WUHS Biology: Mutations Unit

Week 2 – How can mutations result in new traits?

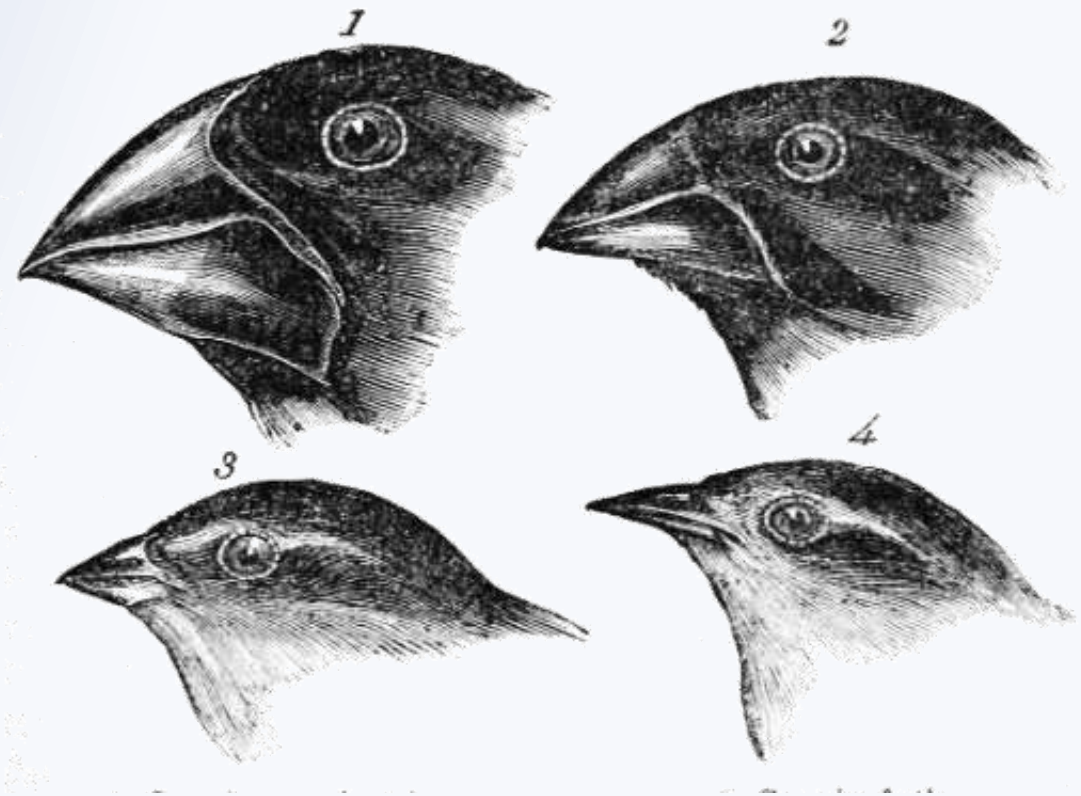


Image Source

Mutations Unit – W2 Driving Question

- **Driving Question: How can mutations result in new traits?**
- How do environmental conditions and competition affect whether mutations are helpful, harmful, or neutral?
- How and why do the traits of species sometimes change?
- Why do some species' traits change faster than others?
- What factors determine whether a species' traits will change?

Image Source; U. Maine Extension

Recap of Week 1

A mutation occurs when DNA changes through the loss, addition, or switching of at least one base.

Acquired mutations occur after fertilization, are not found in all cells, and are not passed on to offspring.

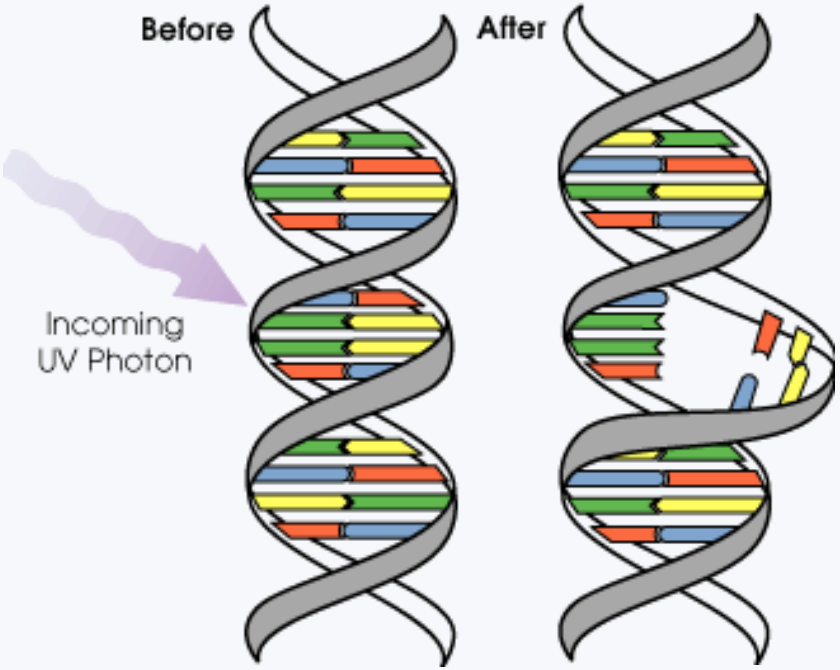
Hereditary mutations occur before fertilization, are found in all cells, and can be passed on to offspring.

Acquired mutations can be caused by replication errors during mitosis or by mutagens (environmental factors like UV radiation that can cause mutations).

Hereditary mutations can be caused by replication errors during meiosis, by errors in crossing over during meiosis, or by mutagens that affect the DNA of sperm or egg cells.

Glu

Arg



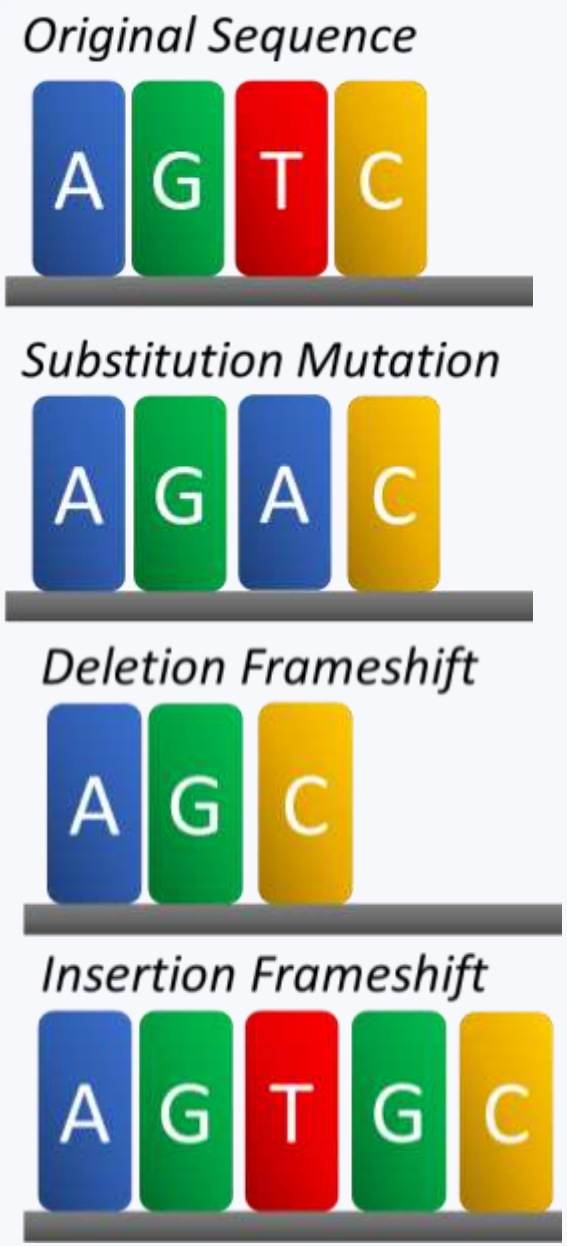
Recap of Week 1

A substitution mutation (or *point* mutation) occurs if one base is replaced by another base.

A frameshift mutation changes every codon that occurs after the mutation due to the insertion or deletion of a base.

Frameshift mutations tend to have the biggest impact on protein assembly because they cause all the other amino acids to change after the mutation.

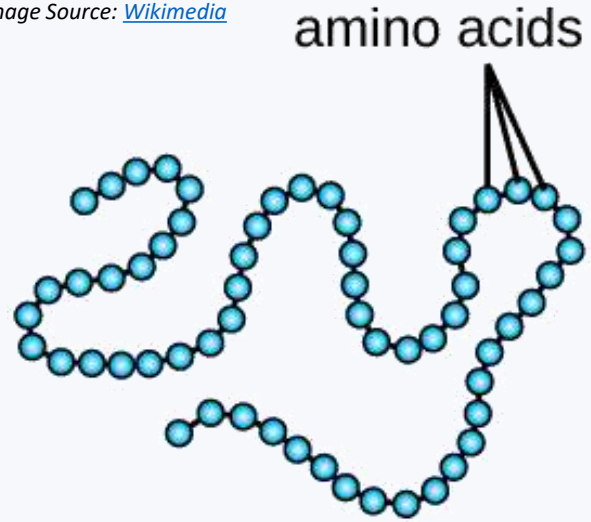
Chromosomal mutations involve changes in the structure of a chromosome and affect multiple genes.



DNA → Proteins → Traits

- **The traits of a species are primarily determined by the types of proteins made in its cells.**
  - All proteins are made from amino acids; different arrangements of amino acids result in different proteins.
  - The order of amino acids is determined by the order of codons in a mRNA copy of DNA.
- **Different kinds of proteins perform different functions within a cell.**
  - For example, *enzymes* are proteins that assemble, disassemble, or rearrange molecules. Enzymes determine what an organism can eat.
  - *Structural* proteins help to determine whether an organism has hair or feathers, among other structures.
  - *Signaling* proteins coordinate how different tissues are produced and arranged (such as bones and muscles).

Image Source: Wikimedia



Amino acids assemble into long chains to form a protein based on instructions in DNA.

A group of genes produce proteins to form a chicken's beak. Blocking those genes causes the bird to develop a mouth w/ teeth (above).

Impacts of Mutations

- **DNA, proteins, and traits can change from mutations.**
  - Mutations can be caused by mutagens, copying errors, and errors during crossing over.
- **Often these changes are harmful; for example, genetic diseases like sickle cell anemia are due to mutations.**
  - Sometimes mutations have no impact on the shape and function of a protein; these are known as silent mutations.
- **In some cases, mutations can be beneficial to an organism.**
  - Any trait that increases an organism's ability to survive and reproduce is called an adaptation.
  - Whether a mutation is harmful, neutral, or helpful depends on the organism's surrounding environment conditions.

Image Source: Wikimedia

DNA level	TTC
mRNA level	AAG
protein level	Lys

DNA level	TTT
mRNA level	AAA
protein level	Lys

Silent mutations occur when changes to DNA do not affect the shape and function of a protein.

Left Image Source: Nat Geo

Right Image Source: Wikimedia

Mutations → Adaptations

- **For example, a random mutation in a single gene caused some birds like vultures and ostriches to lose some or all the feathers on their head.**
  - This gene, called *BMP12*, codes for a signaling protein that works like an on/off switch for head feathers.
  - If the *BMP12* gene is mutated, this signaling protein becomes dysfunctional. This prevents the development of feathers on the head and neck of some birds.

- **Whether this change is beneficial is determined by the environment - the mutation is random and is not inherently helpful or harmful.**
  - This was beneficial for the vulture because it reduced their risk of disease as they fed on dead animals.
  - This was beneficial for ostriches because it helped them stay cooler in hot climates.
  - Birds with this same mutation in cold climates (where feathers are needed for warmth) would be less likely to survive and reproduce.

A lack of feathers on vultures and ostriches provides benefits because of their unique environmental conditions.

Image Source: Wikimedia

Competition

- **Competition also determines whether mutations are harmful or helpful.**
  - Mutations will be less likely to affect survival and reproduction if competition is not needed to acquire resources, for mating, or to avoid predators.
  - The more that organisms must compete for food, mates, and to avoid predation, the more their survival & reproduction is affected by mutations.
- **Increased rates of competition & predation among organisms generally results in more rapid changes to traits.**
  - Reduced rates of competition/predation tend to slow the rate of genetic change.
- **For example, some species like sharks and crocodiles have changed very little over millions of years.**
  - As apex predators at the top of their food chains, these species have limited competition for resources; their adaptations are sufficiently effective for their environments.
  - As a result, changes in their genes are less likely to provide competitive benefits.

Natural Selection

- **<u>Natural selection</u> is the process that determines whether changes from mutations increase or decrease an organism's capacity for survival and reproduction in response to their surroundings.**
  - Natural selection is a naturally occurring phenomenon; it emerges as a result of interactions between mutations, environmental conditions, and competition for survival and reproduction.
- **Green and gray tree frogs are examples of natural selection.**
  - Green tree frogs blend in with green vegetation common in wetlands.
  - Gray tree frogs have an advantage in wooded areas because they blend in with the gray tree bark.
  - As a result of natural selection, higher proportions of green tree frogs are found in wetland areas, and wooded areas have higher proportions of gray tree frogs.

Image Source; U. Maine Extension

Artificial Selection

- **<u>Artificial selection</u> is the process in which organisms are selected for genetic traits that benefit human needs.**
  - In both artificial selection and natural selection, species with advantageous traits more likely to survive & reproduce.
  - However, in artificial selection, human needs determine whether a trait is beneficial (instead of whether a trait improves an organism's ability to survive & reproduce).
  - <u>Domestication</u> occurs when humans select for beneficial genetic changes to the extent that the organism becomes physiologically different from its wild counterparts.
- **For example, modern corn descended from an ancient plant called teosinte.**
  - Domesticated corn looks very different from teosinte and is less likely to survive in wild habitats.
  - However, corn provides far greater benefits for humans than teosinte; as a result, human intervention ensures that corn survives and reproduces.

Modern corn plants (right) emerged from teosinte (left) via artificial selection.

Image source: Wikimedia

Image Source: Genome.gov

Changes Over Time

- **If beneficial changes from random mutations can be passed on to offspring, these traits are likely to become more prevalent in those populations.**
  - If a beneficial mutation is an acquired mutation (cannot be passed on), it will only change that one organism.
  - If a beneficial mutation is a hereditary mutation (can be passed on), it can affect multiple organisms within a species.
  - Over time, the species may change as beneficial hereditary mutations become more and more prevalent.
- **Changes to a species over time due to natural selection is known as <u>evolution</u>.**
  - Evolution usually takes many, many generations for enough changes to occur in order for a species to change.

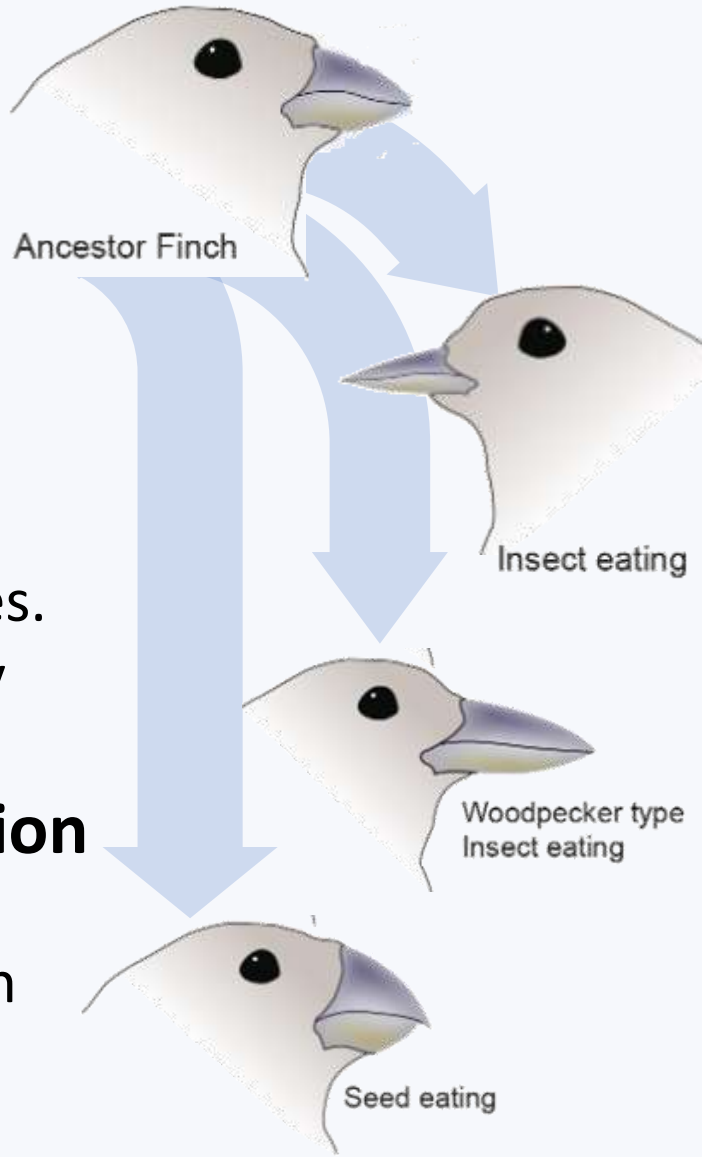


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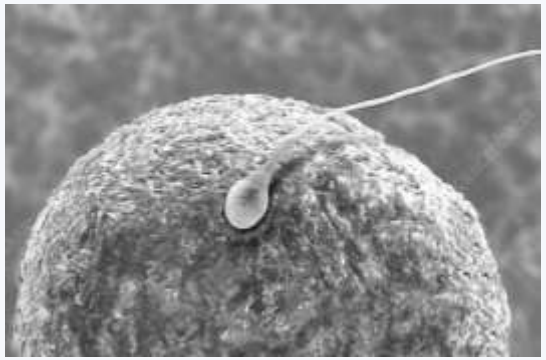
Image Source: SciencePhoto

Four Factors for Evolution

- **Evolution by natural selection requires four factors:**
  - Sexual Reproduction: Mating increases genetic diversity and can result in new combinations of genes and physical traits.
  - Heritable Genetic Variation: Hereditary mutations result in new varieties of genes and physical traits that can be passed on.
  - Competition: Struggles for limited food, mates, and to avoid predation determines whether a set of traits is advantageous for an organism in that environment.
  - Differences in Reproduction & Survival Rates: Organisms with advantageous traits are more likely to survive and reproduce, increasing the prevalence of those traits in that environment.



Source: m.harunyahya.com

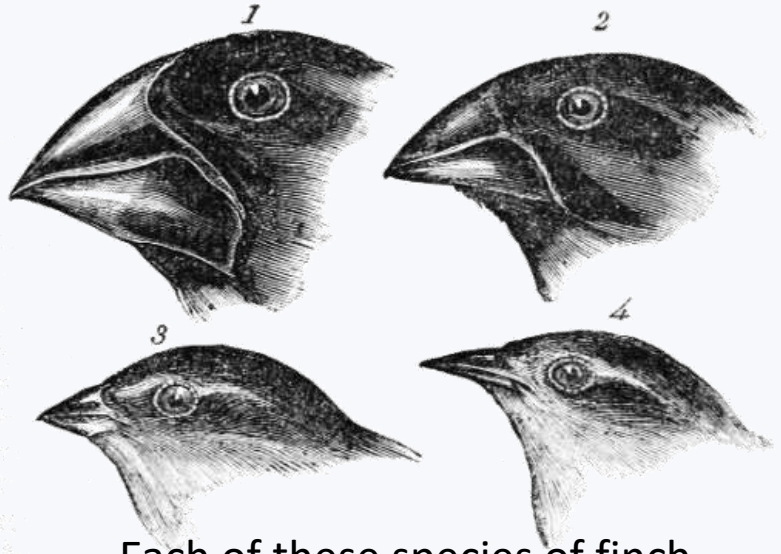
Source: www.seahawks.net

Source: www.telegraph.co.uk

Image Source

When is it a new species?

- **If enough changes occur as a result of natural selection, a group of organisms can form a new species.**
  - A species is a group of organisms with similar traits that can breed and produce fertile offspring.
- **For example, a single species of bird arrived on an isolated chain of islands known as the Galapagos Islands.**
  - Since that time, 15 new species of birds have evolved from that original species.
  - Some mutations resulted in traits that provided some birds with the ability to utilize new sources of food.
  - Some birds accumulated enough new genetic changes that they no longer belonged to the same species.

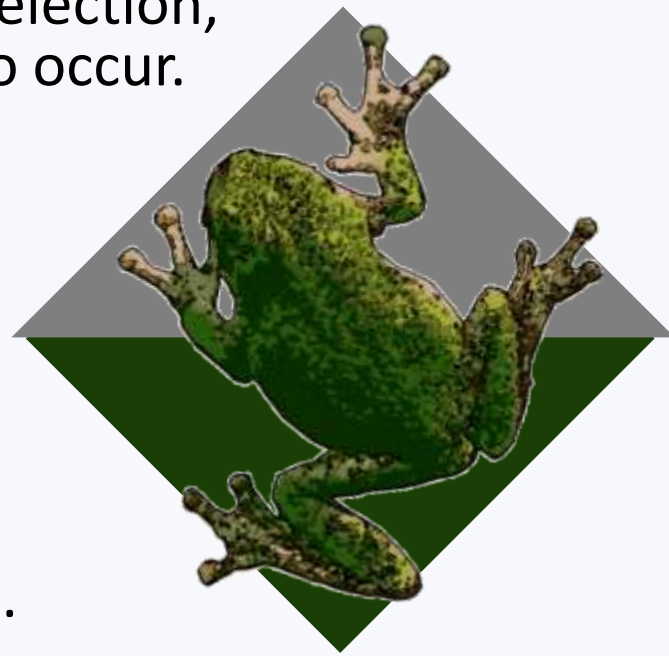


Each of these species of finch evolved over millions of years from a single common species.

Image Source: SVG

Clarification on Mutation

- **Evolution primarily depends on hereditary mutations.**
  - *Hereditary* mutations are present throughout an organism's life, are found in every cell, and can be passed on from generation to generation.
  - Mutations that are not hereditary (i.e., *acquired* mutations) may affect the survival of an individual organism but cannot result in changes to a species.
- **Mutations occur randomly and independently from the environment.**
  - Beneficial traits will become more common due to natural selection, but environments do not cause specific traits & mutations to occur.
  - For example, natural selection favors green tree frogs in wetlands and gray tree frogs in forested areas, but these frogs do not change color if they move to a new habitat.
  - Similarly, a giraffe's neck did not get longer because of taller trees; random mutations caused a longer neck.
  - Tree frog color and longer giraffe necks were caused by random mutations; natural selection enabled these traits to become more prevalent in specific kinds of environments.



Evidence for Evolution by Natural Selection

What evidence suggests that this occurs among species?

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Image Source: Wikimedia

Evidence for Evolution

- **In his publication *On the Origin of Species* in 1859, Charles Darwin first described how natural selection enables evolution.**
  - Evidence continues to emerge supporting the idea that random heritable mutations and environmental pressures can lead to changes to species.

- **A key source of evidence is that many species share unique physical features.**
  - Shared anatomical features across multiple species are known as homologous structures.
  - For example, the bones in the forelimbs of humans, whales, birds, and dogs all contain an arrangement of the same kinds of bones.
  - This suggests they share a common ancestor.

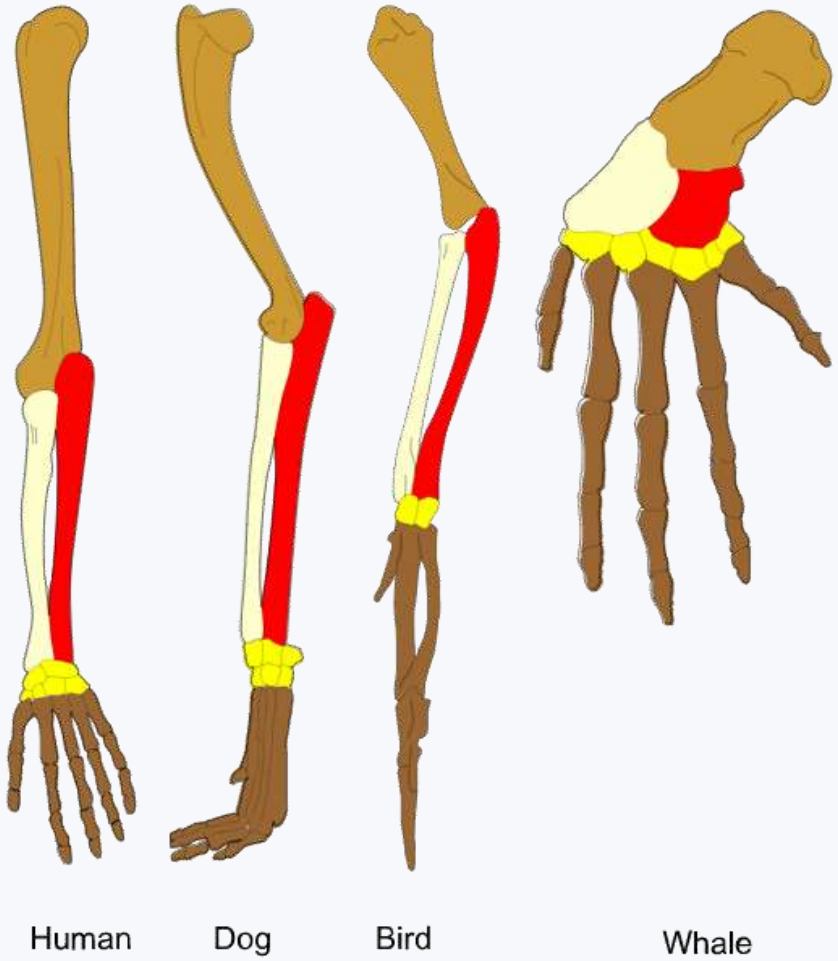
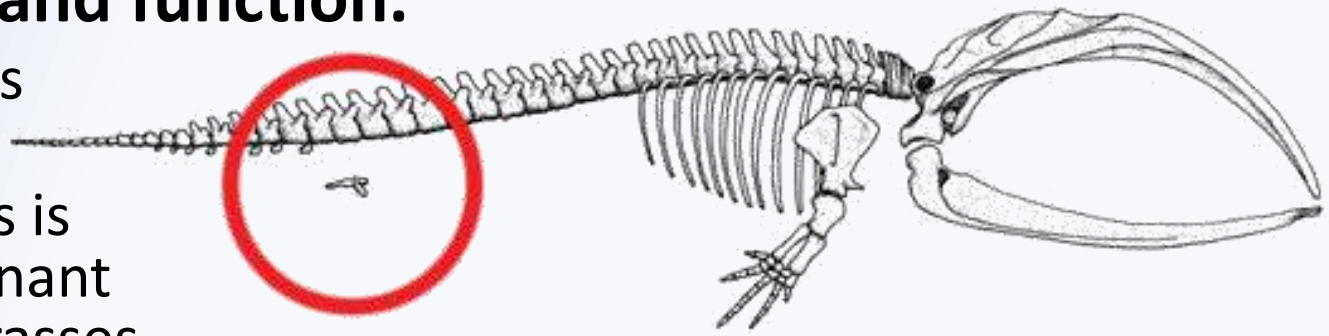


Image Source: Flickr

Evidence for Evolution

- **Analogous structures and vestigial structures are also evidence for evolution.**
- **<u>Analogous structures</u> are body parts that are different in terms of structure but share a similar function.**
  - For example, both dolphins and sharks have similar dorsal fins that emerged separately as a result of different random mutations and similar environmental pressures.
- **<u>Vestigial structures</u> are anatomical features that have lost much of their original size and function.**
  - For example, whales and dolphins continue to have hip bones →
  - Similarly, the appendix in humans is a vestigial structure; it is the remnant of a former organ for digesting grasses.

Dorsal fins of sharks and dolphins are structurally different but similar in function.



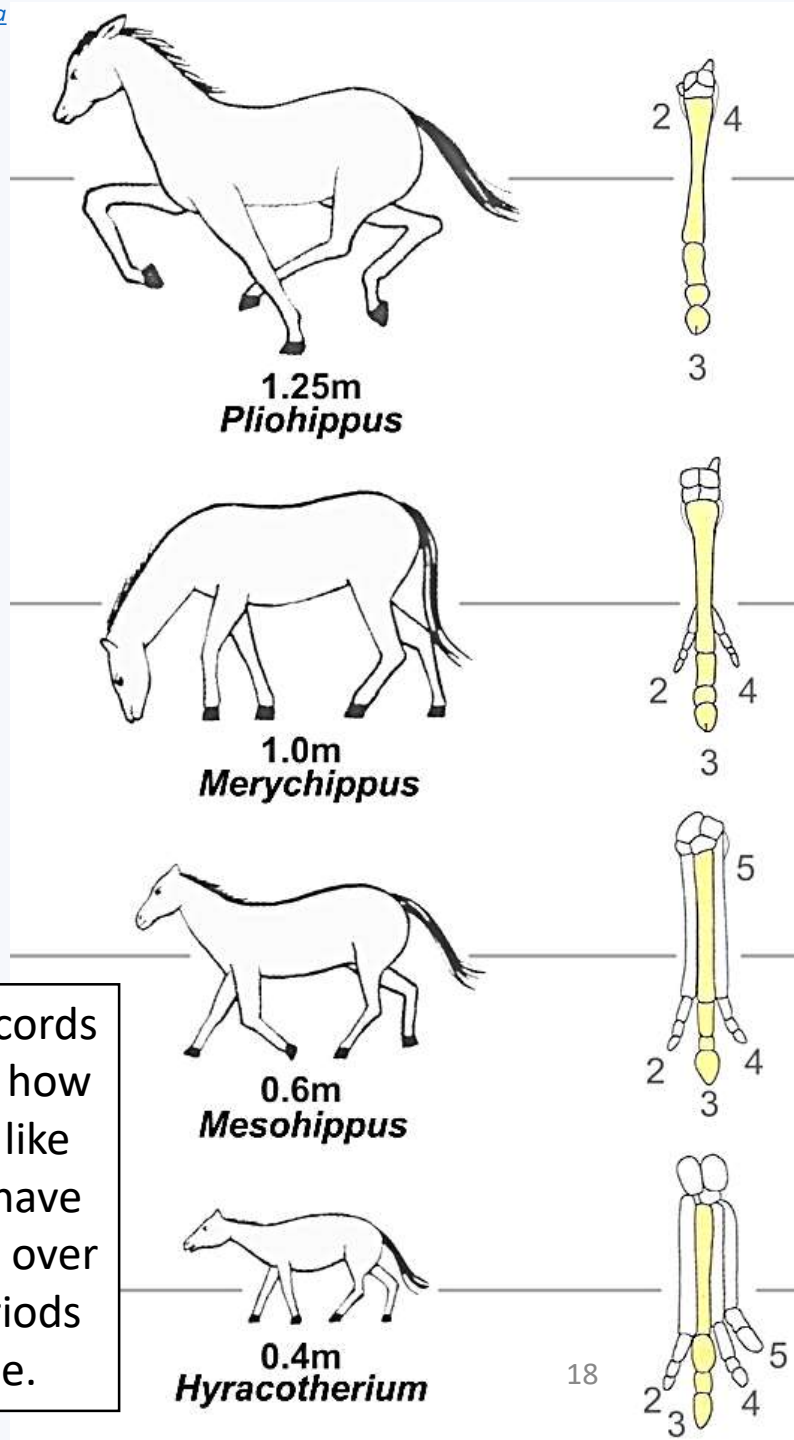
The hip bones of whales are vestigial structures. These bones are evidence of a land-dwelling ancestor.

Image Source: Wikimedia

Image Source: Wikimedia

Evidence for Evolution

- **DNA also provides strong evidence for evolution.**
  - All organisms use DNA in a similar manner to assemble proteins through transcription & translation.
  - Furthermore, species that share more recent genetic ancestors also share more of the same genes.
    - *For example, humans, cows, chickens, and chimpanzees all share a gene for the insulin protein.*
- **The fossil record also provides evidence for evolution.**
  - Fossils are remnants of prehistoric organisms that have been preserved in the earth's crust.
  - Fossil records indicate that many different organisms have lived throughout Earth's history.
  - Evolution can be observed by comparing fossils of organisms at different points in geological history.



Fossil records indicate how species like horses have changed over long periods of time.

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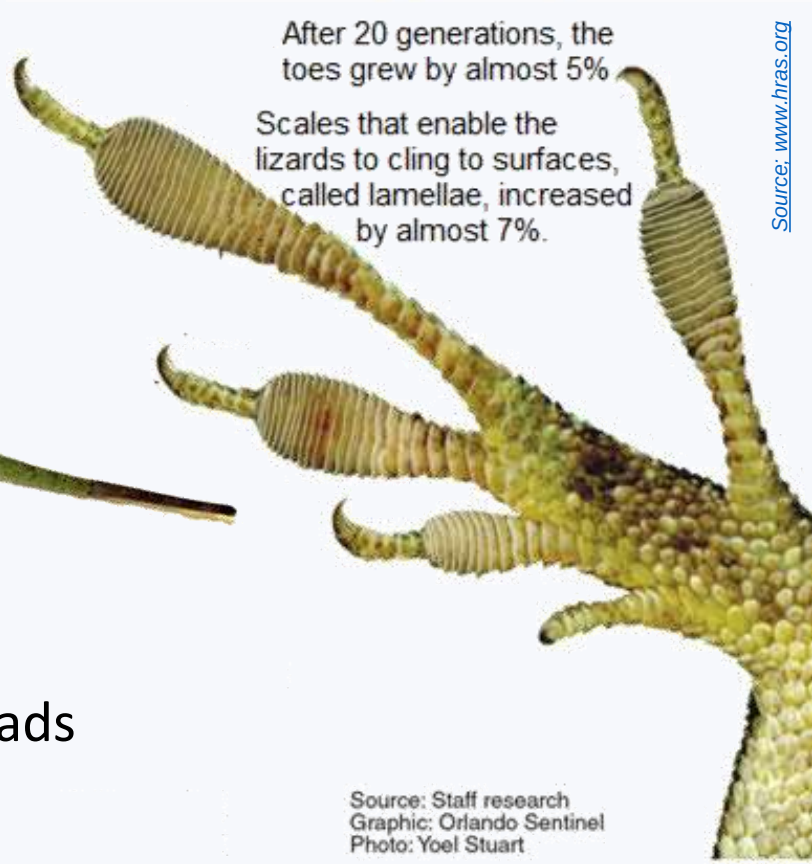
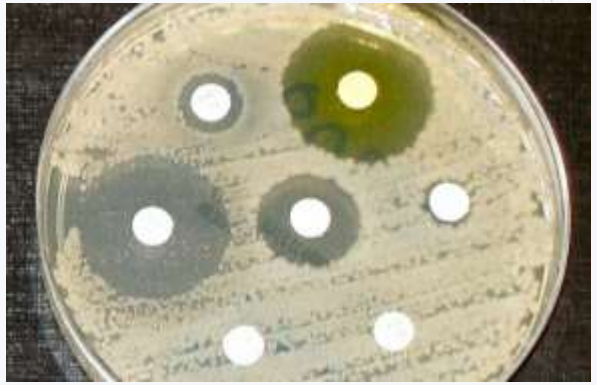
Source: www.reptilesmagazine.com

Evidence for Evolution



Source; www.hras.org

- **Lastly, evolution can sometimes be measured as it is occurring.**
  - For example, the green anole is a lizard that lives in trees in Florida.
  - A newly introduced species (the brown anole) was better able to compete for food and resources.
  - This forced the green anole to move to higher branches.
  - In only 20 generations, the green anole evolved larger toepads with more scales to better cling to higher branches.
- **Measurable evolution also occurs among bacteria, insects, weeds, and viruses.**
  - For example, increasingly more bacteria have mutations that enable them to survive antibiotic treatments.
    - *This is known as antibiotic resistance.*
  - Similarly, increasingly more weeds are resistant to herbicides and more harmful insects are unaffected by insecticides.
  - The need for a new flu shot every year is also evidence that the flu virus is rapidly evolving to have new genes and traits.

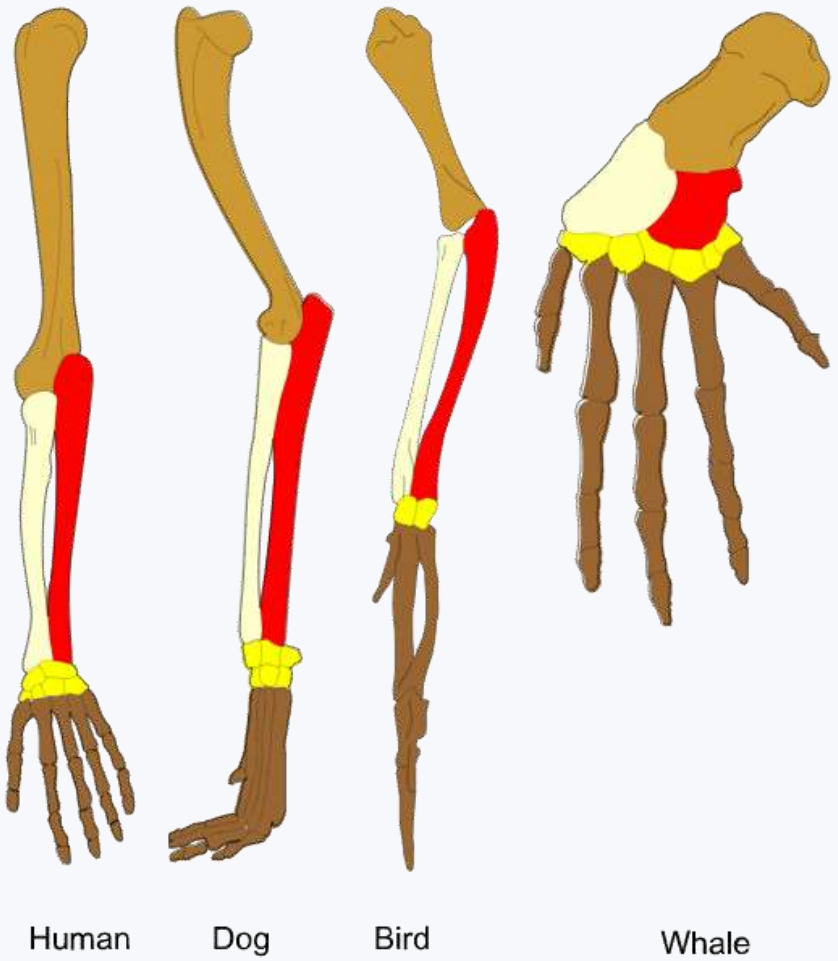


Bacteria growing in this petri dish are resistant to most of the antibiotics in the white disks.

Image Source: Wikimedia

Revising Our Claims

- **Revisit your ideas from Part 1.**
  - How could you improve your responses to our Driving Questions?
- **How can mutations result in new traits?**
- How do environmental conditions and competition affect whether mutations are helpful, harmful, or neutral?
- How and why to the traits of species sometimes change?
- Why do some species' traits change faster than others?
- What factors determine whether a species' traits will change?



Looking Ahead: Part 3 Investigation

- **In Part 3 you will use computer models to compare how environmental factors (competition, predation, etc.) affect the prevalence of different traits and adaptations.**

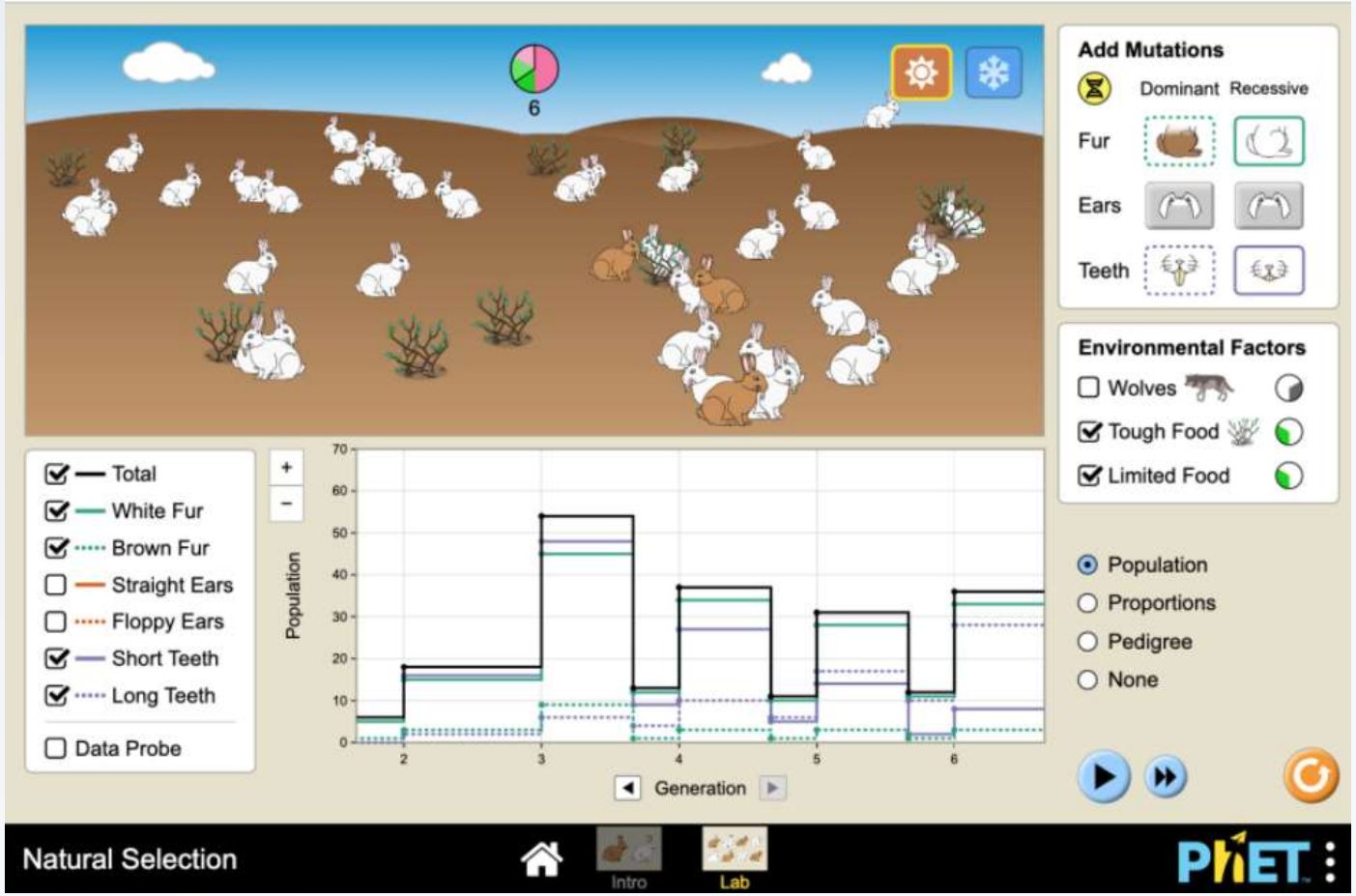


Image Source: Craig Kohn

Key Points

- **Whether changes from mutations are harmful, neutral, or beneficial depends on an organism's surrounding environment.**
  - Silent mutations do not affect the shape and function of a protein.
  - Traits from mutations that improve an organism's ability to survive and reproduce are called adaptations.
- **Competition also affects whether mutations are harmful, neutral, or beneficial.**
  - The more that organisms must compete for food, mates, and to avoid predation, the more their survival & reproduction is affected by mutations.
  - Increased rates of competition & predation among organisms generally results in more rapid changes to traits.
- **Natural selection is the process that determines whether changes from mutations increase or decrease an organism's capacity for survival and reproduction in response to their surroundings.**
  - Artificial selection is the process in which organisms are selected for genetic traits that benefit human needs.

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Key Points

- **Changes to a species over time due to natural selection is known as <u>evolution</u>.**
  - If enough changes occur as a result of natural selection, a group of organisms can form a new <u>species</u> (organisms with similar traits that can produce fertile offspring).
- **Evolution by natural selection requires four factors:**
  - <u>Sexual Reproduction</u>: Mating increases genetic diversity and can result in new combinations of genes and physical traits.
  - <u>Heritable Genetic Variation</u>: Hereditary mutations result in new varieties of genes and physical traits that can be passed on.
  - <u>Competition</u>: Competition for limited food, mates, and to avoid predation determines whether a set of traits is advantageous for an organism in that environment.
  - <u>Differences in Reproduction & Survival Rates</u>: Organisms with advantageous traits are more likely to survive and reproduce, increasing the prevalence of those traits in that environment.

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Key Points

- **Evolution primarily depends on hereditary mutations.**
  - Mutations occur randomly and independently from the environment.
  - Natural selection determines whether traits enhance survival and reproduction, but environments do not create specific traits.
  - Adaptations are caused by random mutations; natural selection enables these traits to become more prevalent as species compete for food, mates, and survival.
- **Evidence for evolution by natural selection includes…**
  - Homologous structures: shared anatomical features across multiple species.
  - Analogous structures: body parts w/ different structure but shared function.
  - Vestigial structures: anatomical features that lost their original size & function.
  - DNA: species that share recent genetic ancestors also share more similar genes.
  - Fossils: comparing species' fossils at different points shows evolutionary change.
  - Measurable evolution occurs in some species (e.g., anoles, bacteria, viruses, etc.)

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Key Vocab

- **Silent mutations do not affect the shape and function of a protein.**
- **Adaptations: traits from mutations that improve an organism's ability to survive and reproduce.**
- **Natural selection is the process that determines whether changes from mutations increase or decrease an organism's capacity for survival and reproduction in response to their surroundings.**
- **Artificial selection is the process in which organisms are selected for genetic traits that benefit human needs.**
- **Domestication: when humans select for beneficial genetic changes to the extent that the organism becomes physiologically different from its wild counterparts.**
- **Evolution: changes to a species over time due to natural selection.**
- **Species: organisms with similar traits that can produce fertile offspring.**
- **Homologous structures: shared anatomical features across multiple species.**
- **Analogous structures: body parts w/ different structure but shared function.**
- **Vestigial structures: anatomical features that lost their original size & function.**
- **Fossils: remnants of prehistoric organisms that have been preserved in the earth's crust.**

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