangaroos in Australia suggest **common ancestry** due to **geographic isolation**.
  - **Endemic Species:** Found only in **specific** places, like **finches** on the **Galápagos**.

- **Homologies -** # COMPARATIVE ANATOMY
  - **Traits shared** by species because they came from a **common ancestor.**
    - **Anatomical Homologies: Similar structures, different functions,** like the bones in a whale's fin and a human hand - **Common Ancestry**
    - **Analogous Structures**: **Different structures**, **similar functions**, like the wings of insects, bats, and birds. No commonality

HOMOLOGOUS	ANALOGOUS



- **Vestigial Structures**: **non-use**, what your **ancestors used** - appendix, wisdom teeth



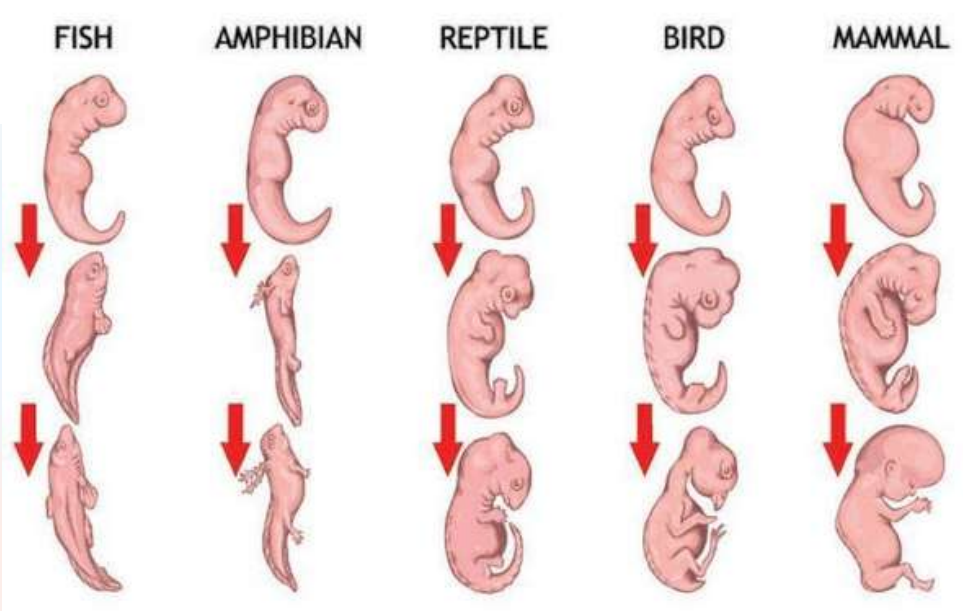
MOLECULAR HOMOLOGIES

Cytochrome *c* Evolution	
Organism	Number of amino acid differences from humans
Chimpanzee	0
Rhesus monkey	1
Rabbit	9
Cow	10
Pigeon	12
Bullfrog	20
Fruit fly	24
Wheat germ	37
Yeast	42

- **Similar DNA** or **proteins (**e.g., **fewer** differences in cytochrome c in closely related species).

DEVELOPMENTAL HOMOLOGIES

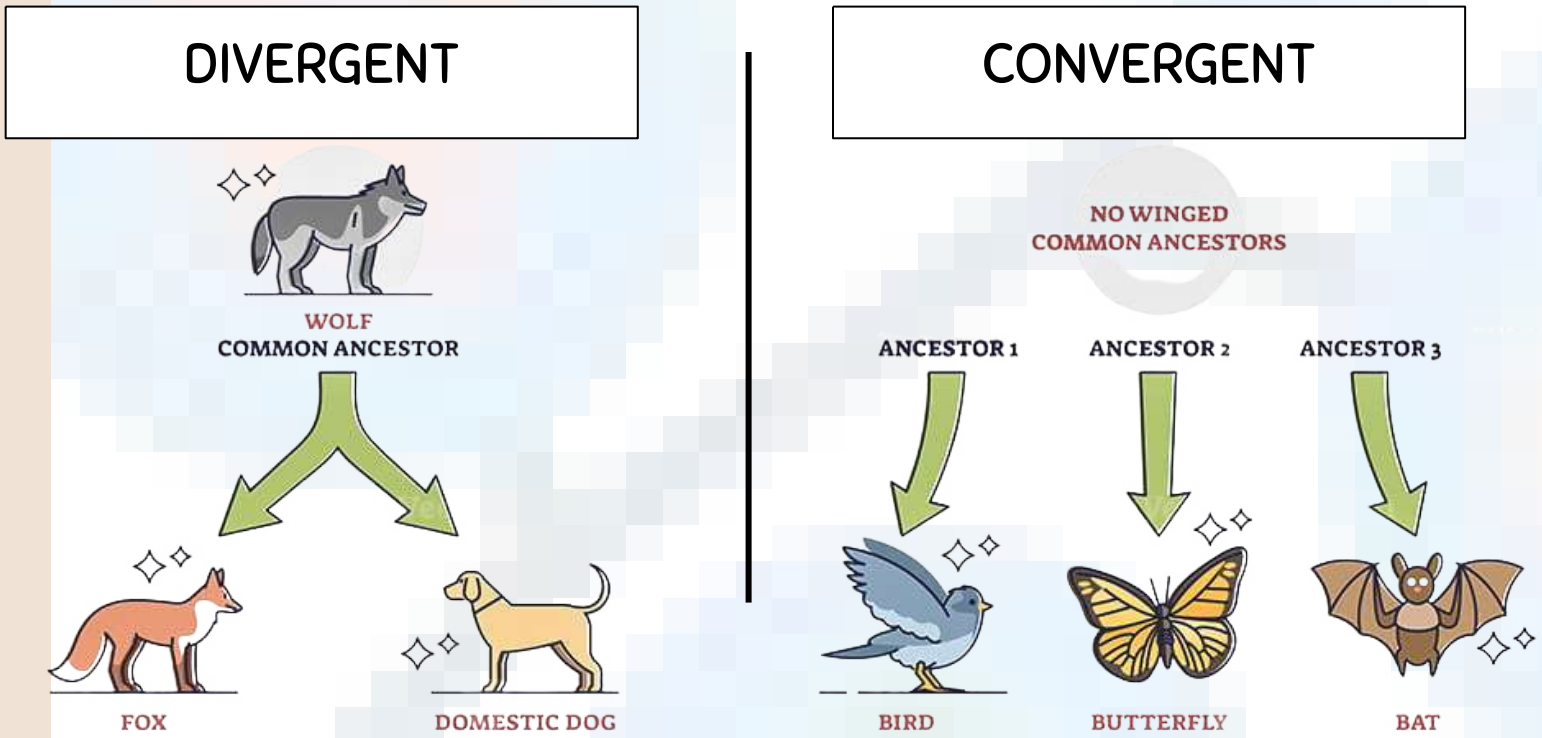
- **Embryos** of **different** animals (e.g., humans and chickens) **look similar** during **early** stages.

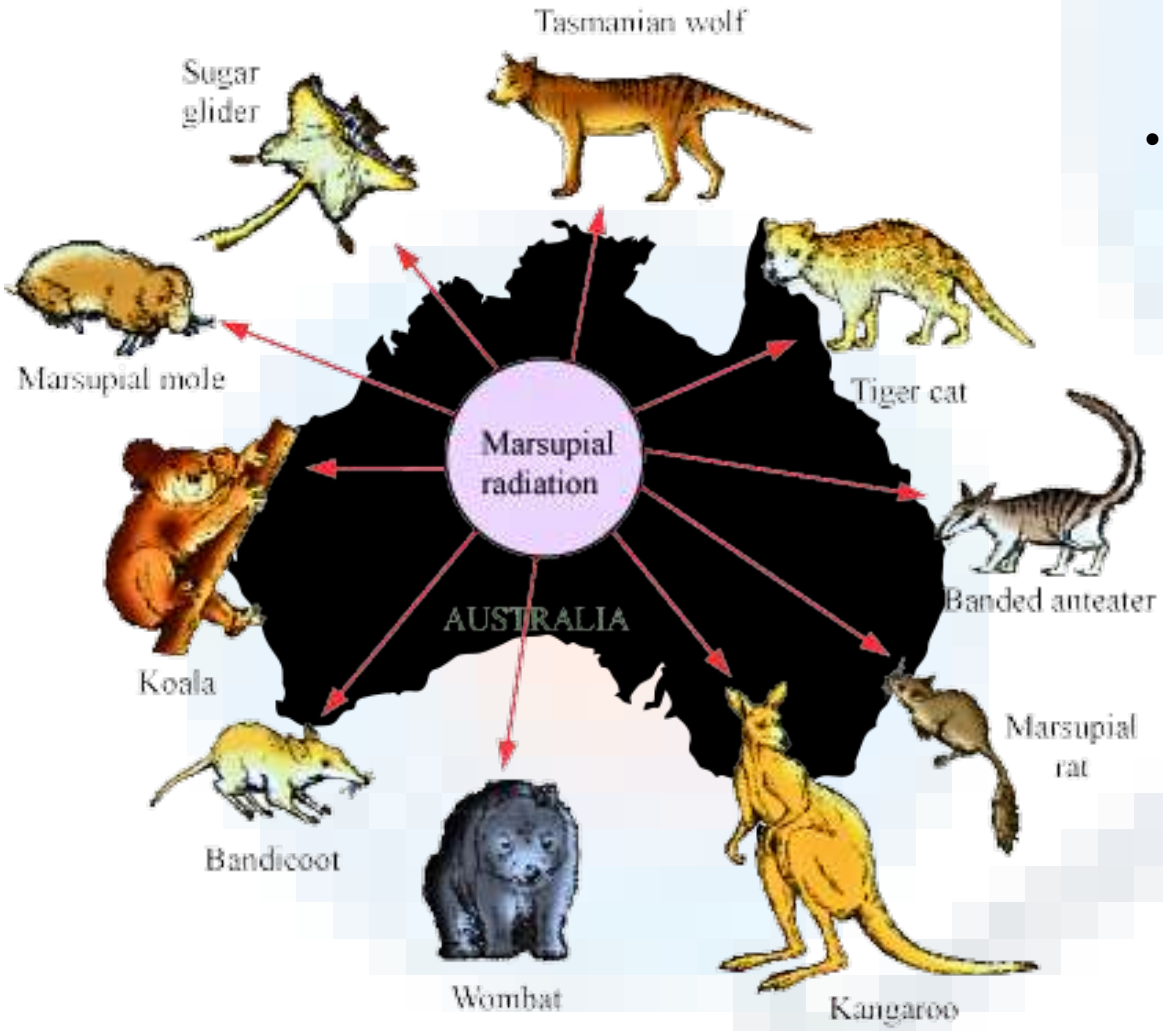


- What are some examples of evidence scientists use to show that evolution has happened?
- How do fossils help scientists learn about animals and plants from the past?
- Why are homologous structures, like similar bones in different animals, important for understanding evolution?
- What do embryos of different animals tell us about how species are related?

Patterns of Evolution

- **Convergent** Evolution: **Unrelated** species **develop** similar **traits** because they **live** in **similar** environments.
  - **Example**: Wings of birds and bats.
- **Divergent Evolution: Related** species **evolve** different **traits** due to **different** environments.
  - **Example:** Darwin's **finches** with **varied** beak **shapes**.



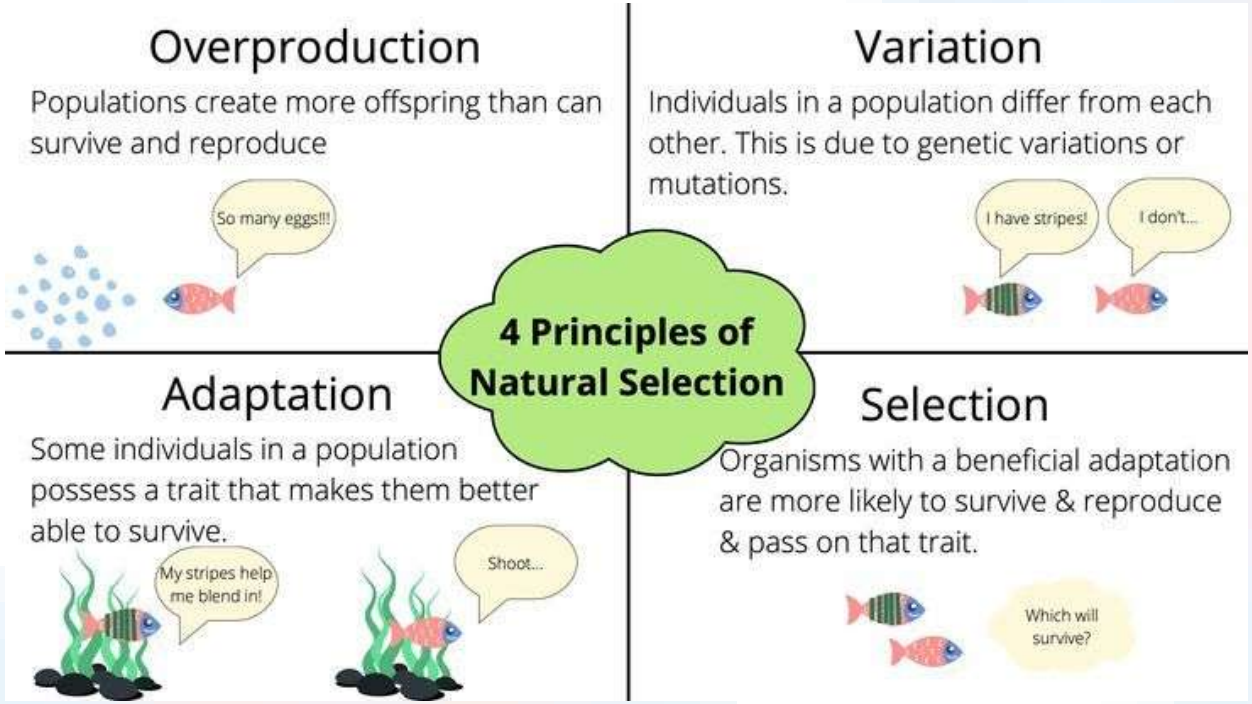


- **Adaptive Radiation:** One species **evolves** into **many** to fill different **roles** in an **environment**.
    - **Example: Australian Marsupials –** Different marsupial species evolved to fill ecological roles similar to placental mammals found elsewhere.

- What is the difference between divergent and convergent evolution? Can you give an example of each?
- How does coevolution show how species can depend on each other to survive?
- Why do you think extinction is a natural part of evolution, and what might cause it to happen faster?
- What is the difference between gradualism and punctuated equilibrium, and which one do you think explains most changes in nature?
- Can you think of a real-life

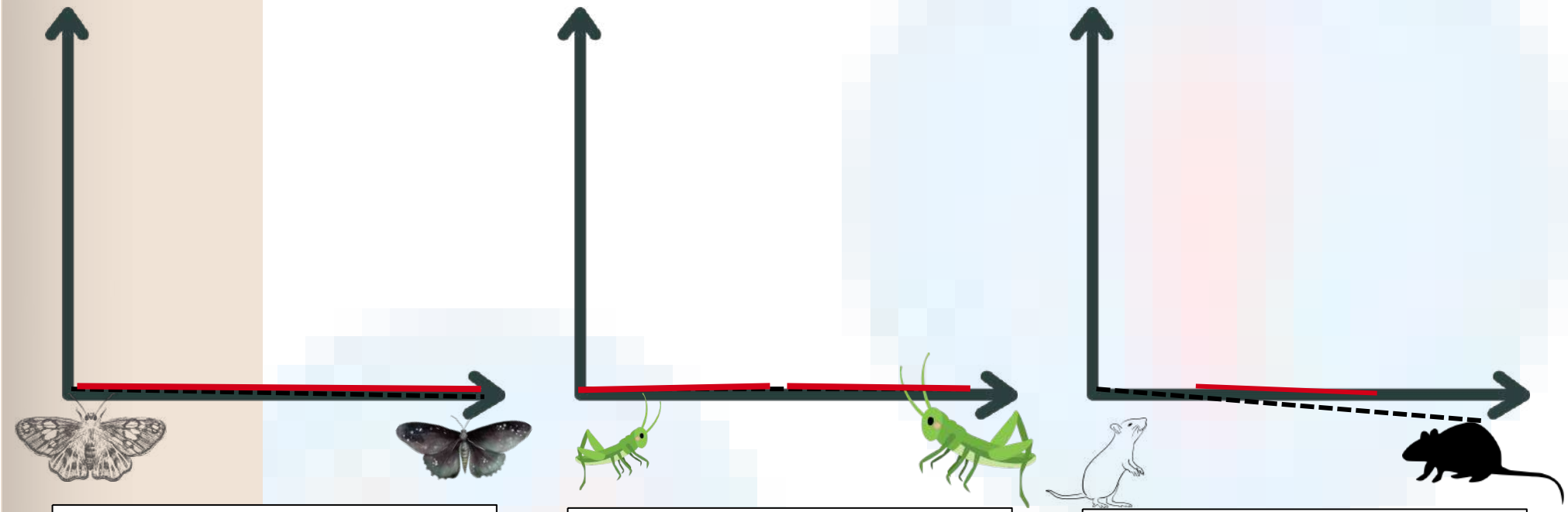
NATURAL SELECTION

- **Key Concepts**
- **Definition:** The process where organisms with helpful traits survive and reproduce.
- **Key Elements:**
  - **Inherited Variation:** Traits are passed from parents to offspring.
  - **Overproduction of Offspring:** More offspring are born than can survive.
  - **Competition for Resources (Selection):** Organisms struggle for food, water, and space.
  - **Differential Reproductive Success (Adaptation):** Organisms with the best traits have more babies.



TYPES OF SELECTION

- **Directional Selection**: Favors one **extreme trait**.
  - **Example**: Giraffes with longer necks.
- **Disruptive Selection**: Favors **both extreme traits** but not the average.
  - **Example**: Birds with very small or very large beaks.
- **Stabilizing Selection**: Favors **average** traits and removes extremes.
  - Example: Huma

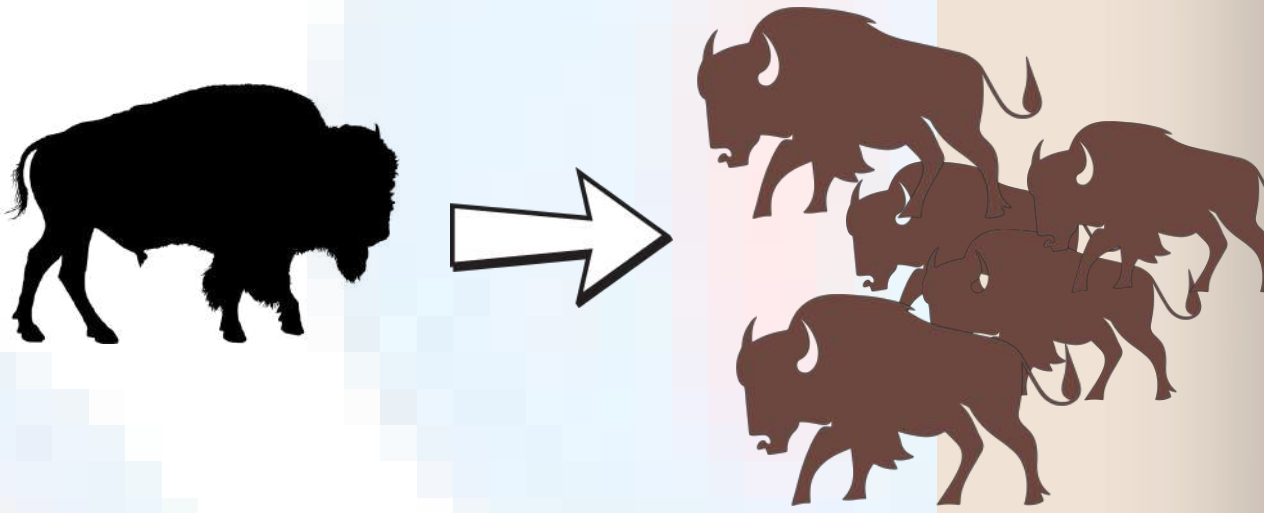


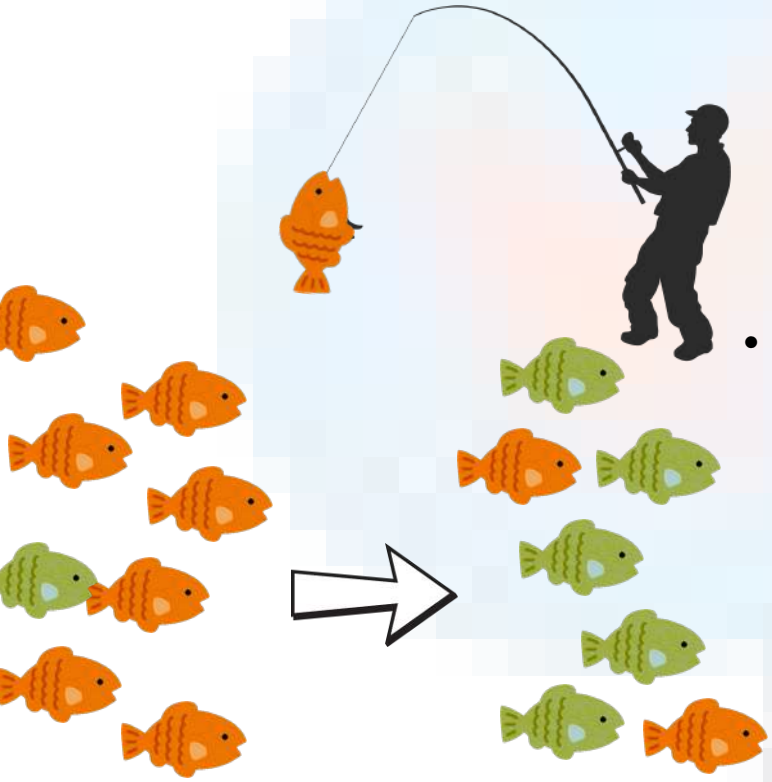
- What are the four main parts of natural selection, and why are they important for evolution?
- How do inherited traits help some animals survive better than others?
- Why is it important for a species to have variation in its population?
- What happens over time when a helpful trait becomes more common in a population?
- Can you think of an example from nature where a species has changed because of natural selection?

MECHANISMS OF SELECTION

GENE FLOW

- **Movement** of **genes** between **populations** (e.g., animals **migrating** and **breeding** in new areas).





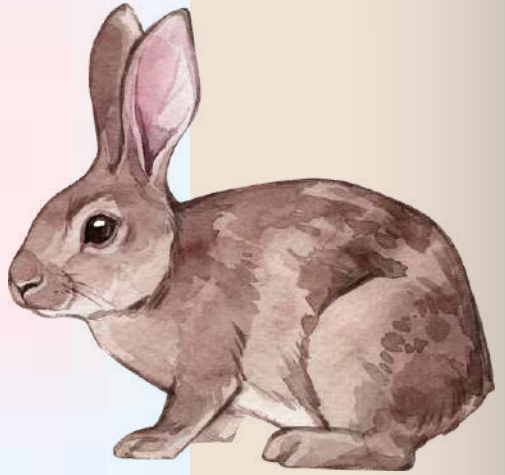
GENETIC DRIFT

- **Random** changes in **traits**, especially in **small** populations. The **disappearance** of **genes** from a population
  - **Bottleneck Effect:** Population **shrinks**, **losing** genetic **diversity** (e.g., cheetahs)
  - **Founder Effect**: A small **group starts** a new **population** with **limited** traits.

MECHANISMS OF SELECTION

MUTATIONS

- **Changes** in **DNA** introduce **new** traits.
- **Example**: A mutation in **fur color** can help **animals blend** into their environment.



SEXUAL SELECTION

- **Mating Patterns: Random vs. Non-Random Mating**
  - **Random Mating**
    - Mates pair by chance.
    - No preference for specific traits.
    - All individuals have equal chances of reproducing.
    - **Example**: Wind-pollinated plants.

MECHANISMS OF SELECTION

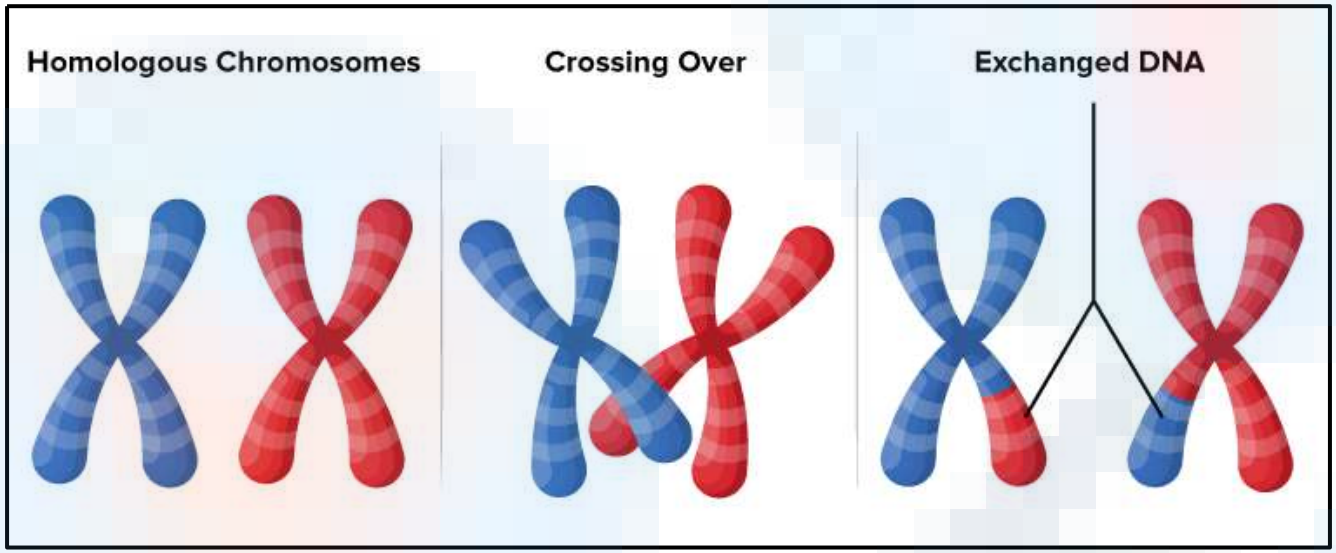
SEXUAL SELECTION

- A type of natural selection where certain traits increase an individual's chances of attracting a mate and reproducing.
  - Focuses on traits that help with mating success, not just survival.
    - **Two Main Types:**
      - **Intrasexual Selection**
        - Competition within the **same sex** (usually males) for access to mates.
        - **Example**: Male deer fighting with antlers.
      - **Intersexual Selection**
        - **Mate choice** — individuals (usually females) select mates based on traits.
        - **Example**: Female peacocks choosing males with the most colorful tails.

- **Non-Random Mating**
  - **Mates** are chosen **based** on **specific** traits.
  - Includes sexual selection and other behaviors.
  - **Leads** to **changes** in **allele frequency** over time (evolution).
  - **Example**: Female birds choosing brighter males.

GENETIC VARIAITON

- **Mixing** of genes during **reproduction** creates new **trait** combinations.
- **Example**: **Crossing Over** during **prophase** I in **Meiosis**



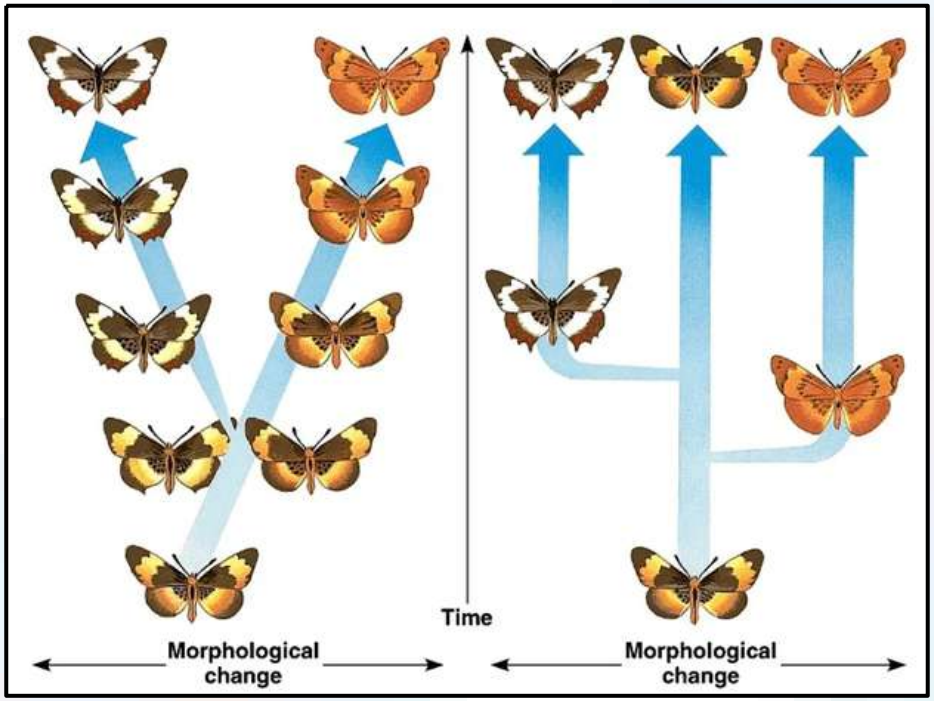
- How do mutations create new traits, and why are they important for natural selection?
- What role does genetic recombination play in making populations more diverse?
- How can a trait that starts as a random mutation become common in a population?
- Why is it helpful for populations to have a lot of genetic variation?
- Can you think of an example where a mutation or recombination might help a species survive in a changing environment?

Speciation

- **Definition**
  - The **formation** of new **species** when **populations** become **isolated** and stop **interbreeding.**
- **Causes**
  - **Geographic Isolation:** Physical **barriers**, like mountains or rivers.
  - **Behavioral Isolation:** Differences in **mating** behaviors.
  - **Temporal Isolation: Reproducing** at **different** times.

Rates of Evolution

- **Gradualism**
  - Evolution happens **slowly** over a **long** time.
  - Fossil evidence shows **continuous**, small changes.
- **Punctuated Equilibrium**
  - Evolution happens in **bursts** with **long periods** of **no change** (**stasis**).
  - Triggered by **sudden** environmental **changes** or **mutations**.



GRADUALISM

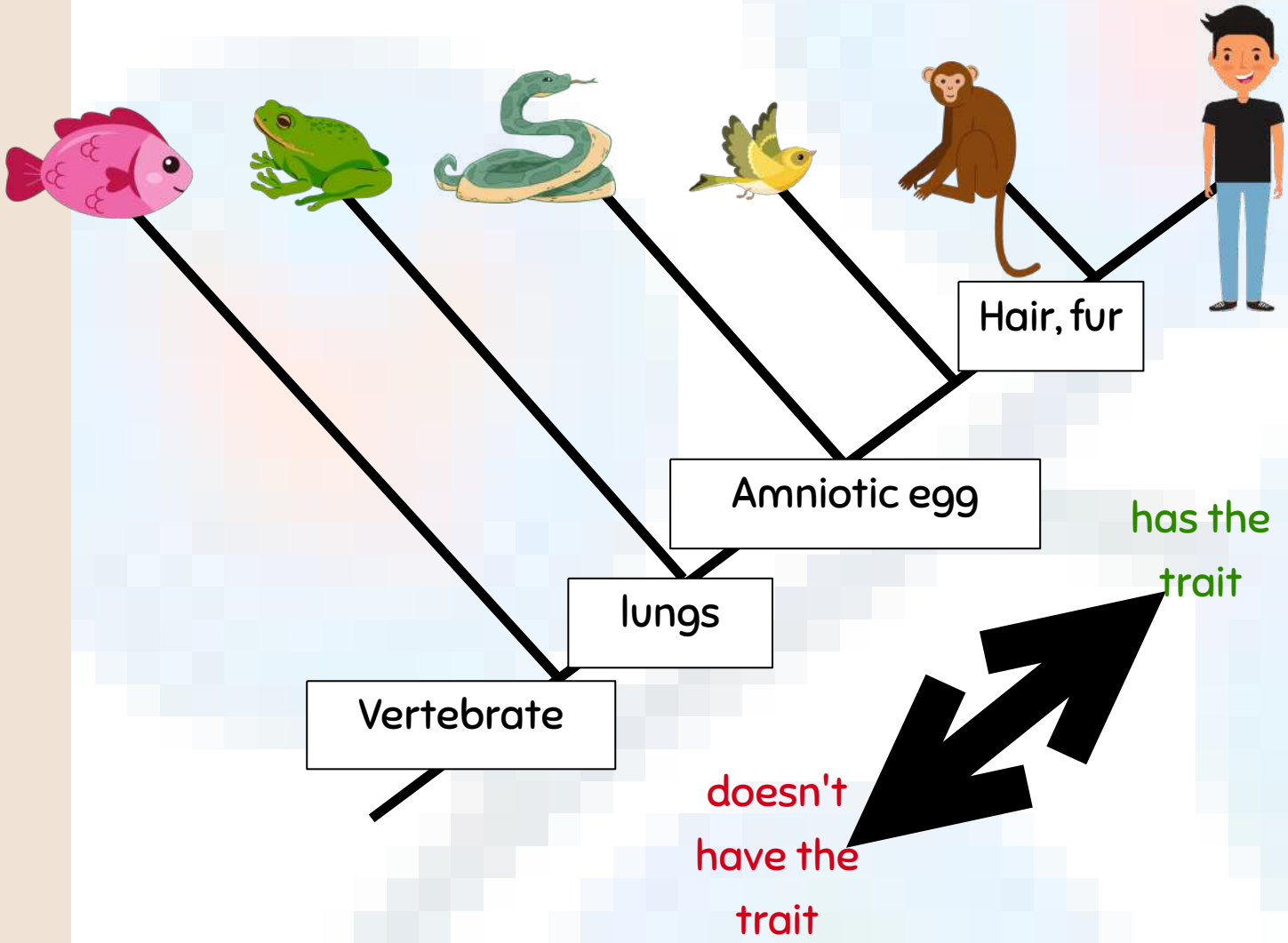
PUNCTUATED EQUILIBRIUM

- What is catastrophism, and how does it explain sudden changes in Earth's history?
- How does gradualism describe the way changes happen over a long period of time?
- What makes punctuated equilibrium different from gradualism?
- How might a natural disaster, like a volcanic eruption, fit into the idea of catastrophism?
- Can you think of an example in nature that could show gradual change and one that might show sudden change?

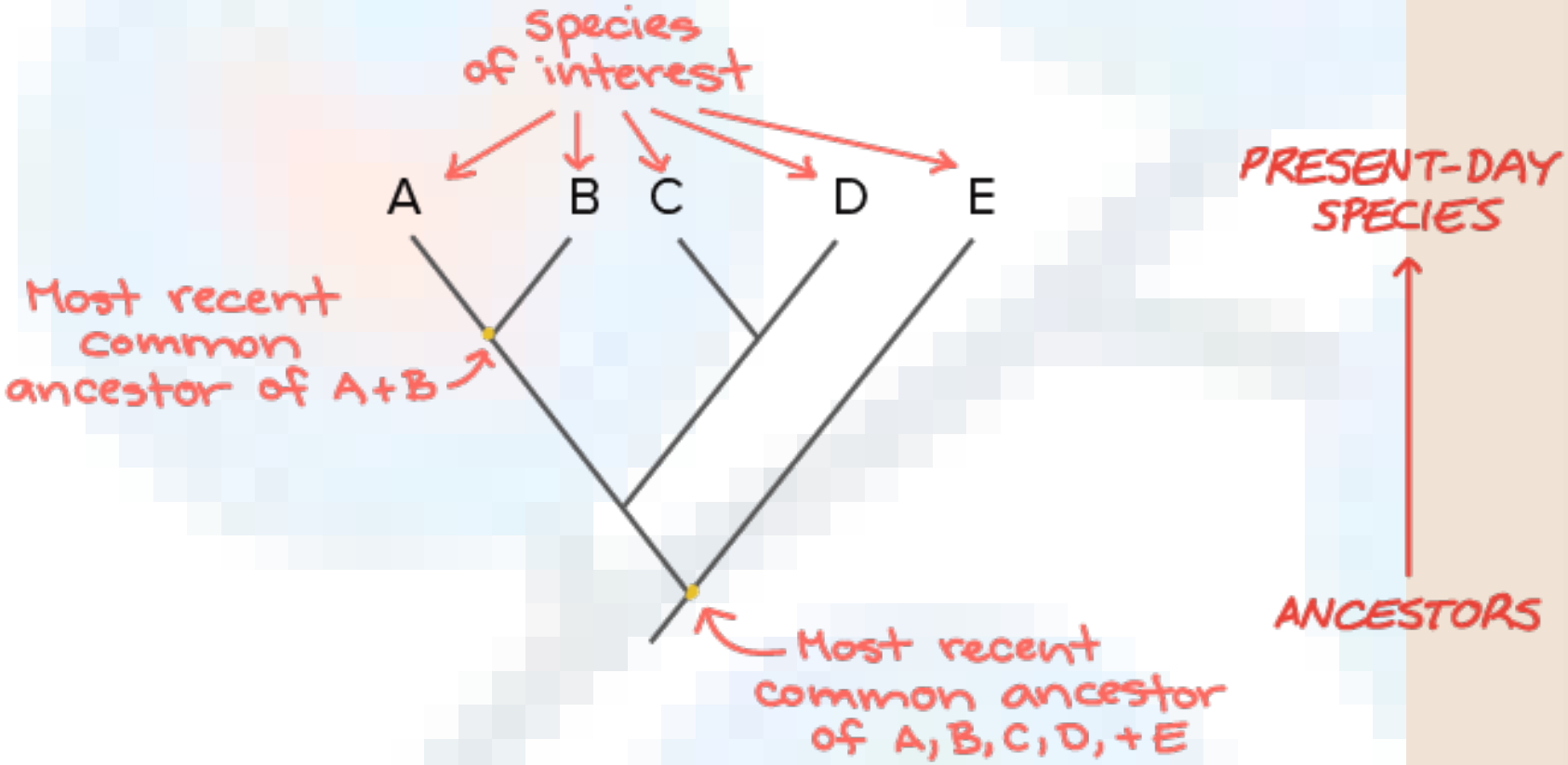
TRACING EVOLUTION

Cladograms and **Phylogenetic Trees**

- Definitions
  - **Cladogram**: Shows **relationships** based on shared **traits**.



- **Phylogenetic Tree:** Shows evolutionary **relationships**, often with **time** included.
- How to Read
  - **Nodes**: Represent **common ancestors.**
  - **Branches**: Show evolutionary **paths**.
- Example:
  - Species **closer** on the tree **share** a more **recent** ancestor.
  - **Longer** branches indicate **more** evolutionary **change** or time.



Factors Affecting Evolution

- **Population Changes**
  - **Favorable** conditions lead to population **growth**.
  - **Unfavorable** conditions can lead to **extinction**.
- **Speciation**
  - New species form when environments **change** and populations **adapt**.
- **Extinction**
  - Rapid changes, like habitat **destruction**, can **eliminate** species **unable** to **adapt**.

Summary

- How does the fossil record provide evidence for the evolution of life over time?
  - "The fossil record shows how organisms have changed by _____."
  - "Older fossils are found deeper in the ground, which tells us that _____."
- What are anatomical homologies, and how do they support the idea of common ancestry?
  - "Anatomical homologies are body parts that are similar in structure but _____."
  - "These similarities suggest that the organisms came from _____."
- How does natural selection lead to changes in populations over time?
  - "Natural selection causes populations to change because individuals with helpful traits _____."
  - "Over many generations, these traits become more common, which means _____."
- What is speciation, and how can it happen when populations become separated?
  - "Speciation happens when a group of organisms becomes so different that _____."
  - "This can happen because of geographic isolation or _____."
- How do genetic mechanisms like mutations and gene flow affect evolution?
  - "Mutations add new traits by changing _____."
  - "Gene flow happens when genes move between populations, which can _____."
- What patterns of evolutionary change did you observe, and how do they connect to environmental conditions?
  - "Gradualism is a slow change over time, while punctuated equilibrium is _____."
  - "Changes in the environment can cause species to _____ or even go extinct."

RESOURCES

Bozeman Science. (2012, November 3). Endosymbiosis [Video]. YouTube. https://www.youtube.com/watch?v=-FQmAnmLZtE

Teacher's Pet. (2015, April 21). Evidence for evolution [Video]. YouTube. https://www.youtube.com/watch?v=021VOcLIb3M

Amoeba Sisters. (2016, January 29). Natural selection [Video]. YouTube. https://www.youtube.com/watch?v=7VM9YxmULuo

Professor Dave Explains. (2017, November 13). The evolution of populations: natural selection, genetic drift, and gene flow [Video]. YouTube. https://www.youtube.com/watch?v=SRWXEMII0_U

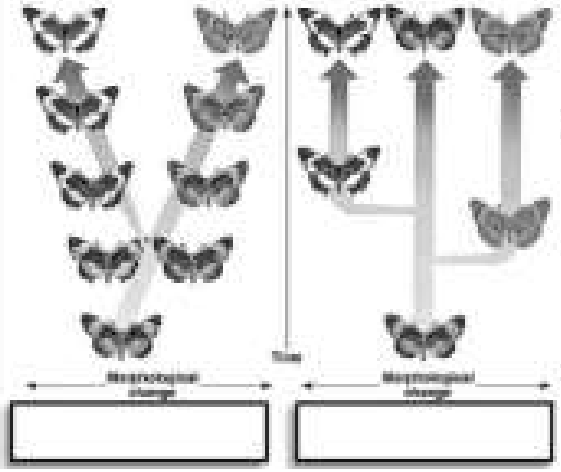
Natural Selection

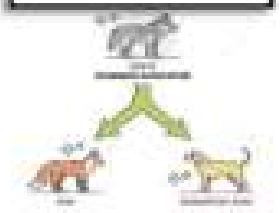
Change in a species over time

differences

Trait better suited to SURVIVE

variation





differences

Too many

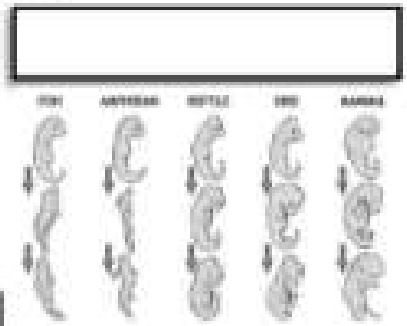
Beneficial trait

Time

Mechanisms

Evidences

1



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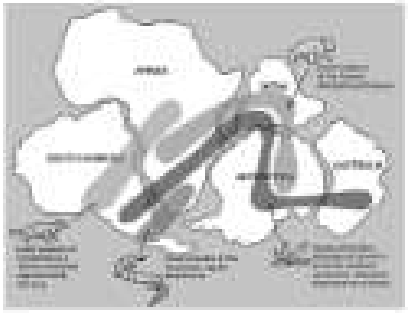
Closer the populations, the more related



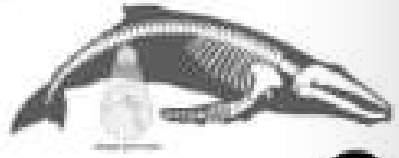
5

Track species over time – transitional fossils

Common ancestry

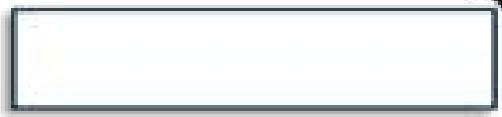
No evidence of Common ancestry

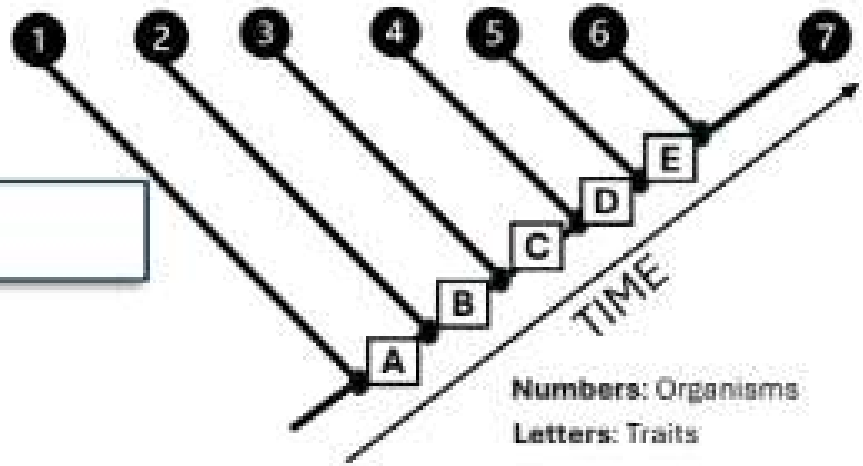
Non-use, ancestors



Proteins and sequences of Nucleotides – Similar - Evidence of Common Ancestry

Mechanisms for Evolution



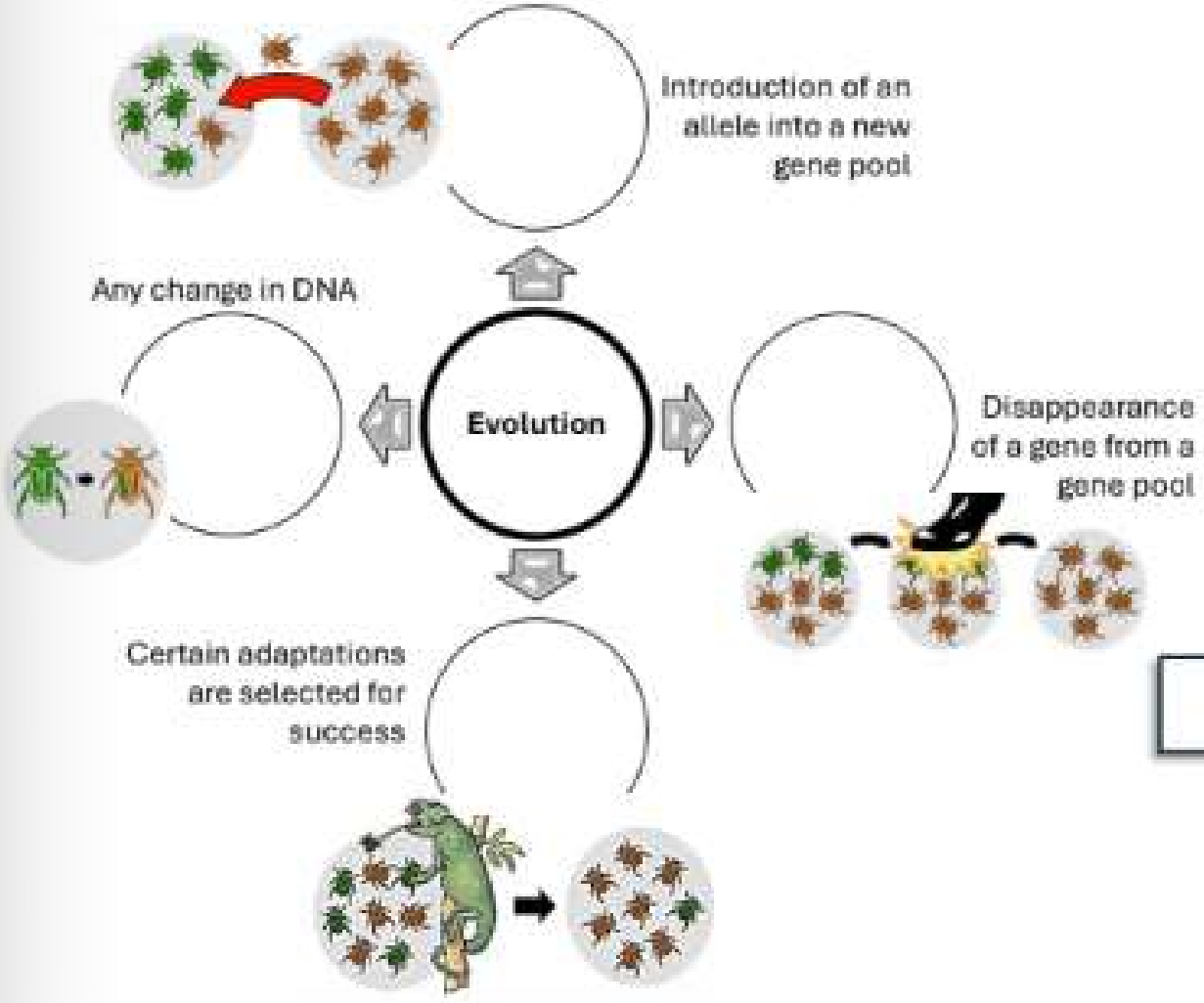


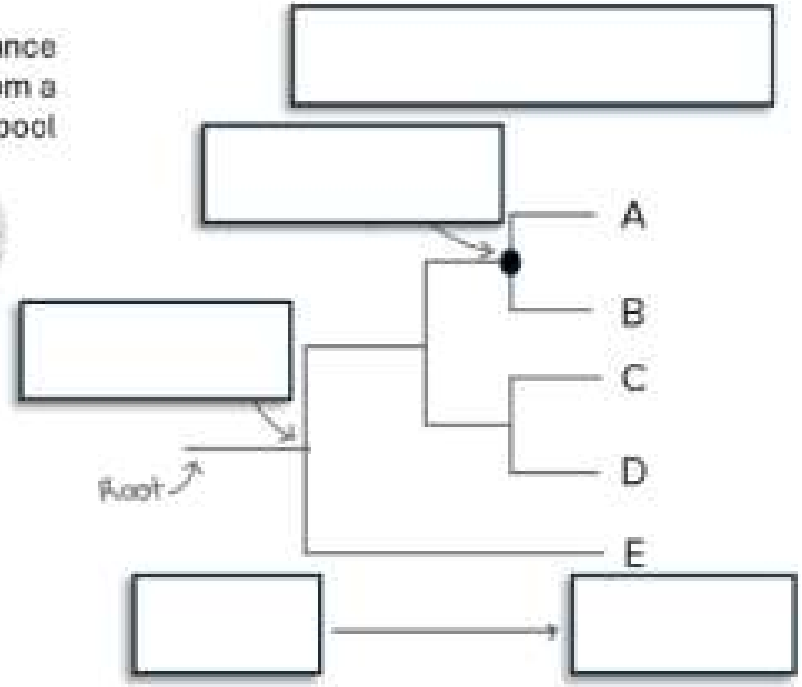
Numbers: Organisms

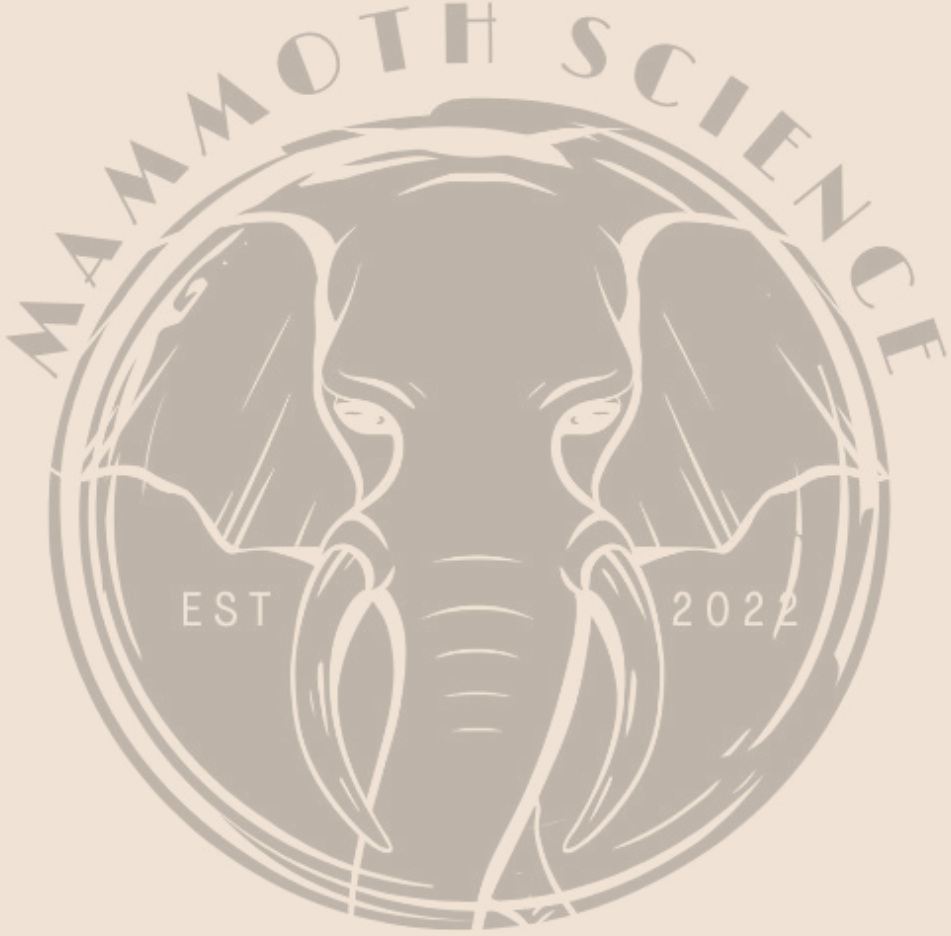
Letters: Traits

- **Common Ancestors**

Given a trait (B), everything **above** that trait **has** the characteristic. Everything **below**, **does not**.



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2022