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AP BIOLOGY

Evolution & Classification

March 2014

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Evolution & Classification

[*Click on the topic to go to that section*](#)

- **Darwin**
- **Evidence for Evolution**
- **Natural Selection**
- **Population Genetics**
- **Macroevolution**
- **Reproductive Isolation**
- **Phylogenetics**

Darwin

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Evolution Defined

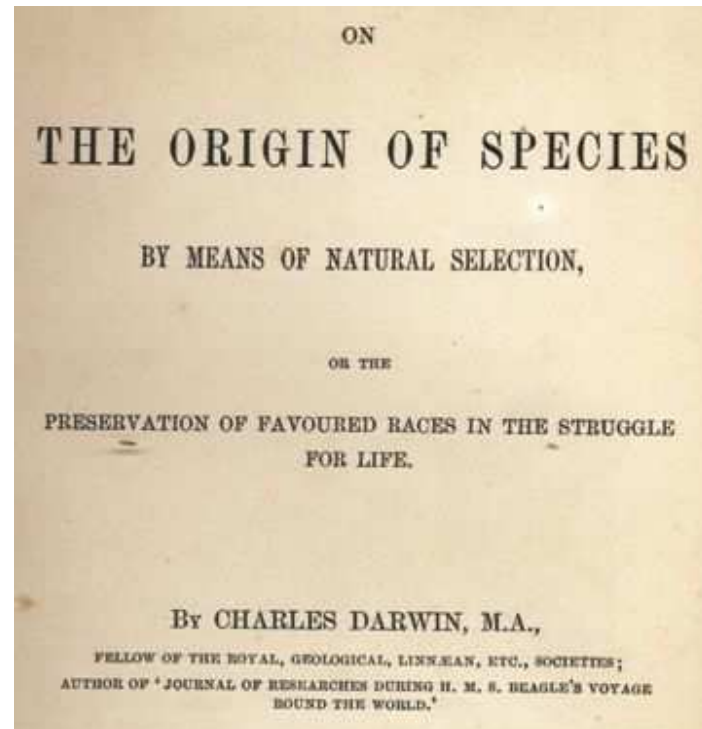
ev·o·lu·tion

Biology- a. Change in the genetic composition of a population during successive generations, as a result of natural selection acting on the genetic variation among individuals, and resulting in the development of new species.

Evolution Defined

"Change in the genetic composition of a population during successive generations, as a result of natural selection acting on the genetic variation among individuals, and resulting in the development of new species."

The person most responsible for this current definition of biological evolution is **Charles Darwin** and his theories presented in his book "**The Origin of Species**"



Journey of the H.M.S. Beagle 1831-1836



The Galapagos Islands

In the 4th year of the voyage, the H.M.S Beagle reached the Galapagos Islands off the coast of Equador.

Darwin found many plant and animal species that were very similar to the species on the mainland of South America.



He compared the island and mainland species and found that the island varieties had different adaptations from the same mainland species.

Darwin in South America

As the ship's crew surveyed the coast of South America, including the Galapagos Islands, Darwin spent most of his time inland collecting thousands of living plants and animals as well as old bones.

During his 5 year voyage Darwin made many observations that led to his published theories.



Darwin's Observations

As we go over the 5 major observations that Darwin made in South America, write down some of your own theories.

The question we need to answer:

Why do living things do what Darwin observed?



Darwin's Observations

1st Observation

In the majority of species observed by humans, more offspring are born than can survive to become adults. Female fish can hatch thousands of offspring, but usually only one or two survive to become adults. The same is true for the bugs, turtles, birds and plant species Darwin observed.

WHY? Producing offspring uses a lot of energy. Why would individuals make so many if only a few can survive?

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is not currently
supported in PDFs.
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document file.



Think about it for a minute

Darwin's Observations

2nd Observation

There are a limited amount of resources (food, water, shelter) available to any given species. These resources limit the amount of offspring that can survive, yet species would quickly exceed that limit if all of their offspring survived.

WHY? Species would go extinct if their numbers outgrew the available resources. Why do individuals have the ability to produce enough offspring to easily deplete resources?

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Think about it for a minute

Darwin's Observations

3rd Observation

The number of individuals in a group of the same species remains relatively constant over the long term.

WHY? Given the 1st and 2nd observation, why do we not see an increase in the overall number of individuals? Why does the overall number of individuals not decrease due to the limitations of resources?



Think about it for a minute

Darwin's Observations

4th Observation

Individuals of a species vary in almost all of their characteristics. He observed beak sizes in birds, shells of tortoises, spotting patterns of beetles, color of flowers and many more variations of common features.

WHY? It must be important to have these variations, but why?



Think about it for a minute

Darwin's Observations

5th Observation

Each mating season parents produce more offspring. The variations that are present in the successful parents are passed to their offspring. This process of **heredity** is repeated generation after generation.

WHY? It must be important to the species to have the specific variations of the successful parents, but why?

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Think about it for a minute

Darwin's Observations

Now take 2 minutes and look over your thoughts regarding the previous questions. Can you put your reasons for these observations of life into a few clear statements. Compare your statements with other students' statements.



Think about it

Darwin's Inferences

In the previous activity you were producing **inferences**. These are statements made taking into account past observations. This is how a hypothesis is created.

Darwin did the same. Compare your inferences with Darwin's...

Darwin's Inferences

1st Inference

A **population** is a group of individuals of the same species living in the same geographic area that are capable of interbreeding. The individuals of a population are in constant competition with one another for the limited resources available.

This inference is based on the first three observations. It accounts for why populations remain relatively constant in number of individuals even though there is a high number of offspring in each new generation.

Darwin's Inferences

2nd Inference

The variations in the individuals of a population help the individual to survive or can lead to its death in the competition for survival.

This inference is based on the fourth observation. It explains the purpose of variation. They give an individual more or less chance at survival. Any variation that consistently helped individuals survive would be beneficial to the entire population.

Darwin's Inferences

3rd Inference

Individuals that survive the competition are able to breed and produce offspring. Since these individuals pass their traits on and the losers do not, over many generations the different rates of survival based on variation causes the population to transform. The "good" traits survive, the "bad" traits are weeded out.

This inference is based on the fifth observation. It explains that heredity is the key to an evolving population. This inference has become known as **survival of the fittest.**

Darwin's Inferences

Practice

Explain the following scenario using Darwin's inferences. Work in small groups to produce step by step reasoning that is consistent with Darwin's ideas.

A population of bears living in southern Oregon has individuals with varying thickness in their coats of fur. Over many years the climate of their area becomes 10 degrees hotter.

A scientist has recorded the number of thick furred individuals and thin furred individuals. Over the 10 years there has been a 50% increase in thin furred and 50% decrease in thick furred.

Darwin's Hypothesis

Statement: Evolution of a species and the genesis of new species occur by a process of **natural selection**.

Explanation: Individuals having certain characteristics that enable them to survive better than others contribute more offspring to the next generation than those having other characteristics. Since these characteristics are inherited the composition of the population is changed in the next generation.

Darwin's Evidence

In order to support his hypothesis of natural selection, Darwin collected many samples and other pieces of evidence to support his claim.

This evidence along with supporting input and evidence from many other scientists and institutions is why we now call Darwin's hypothesis...

The Theory of Evolution by Natural Selection.

Species of the Galapagos

The Galapagos Islands provided Darwin his important observations and the specimens of species he collected from them served as his primary evidence.

The Islands are close enough together to have similar climates but far enough apart to isolate the species that live on one island from the other islands.



Species of the Galapagos

Also their proximity to South America allowed Darwin to compare species from the main land to species in the islands.



Marine and Terrestrial Iguanas

Terrestrial iguana
Mainland S.America

- round tail
- eat mostly cactus fruit on land
- fear of man
- smaller skin flaps on back
- short, rounded claws
- small, flat teeth



Marine iguana
Galapagos

- flat tail
- dove to the bottom of the ocean to eat algae on the rocks
- no fear of man
- large skin flaps on back
- longer and sharper claws
- longer and sharper teeth



Physical Adaptations of the Marine Iguana

Darwin suggested that the terrestrial iguanas were ancestors of the marine iguanas who adapted to the conditions on the islands.

The main source of food for terrestrial iguanas was fruit from a cactus that is not available on the islands. This means the marine iguanas need to find another food source.

Physical Adaptations of the Marine Iguana

Suggest reasons for each of the trait adaptations below and compare to Darwin's reasoning.

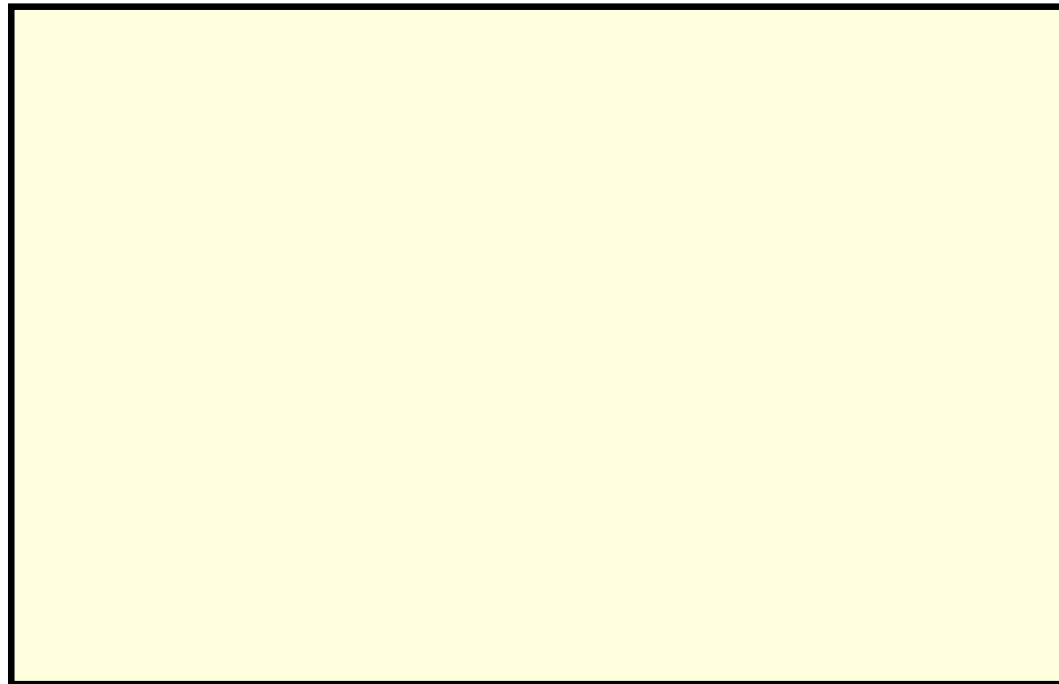
Flat tail:

Eat algae:

Large skin tags:

Sharp claws:

Sharp teeth:



Click square to see Darwin's reasoning

Darwin's Finches

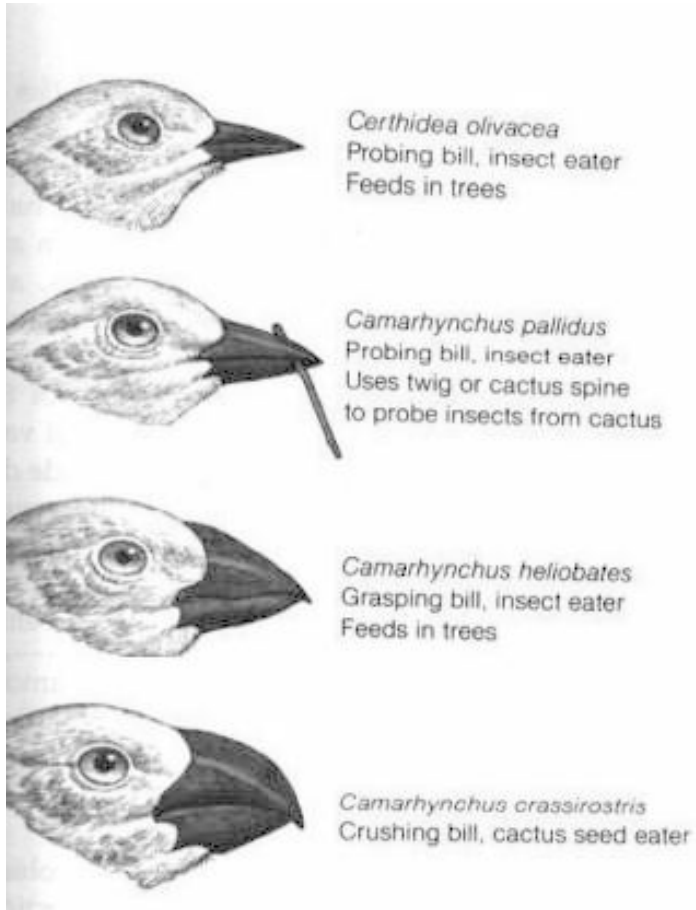
While in the Galapagos, Darwin also studied small songbirds called finches. He studied their anatomy and feeding habits.

He saw that there were many varieties of beaks among the finches.

- large beaks
- small beaks
- thin beaks
- thick beaks



Finch Beak Size and Function

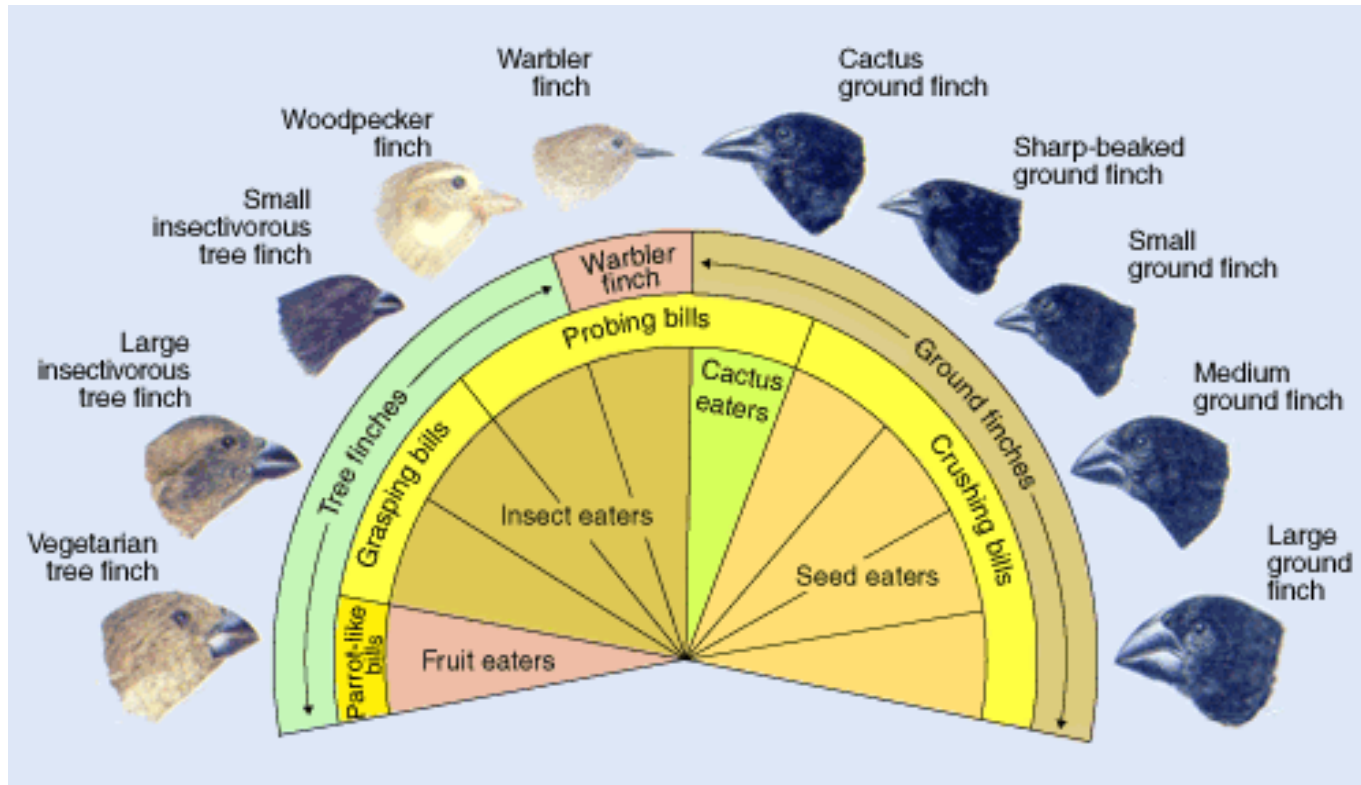


When back in England, Darwin arranged his finch specimens by the island they came from.

He realized that birds from the same island had similar beaks but birds from different islands had large variations

Can you suggest a reason for the variation by island?

Finch Beak Size and Function



Finch Beak Size and Function



After further study it was shown that the South American Common Ground finch was the **common ancestor**, the species that existed before the others, of all the finches Darwin brought back from the islands.

Adaptive Radiation

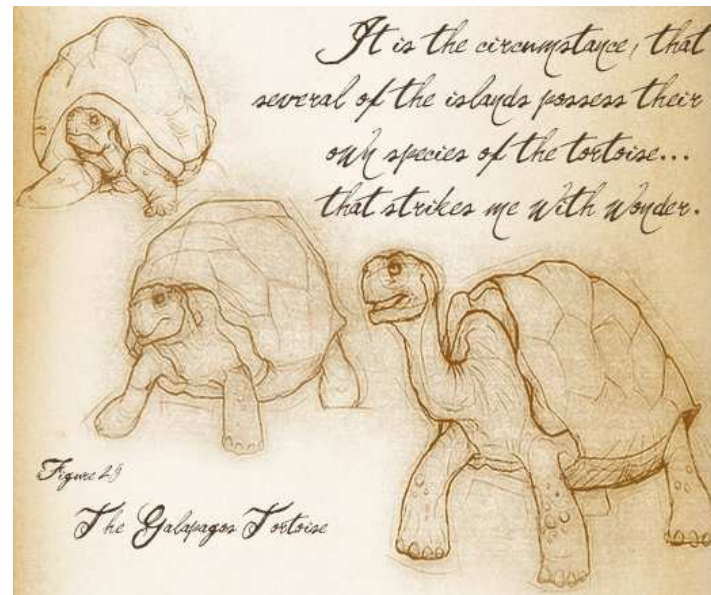


Darwin identified this kind of evolution as adaptive radiation. One ancestor giving rise to many new modified populations.

Darwin's Notebooks

While in the Galapagos, Darwin studied all of the animals and plants there.

Darwin's notebooks were filled with his drawings and descriptions of everything he saw.



The full text of Darwin's observations, drawings and reflections during his voyage around the world available at:

[Click here for The Voyage Of The Beagle by Charles Darwin.](#)

Darwin's Return to England

Upon Darwin's return to England, his collections were hailed by the scientific community.

He immediately began to send out specimens to other scientists for examination while he began to piece together the evidence to determine the mechanism by which evolution happens.

1 Which of the following best describes "survival of the fittest"?

- A The species best adapted to its environment survives.
- B The strongest individuals survive and reproduce.
- C The population best suited to its environment survives.
- D Individuals best adapted to their environment survive and reproduce.

1 Which of the following best describes "survival of the fittest"?

- A The species best adapted to its environment survives.
- B The strongest individuals survive and reproduce.
- C The population best adapted to its environment survives.
- D Individuals best adapted to their environment survive and reproduce.

Answer

C

2 Which of these is a population?

- A The species *Rattus norvegicus* (brown rats)
- B The life in the sewage system of New York City
- C The life in the sewage system of New York City plus the water
- D The brown rats living in the sewage system of NYC

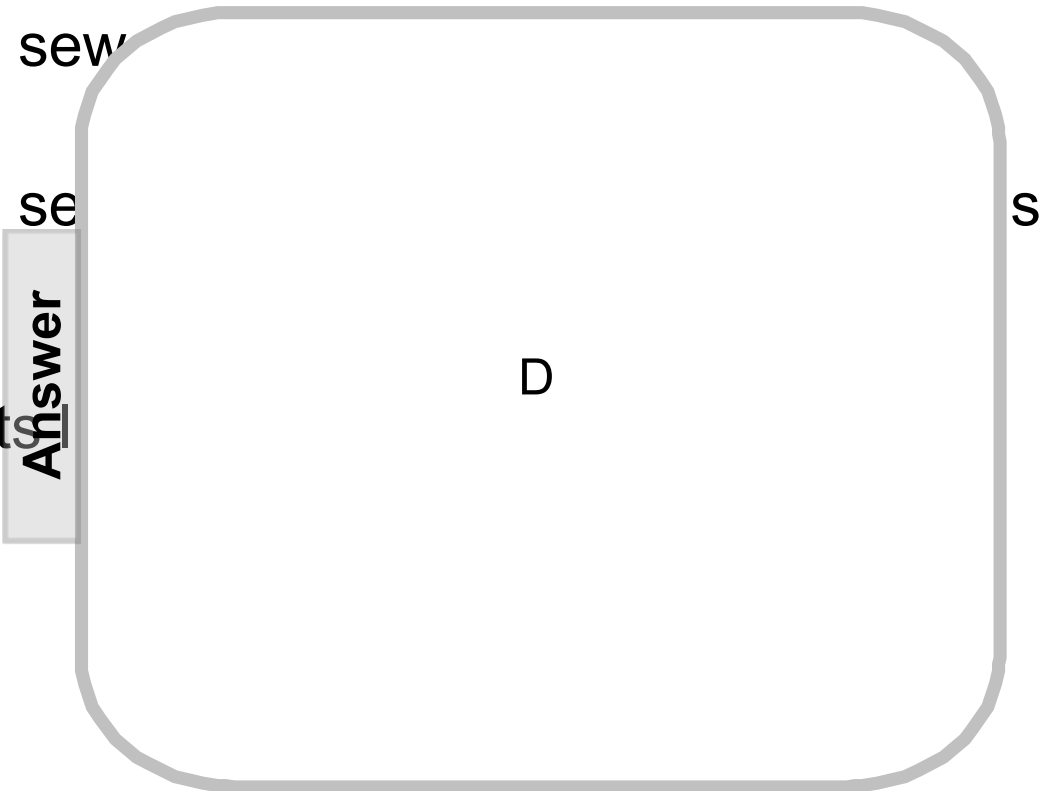
2 Which of these is a population?

A The species *Rattus norvegicus* (brown rats)

B The life in the sewer

C The life in the sewer and the water

D The brown rats in NYC



3 Which of the following best describes adaptive radiation?

- A Different populations in similar environments have similar adaptations.
- B A single ancestral population gives rise to many modified populations as they adapt to new environments.
- C The variation in a population is the result of adaptation to different environments.
- D Adaptations poorly suited to an organism's environment cause the organism to repopulate in a more appropriate environment near the original population.

3 Which of the following best describes adaptive radiation?

- A Different populations in similar environments have similar adaptations.
- B A single ancestor modified populations in different environments.
- C The variation in a population leads to adaptation to a new environment.
- D Adaptations to a new environment can be passed on to a new population.

Answer

B

a

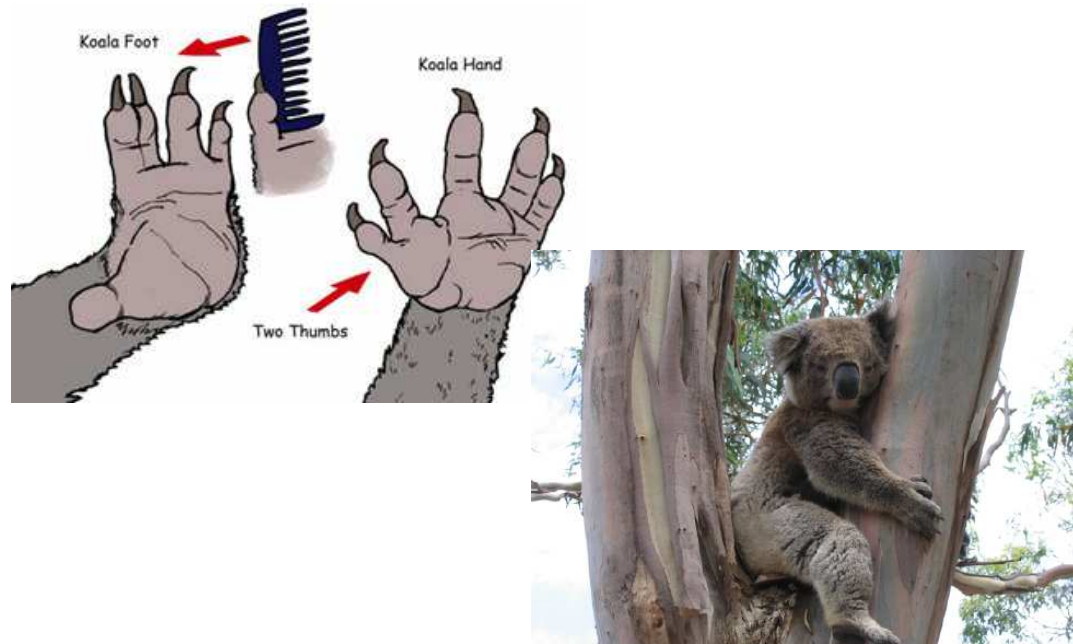
Adaptations

As Darwin continued to study his specimens, he focused on **adaptation**. He began to see that this was the driving force behind evolution.

An **adaptation** is a trait - structure, function, or behavior - that makes a living organism better able to survive and reproduce in its environment.

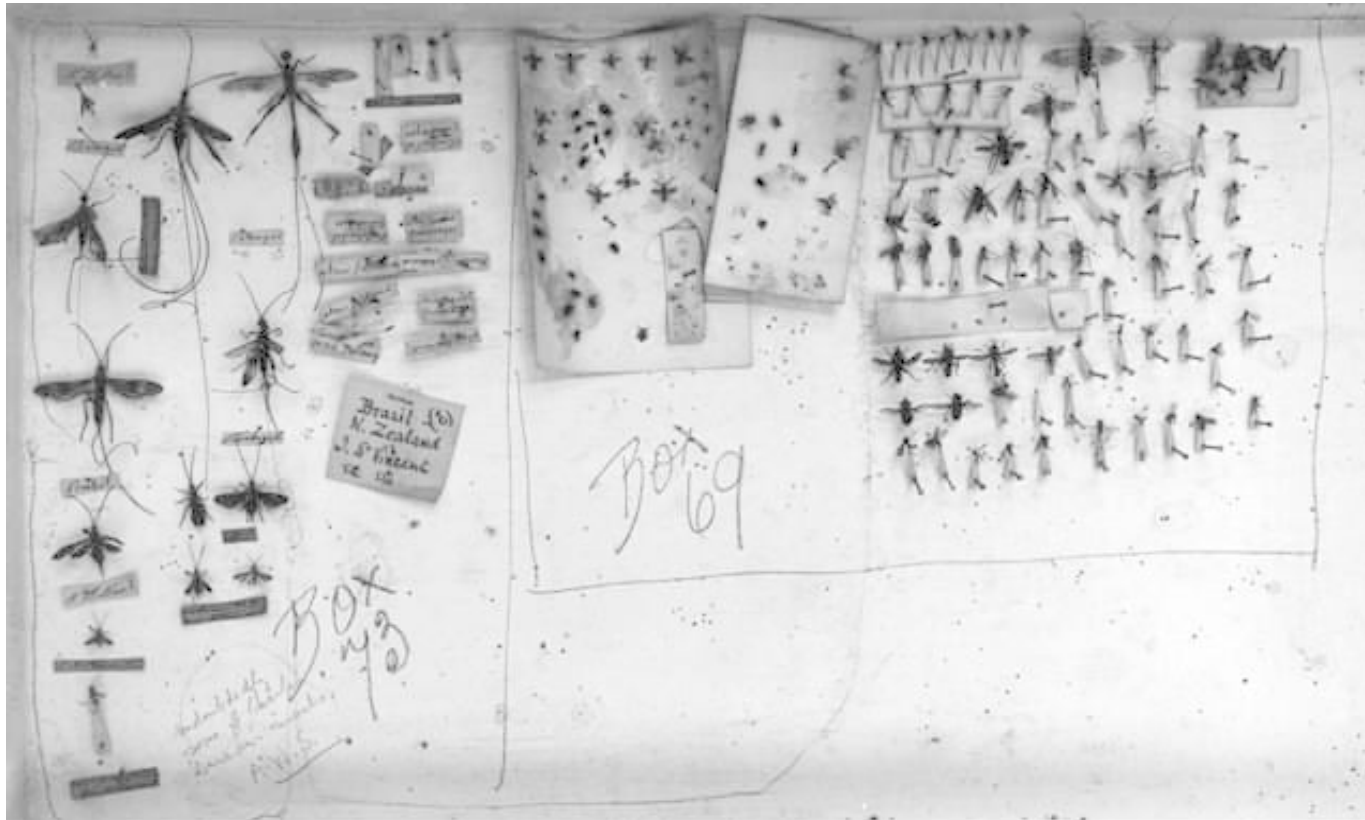
Example:

A koala has two thumbs on each hand, which enables it to get a better grip when climbing trees.



Adaptation

One of Darwin's examples: insects that fed on flower nectar needed special organs to get to the nectar of the specific species of flowers that existed on the different islands. **Adaptation led to evolution and new species coming into existence.**



Darwin's Bug Collection from the Galapagos and South America

Origin of Species

Darwin had eventually outlined his theory of natural selection as the driving force behind evolution but he did not publish his findings immediately because he feared the public uproar it may have caused.

He began writing an essay entitled "On the Origin of Species by Means of Natural Selection" in 1844 but did not finish it until 1858 and published it a year later.

He only published it after reading the work of another naturalist, Alfred Russell Wallace, who had come to a similar conclusion about natural selection.

[Click here to see a video of Wallace's collection](#)

Darwin's Theories

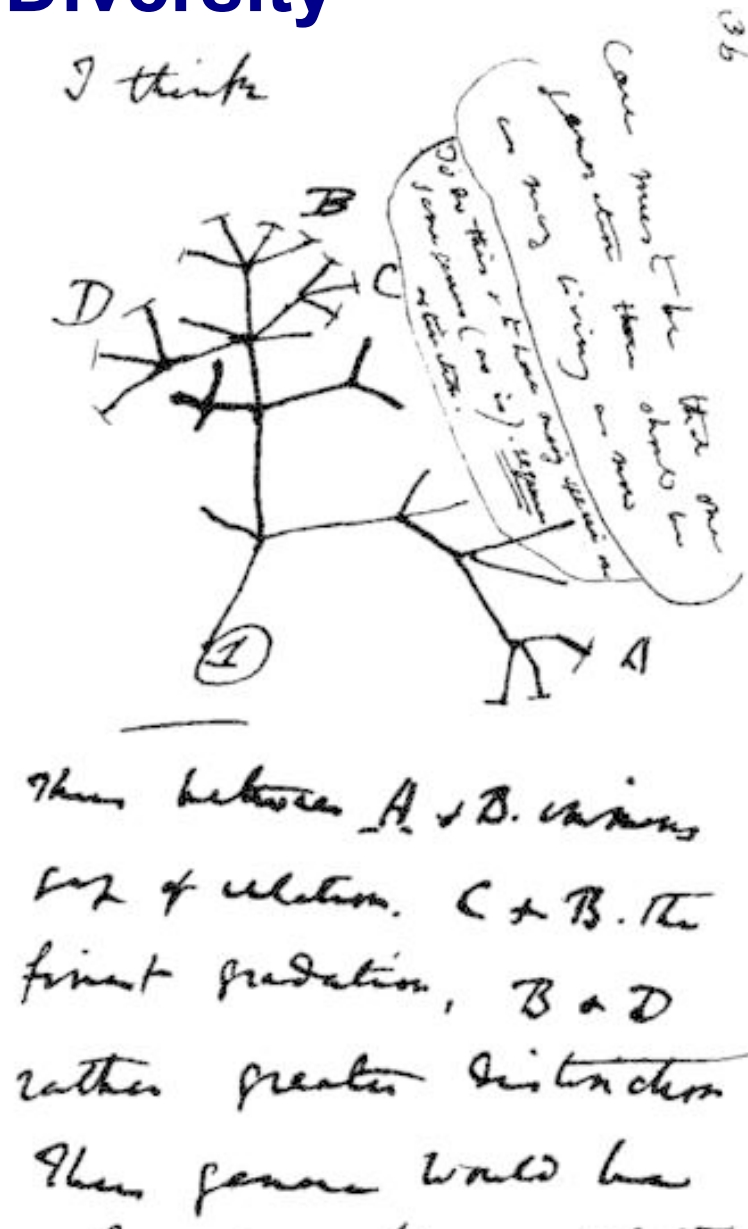
From his work, Darwin developed two main theories:

- 1. Evolution explains life's unity and diversity.**
- 2. Natural selection is the cause of adaptive evolution.**

Unity & Diversity

"I think case must be that one generation should have as many living as now. To do this and to have as many species in same genus (as is) requires extinction. Thus between A and B the immense gap of relation. C and B the finest gradation. B and D rather greater distinction. Thus genera would be formed. Bearing relation to ancient types with several extinct forms"

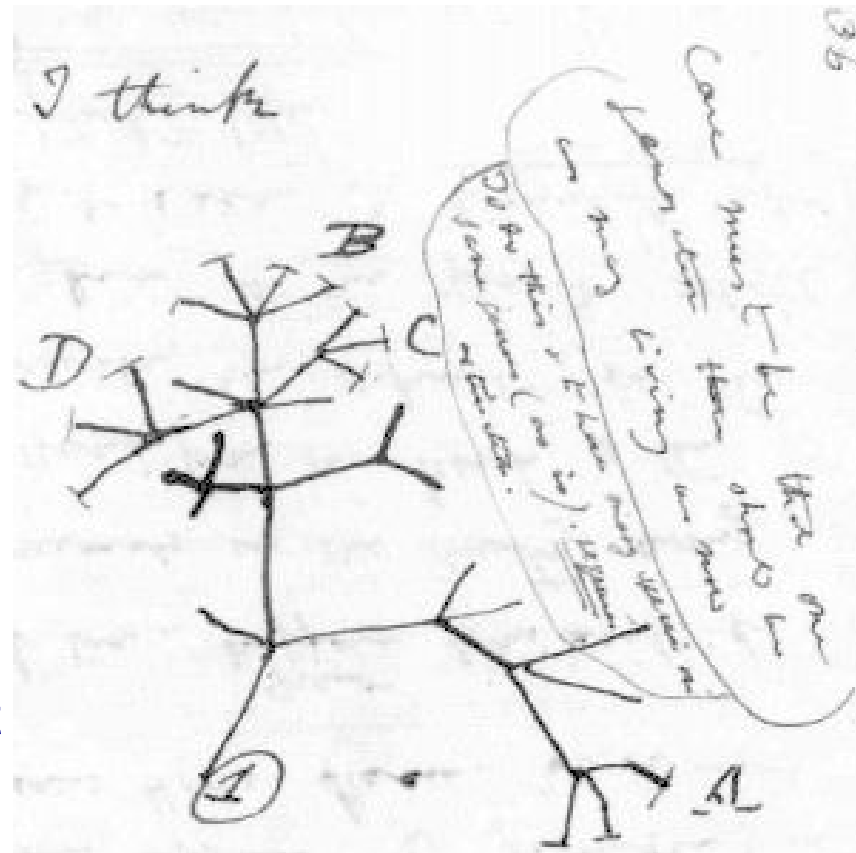
- Charles Darwin 1837 notebook.
First drawing of the tree of life.



Unity & Diversity

As the descendants of this common ancestor spread to different habitats over millions of years, they accumulated adaptations that enabled them to be fit in their environment.

Darwin viewed life as a tree with a common ancestor found at the trunk and all the branches from it that represent the diversity of living organisms.



4 Darwin stated that all organisms were unified in that they all descended from a common ancestor that lived long ago. This idea is now known as:

- A Descent with modification
- B Natural selection
- C LUCA
- D Artificial selection

4 Darwin stated that all organisms were unified in that they all descended from a common ancestor that lived long ago. This idea is now

- A Descent with modification
- B Natural selection
- C LUCA
- D Artificial selection

Answer

C

5 Evolution is the result of adaptation to new environments. Which of the following would not be considered an adaptation?

- A Being heterozygous for the sickle cell allele
- B A mutation in a bacterial genome which provides antibiotic resistance to the bacterium
- C A substitution mutation in the intron of a multicellular eukaryote
- D Possessing a trait which increases the number of offspring produced by an organism.

5 Evolution is the result of adaptation to new environments. Which of the following would not be considered an adaptation?

- A Being heterozygous for a recessive allele
- B A mutation in a gene that confers antibiotic resistance
- C A substitution of a nucleotide in the DNA of a multicellular eukaryote
- D Possessing a trait that increases the number of offspring produced

Answer

C

Evidence for Evolution

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Scientific Evidence for Evolution

Darwin was able to draw upon evidence from different disciplines in the scientific community to formulate his theories. These included:

1. **Homology:** certain characteristics in related species have an underlying similarity even though they may have different functions.
2. **Biogeography:** Recall that Darwin made many observations on the geographic distribution of species. This is referred to as biogeography.
3. **The fossil record:** By comparing changes in fossils in different layers of rock corresponding to different periods of Earth's history, we can see changes that have taken place.

Homology

Homology is defined in biology as a fundamental similarity in structure or behavior because of common descent, a common developmental origin.

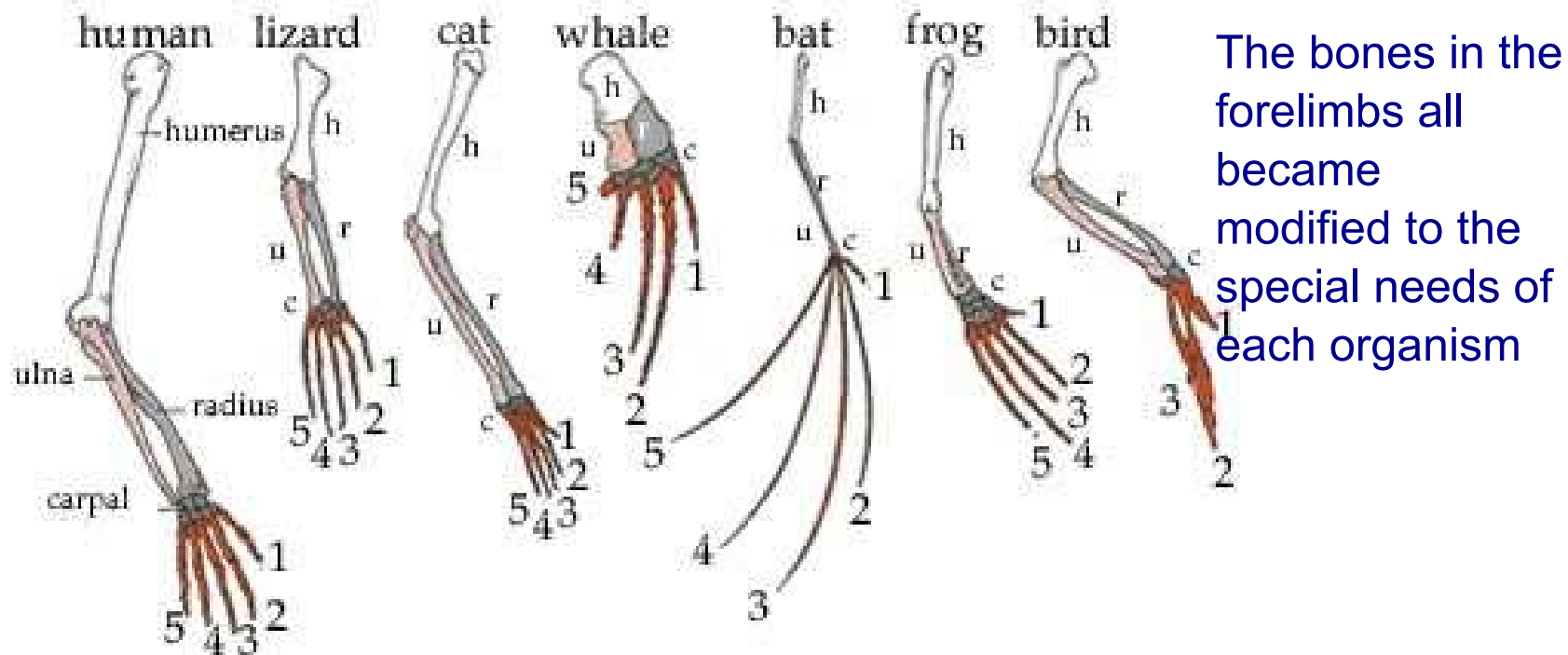
Homology includes:

- homologous structures
- vestigial structures
- comparative embryology
- molecular homology.

Homologous Structures

Darwin noticed that animals have similar body plans and structures.

For example, forelimbs of different animals are made of the same exact bones but modified in shape and size. These are what is known as **homologous structures**.



Vestigial Structures

Vestigial structures are bones or organs of an organism which have lost function and atrophied (shrunk) through time.

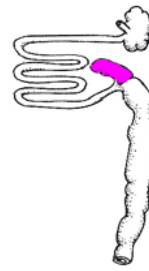
The body part had a function in an ancestor, but through modifications and evolution the body part is no longer useful.

An example would be vestigial wings in flightless birds.

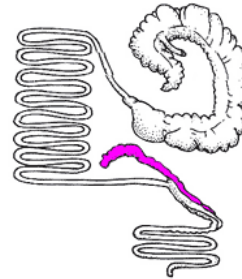


A vestigial organ : the human appendix

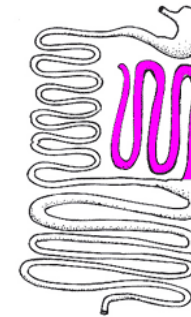
What is now the human appendix was once an extra pouch to help digest food back when our ancestors were herbivores and ate mainly plant material.



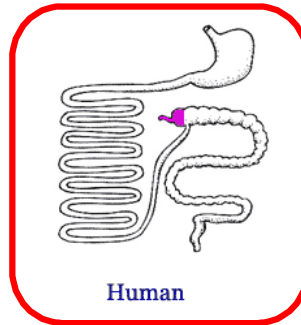
Opossum



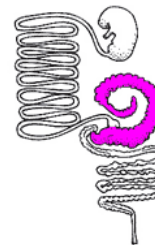
Kangaroo



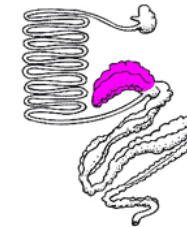
Koala



Human



Rabbit



Zebra

Since then, man has developed into more of an omnivore (eating both meat and plants) so the pouch lost both its function and its original structure related to digestion; however, it does contain lymphatic tissue and does contribute slightly to the immune system. That being said, one can live without their appendix as there are many other organs that contribute major roles to the immune system.

Comparative Embryology

Comparative Embryology is the study of structures that appear during the development of different organisms.

Closely related organisms have similar stages and structures in their development. This gives evidence for evolution and common ancestry.



Human Embryonic Development

Early on in embryonic development, humans possess features that our evolutionary ancestors had.

The older the embryo gets, the more it loses these ancient features because they develop into a more modern feature.



Human Embryonic Development

Apoptosis (programmed cell death) occurs within the webbing to allow for the development of fingers and toes. This also causes a tail to be reabsorbed and gill slits to become structures of our face and neck.

48 day old human hand with webbing



Fetal hand after apoptosis.



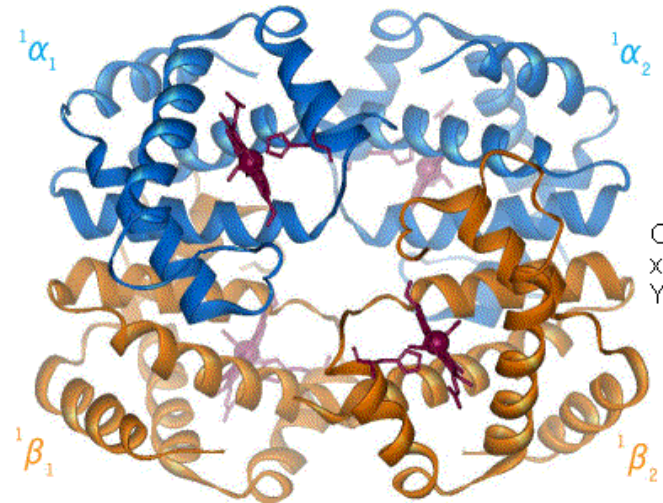
Molecular Homologies

In Darwin's time comparison of molecules was impossible, but now scientists are able to compare species at the microscopic level.

This is a model of a hemoglobin molecule. Many animals including humans, monkeys, mice, fish, birds, worms, bugs and thousands more use a version of this molecule.

The different versions can be compared to see how closely related organisms are.

Less difference = more relation



6 Bat wings and butterfly wings are called analogous structures because they have similar functions but are not evolutionarily related. Bat wings and human arms have similar structures from a common ancestor but have different functions. Bat wings and human arms are considered:

- A homologous structures
- B analogous structures
- C vestigial structures
- D molecular homologies

6 Bat wings and butterfly wings are called analogous structures because they have similar functions but are not evolutionarily related. Bat wings and human arms have similar structures but different functions. Which of the following is considered:

- A homologous structure
- B analogous structure
- C vestigial structure
- D molecular homology

Answer

A

7 Given the following species: goldfish, iguana, cat, dog, and chicken. Which would likely have the most molecular homologies with an eagle?

A goldfish

B iguana

C cat

D chicken

7 Given the following species: goldfish, iguana, cat, dog, and chicken. Which would likely have the most molecular homologies

- A goldfish
- B iguana
- C cat
- D chicken

Answer

D

8 Given the following species: goldfish, iguana, cat, dog, and chicken. Which would likely have the most similar embryos in early development?

- A goldfish and a dog
- B iguana and a cat
- C cat and a dog
- D chicken and a goldfish

8 Given the following species: goldfish, iguana, cat, dog, and chicken. Which would likely have the most similar embryos in early development?

- A goldfish and a dog
- B iguana and a chicken
- C cat and a dog
- D chicken and a goldfish

Answer

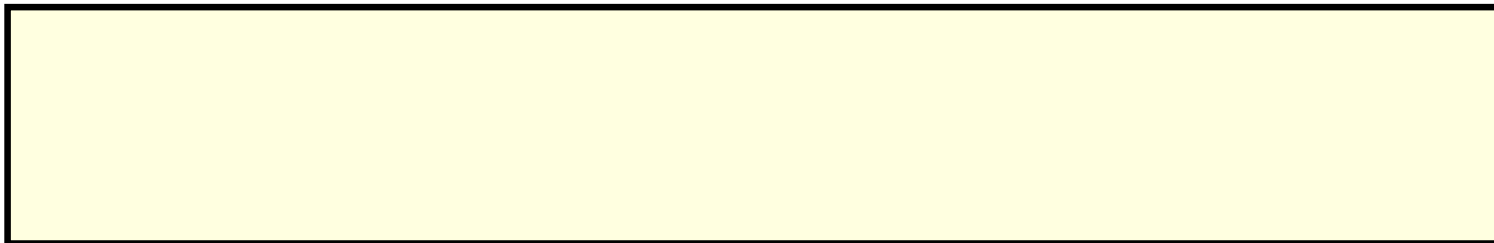
C

Biogeography

Biogeography is the geographical distribution of species.

Darwin observed that the species on the Galapagos resembled the species on mainland South America with observable differences in physical features and behavior. He could **compare geography with biology** to make inferences about this observation.

What inference would you make about this observation?



Click to compare your inference with Darwin's

Fossils

During Darwin's time, the science of geology (Earth science) was making advancements that allowed naturalists (biologists of the time) to estimate the age of bones and other remnants of past life being found by explorers.

These early **fossils** began to tell a story about the history of Earth and its inhabitants.

Fossils

"November 26th - I set out on my return in a direct line for Monte Video. Having heard of some giant's bones at a neighbouring farmhouse on the Sarandis, a small stream entering the Rio Negro, I rode there accompanied by my host, and purchased for the value of eighteen pence the head of an animal equalling in size that of the hippopotamus. Mr Owen in a paper read before the Geological Society, has called this very extraordinary animal, Toxodon, from the curvature of its teeth."

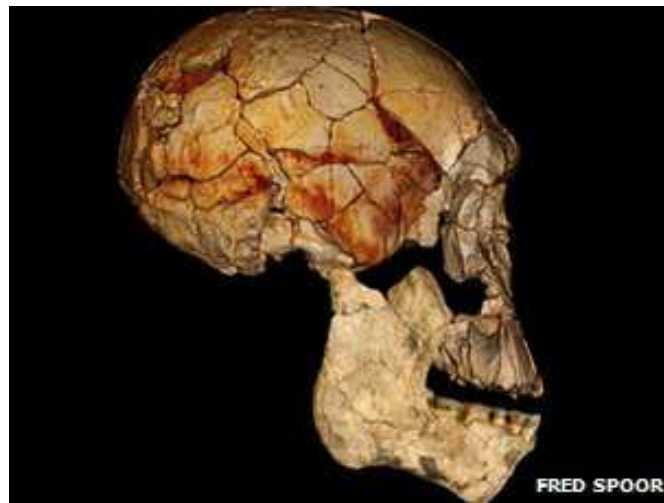
-Charles Darwin, *The Voyage of the Beagle*



Darwin's Toxodon skull sent to England from South America. It has been classified as an ancestor of the modern day rhinoceros.

The Growing Fossil Record

Since Darwin's time, the fossil record has increased by thousands of times its size, providing a clearer picture of evolution's history. It continues to grow.



Researchers studying fossils from northern Kenya have identified a new species of human that lived two million years ago.

BBC News, 8 August 2012

<http://www.bbc.co.uk/news/science-environment-19184370>

The Growing Fossil Record

The fossil record has made it apparent that the key to Darwin's Tree of Life is the ability to pass information from one generation to the next of millions of years. This is the process of **heredity**.



A small sample of models of known hominids (human classification) based on recovered fossils:

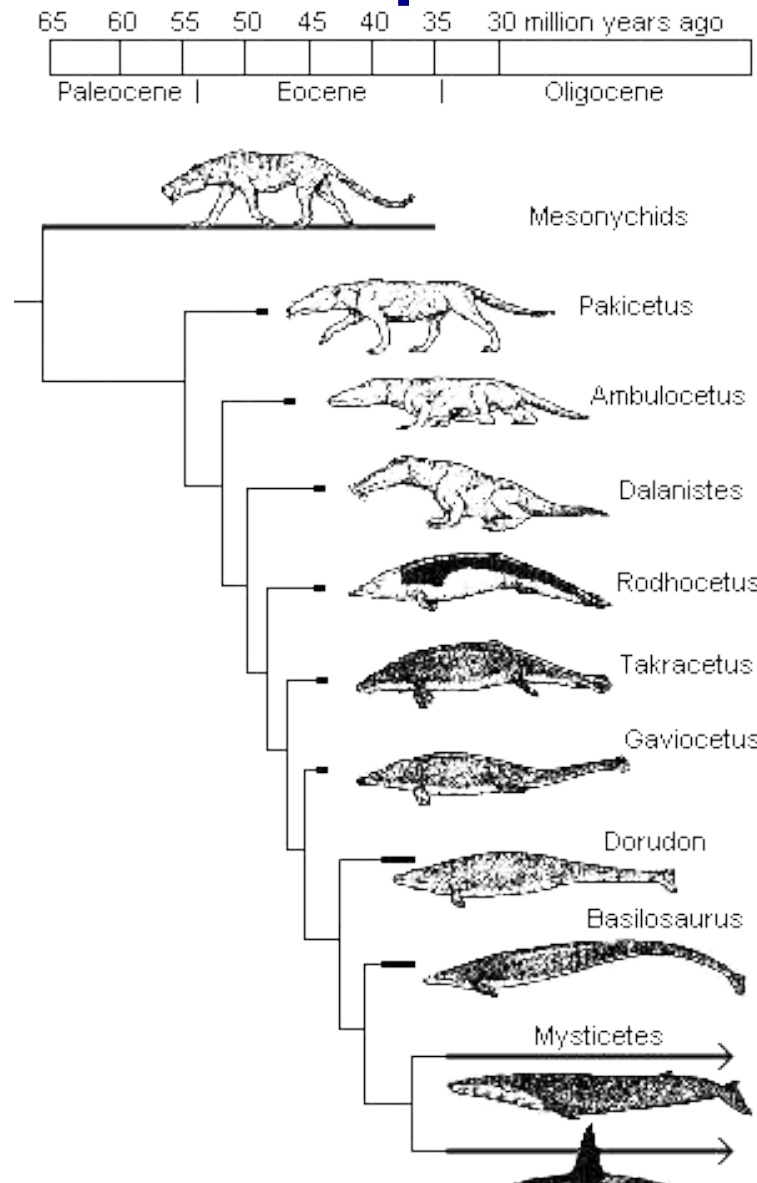
- Homo habilis
- Homo ergaster
- Homo erectus
- Homo antecessor
- Homo heidelbergensis
- Homo neanderthalensis
- **Homo sapiens sapiens:**
modern humans, we are the only surviving hominid!

The Fossil Record: Example

Whale ancestors walked on land:

Darwin knew that mammals had evolved on land and could not show how whales, water dwelling mammals, could have evolved.

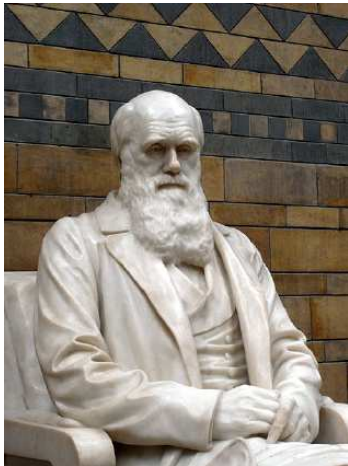
Paleontologists have discovered a fossil record of intermediate species showing the progression of land mammals evolving into species that relied on water hunting, then into ocean dwelling mammals.



The Modern Synthesis of Evolution

Today the work of Darwin has been combined with the work of Mendel and new discoveries about the nature of genes and heredity to form the **modern synthesis**.

This represents our best knowledge of how populations evolve and how new species come to be on this planet.



Darwin
Natural History Museum,
London



Mendel
University of Agriculture and
Forestry
Brno, Czech Republic.



Sheep/Goat genetic hybrid
Created by geneticists,
University of California

The Modern Synthesis of Evolution

The synthesis drew together ideas from several branches of biology including genetics, biochemistry, systematics, botany, morphology, ecology and **paleontology**, the study of prehistoric life.

The modern synthesis includes evidence from biologists, trained in genetics, who studied populations in the field and in the laboratory. These studies were crucial to evolutionary theory.

What We Have Learned Since Darwin and Mendel

The following is a short list of some of the important discoveries that helped to clarify parts of evolutionary theory after the time of Darwin.

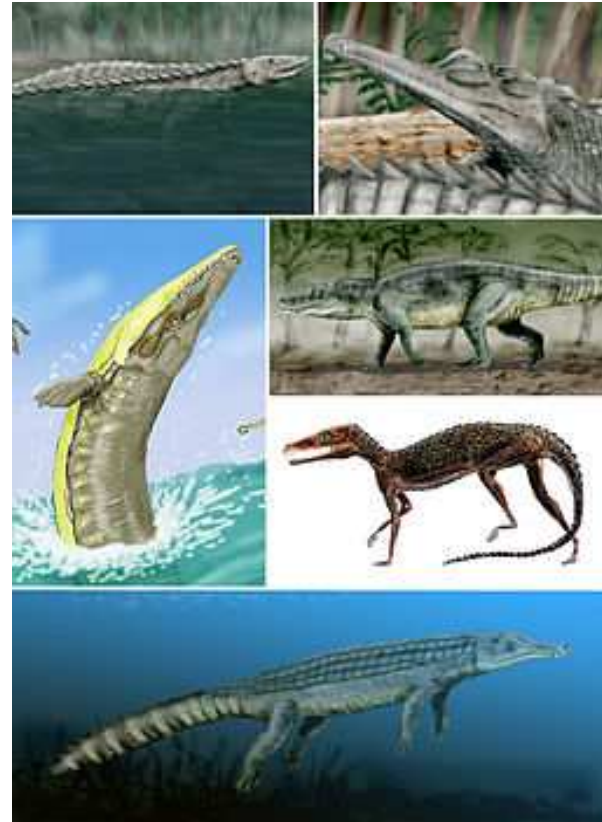
- The age of the Earth has been more precisely dated
- Continental drift discovered, leading to the idea of **Pangea**, a single original land mass
- A massive expansion of the fossil record that now includes remains of early microbial life as well as countless more examples of transitional organisms

Other understandings have clarified evolution further, but these 3 points transformed our understanding of the natural world independently of Darwin's theory. Each is partly responsible for strengthening the theory of biological evolution.

Time

Time was a big problem for Darwin. In his day it was believed that the Earth was about 6,000 years old.

This was a problem for Darwin's theory because this small amount of time would not be enough for all of the diversity of life we see on this planet to have come into existence.



Pan-crocodilians. If all evolved from a common ancestor it would have require millions of years.

Time

Modern geology, by **radiometric dating** and study of the Earth's **strata** (layers of rocks and soil), has shown that the earth is about 4.6 billion years old.

That is about $766,667 \times 6,000$. This is more than enough time to account for the diversity of life by Darwin's and Mendel's theories.

Time: Radiometric Dating

By measuring the decay of radioactive particles that are present in all organisms and the ground in which fossils are found, scientists can accurately determine the age of life and layers in the Earth.

[Click here to see a video that will explain **carbon dating** which is one of the most useful forms of dating for biologists.](#)

Time: Strata

Over the Earth's history sediment has been deposited over and over again forming the crust of our planet. Large scale changes in atmosphere, catastrophic events and the processes of the Earth have formed layers of rock that are universal to the entire planet.

The Grand Canyon was formed by erosion, exposing millions of years of Earth's history.



The Grand Canyon

[Click here to see a video that will explain **strata formation** in the Grand Canyon.](#)

Time: Strata

Since these layers in our planet's crust form a timeline of events, paleontologists can accurately date fossils that are seen in each layer.

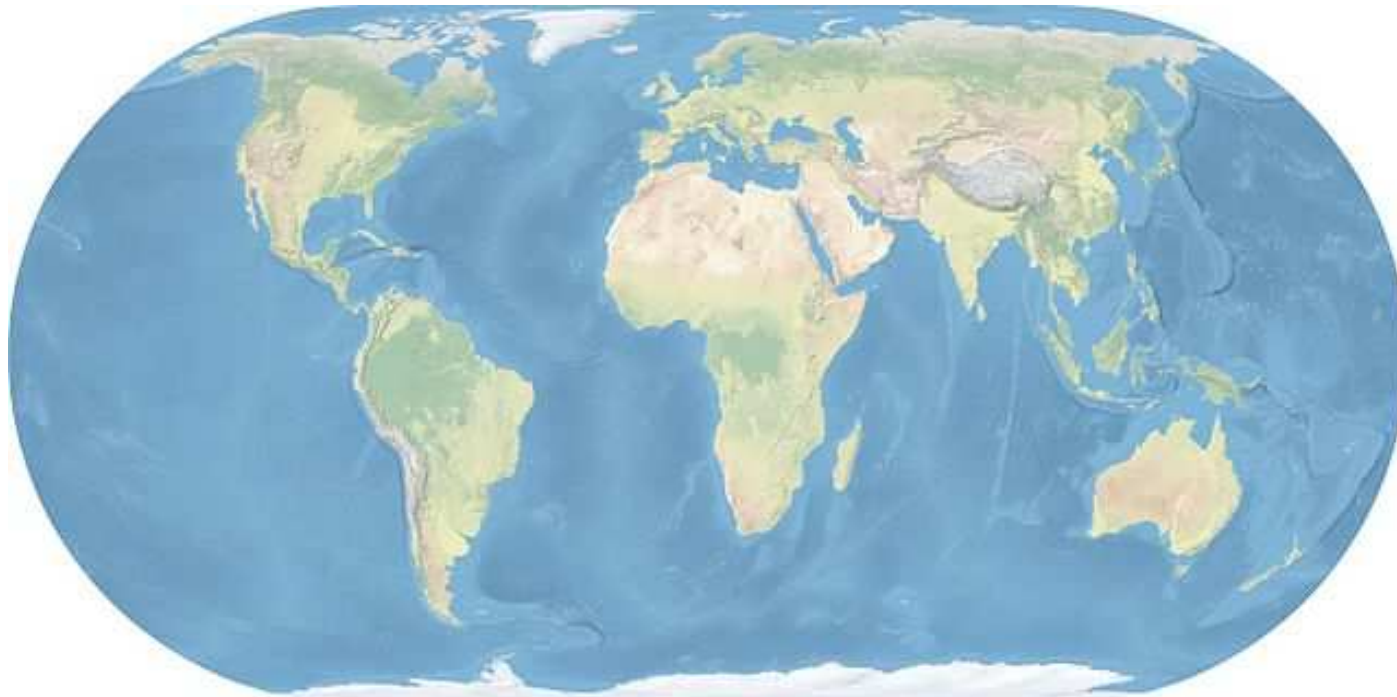
They can also determine when species come into existence and when they go extinct in reference to the Earth's history.



Pangea

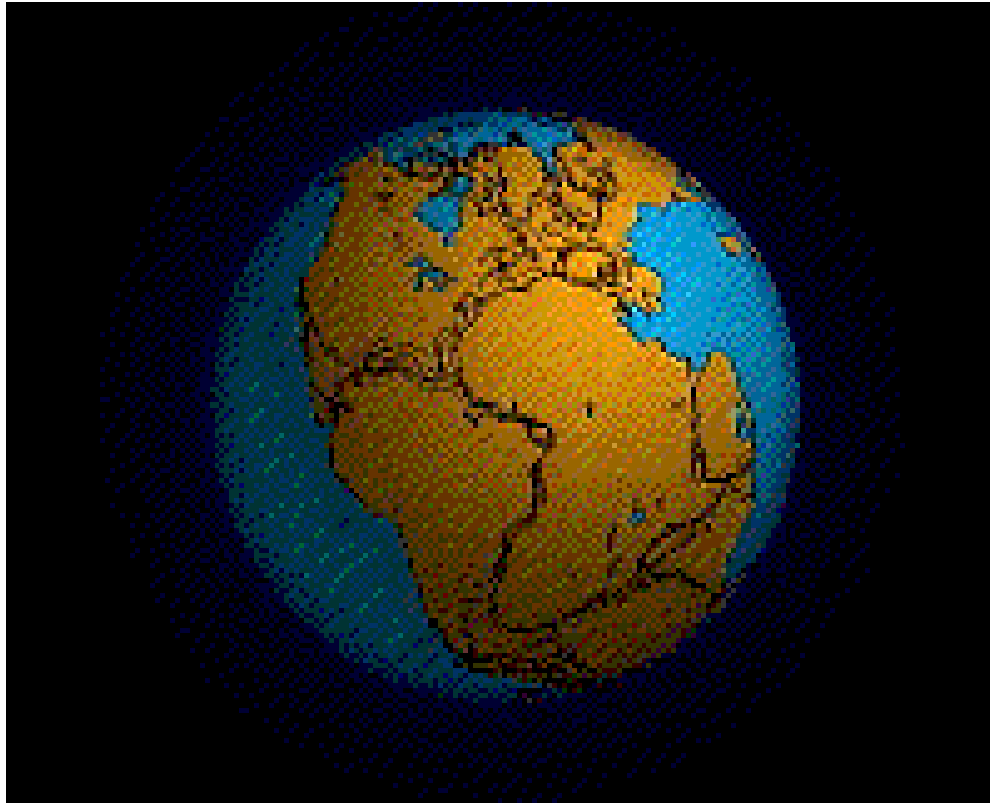
Another problem for Darwin, during his time the common belief was that the continents were fixed land masses.

How could species that seem to be related, be located on different continents if they could not travel by boat or swim?



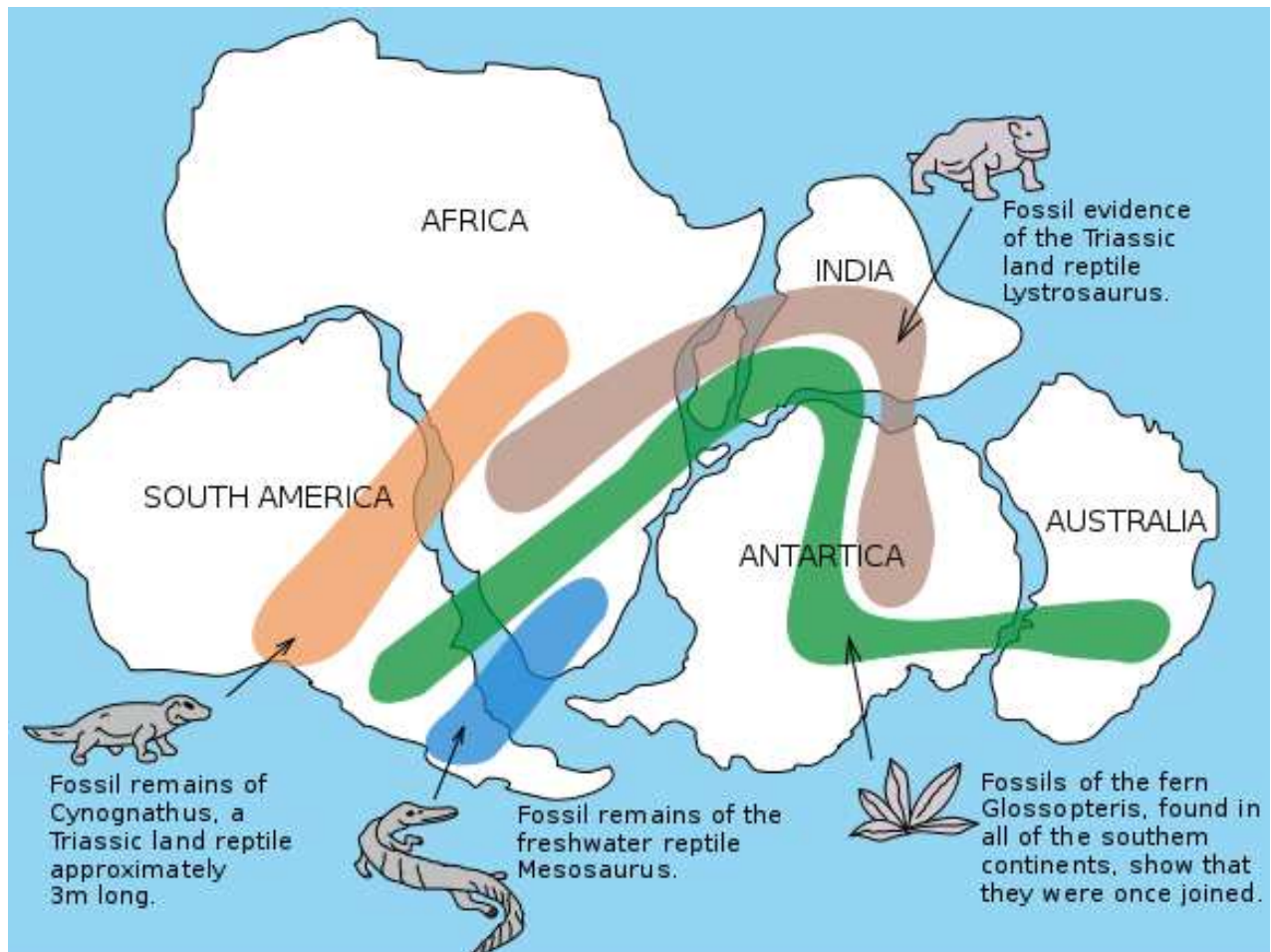
Pangea

Geologists since Darwin's time discovered continental drift. Plate tectonics, the study of large scale motion of floating plates that make up the Earth's crust, showed that all the continents were one large mass about 300 million years ago.



Pangea

Over the next 100 million years the continents drifted apart and broke apart populations of life that existed at the time.



9 The discovery of Pangea most directly relates to which of the types of evidence used during Darwin's time to support evolution?

- A homology
- B vestigial structures
- C biogeography
- D comparative embryology

9 The discovery of Pangea most directly relates to which of the types of evidence used during Darwin's time to support evolution?

- A homology
- B vestigial structures
- C biogeography
- D comparative embryology

Answer

C

10 Which of the following best describes a transitional species?

- A A fossilized organism that possesses an intermediate trait between two closely related species.
- B A living organism that possesses an intermediate trait between two closely related species.
- C Any organism that possesses an intermediate trait.
- D Any organism that possesses a vestigial structure which is intermediate to two traits found in closely related species.

10 Which of the following best describes a transitional species?

- A A fossilized organism with intermediate traits between two species.
- B A living organism with a trait between two species.
- C Any organism that has a trait.
- D Any organism that possesses a vestigial structure which is intermediate to two traits found in closely related species.

Answer

A

11 Carbon-14 has a half life of 5730 years. What percentage of carbon-14 would remain in the bones of an organism that had been deceased for 45,840 years.

11 Carbon-14 has a half life of 5730 years. What percentage of carbon-14 would remain in the bones of an organism that had been deceased for 15,810 years.

Answer

0.39%

12 A bone has 12.5% of its carbon-14 remaining. How long has the organism been deceased?

12 A bone has 12.5% of its carbon-14 remaining. How long has the organism been deceased?

Answer

17,190 years

Natural Selection

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Natural Selection

The following slides illustrate the different modes of natural selection and the effect it has on a **population**.

A population is the smallest unit that can evolve. We will see that individuals cannot evolve. They can only contribute their genes to the next generation of the population.

Roly Poly Selection

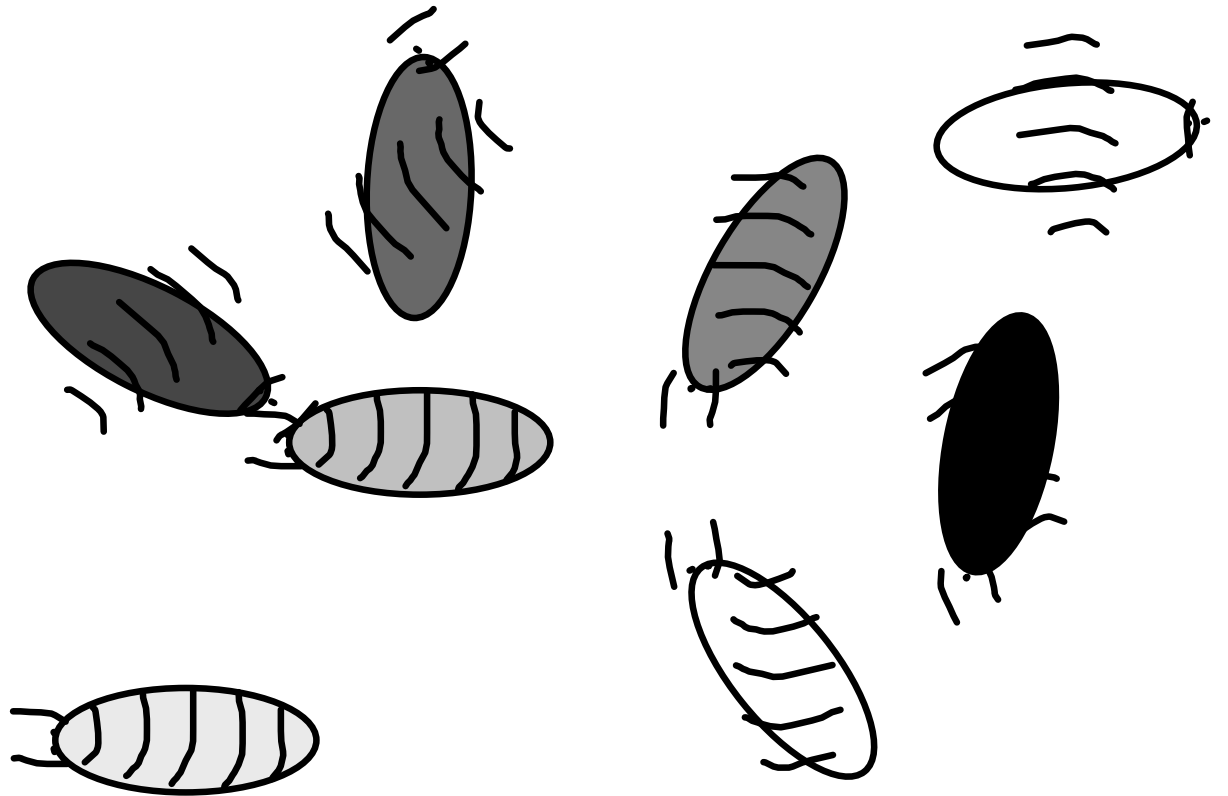
Armadillidium vulgare, known as pill bugs or roly polys, are a favorite snack of predatory birds. For this reason they tend to evolve to the color of the ground they inhabit for camouflage.

But how do they know the color of their background? The answer is they don't, they are bugs with very little brain power.



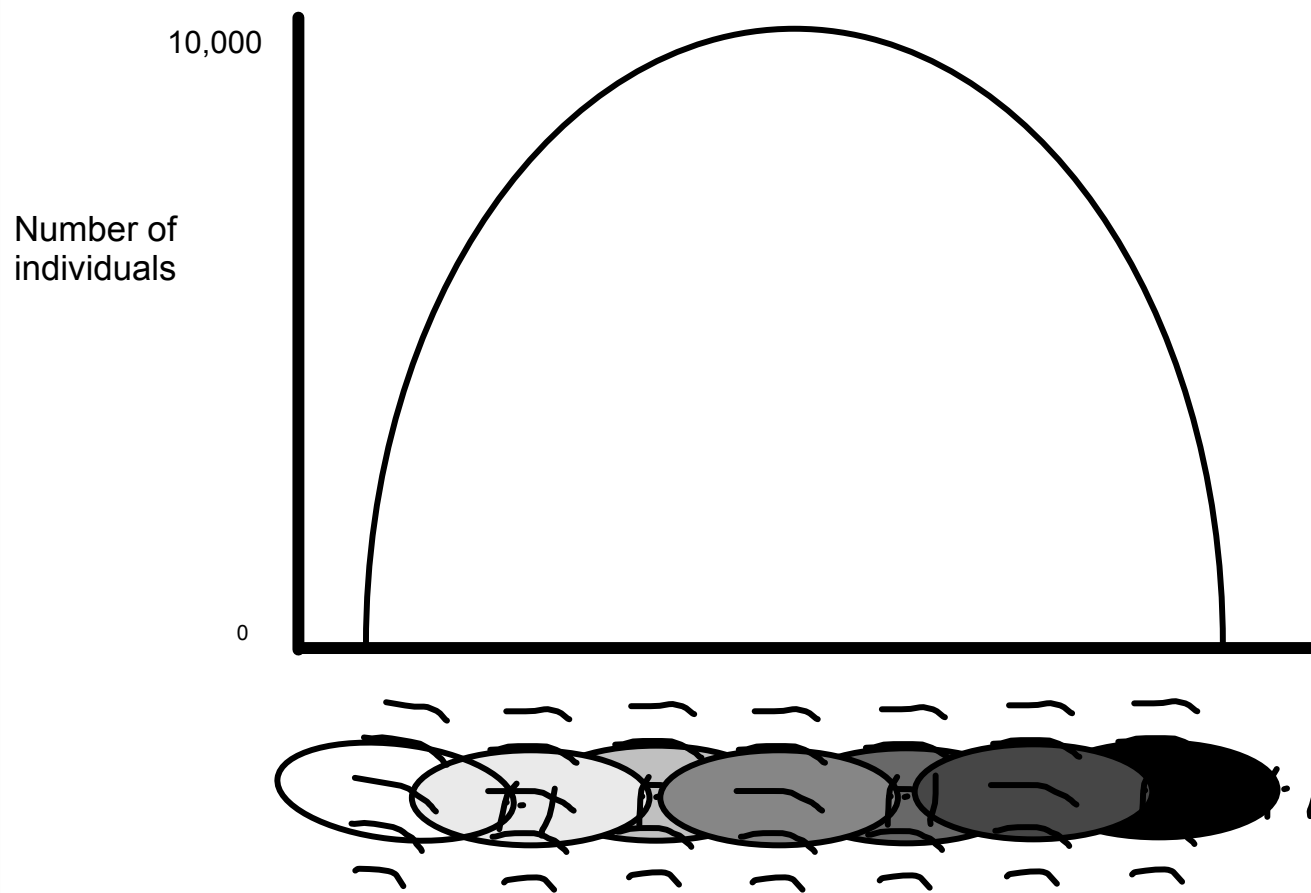
Roly Poly Selection

Let's consider a fictitious population of roly polys that migrate to a new area. This population has a gradient of shades that run from white to black.



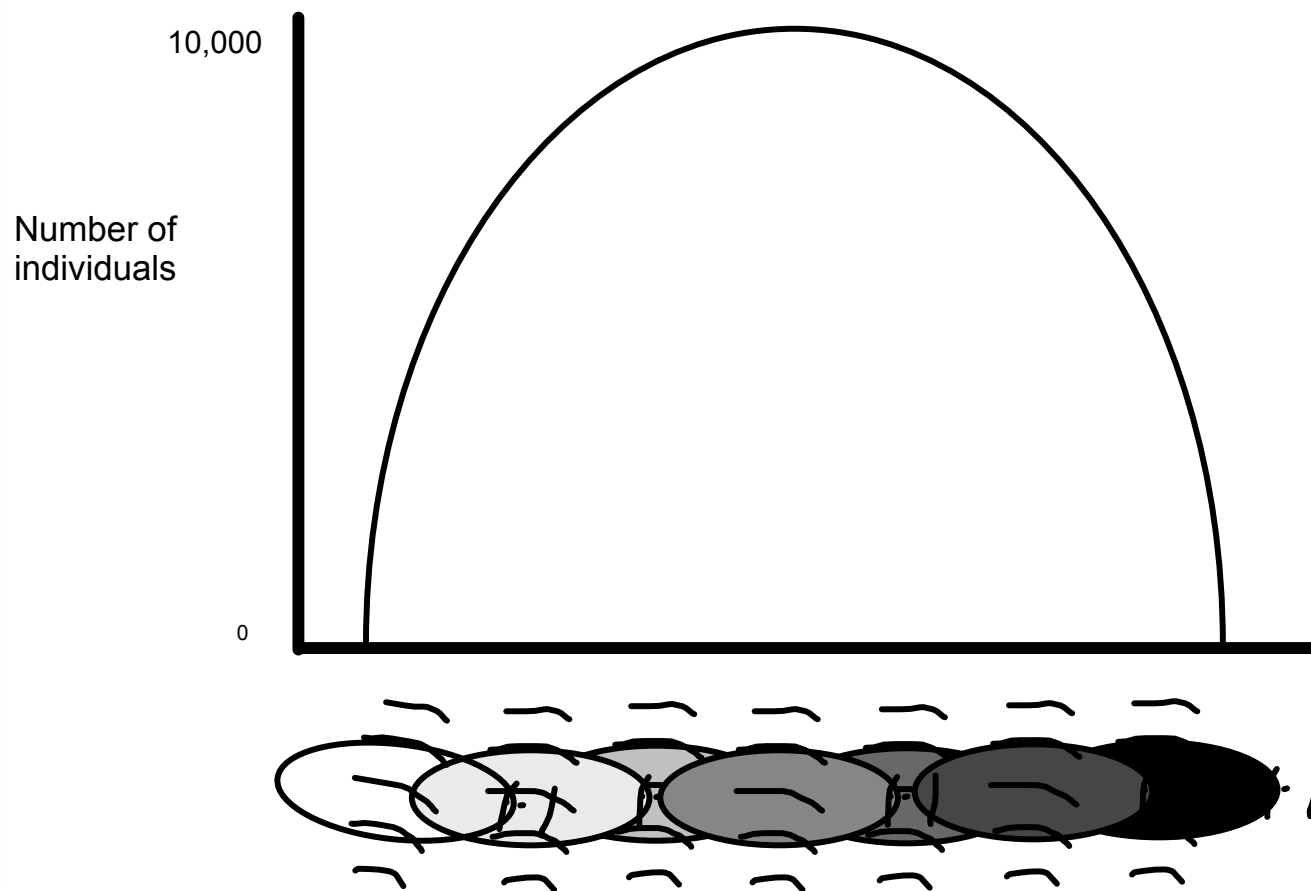
Roly Poly Selection

A scientist studying the population randomly samples the individuals and creates a graph that shows distribution of shade



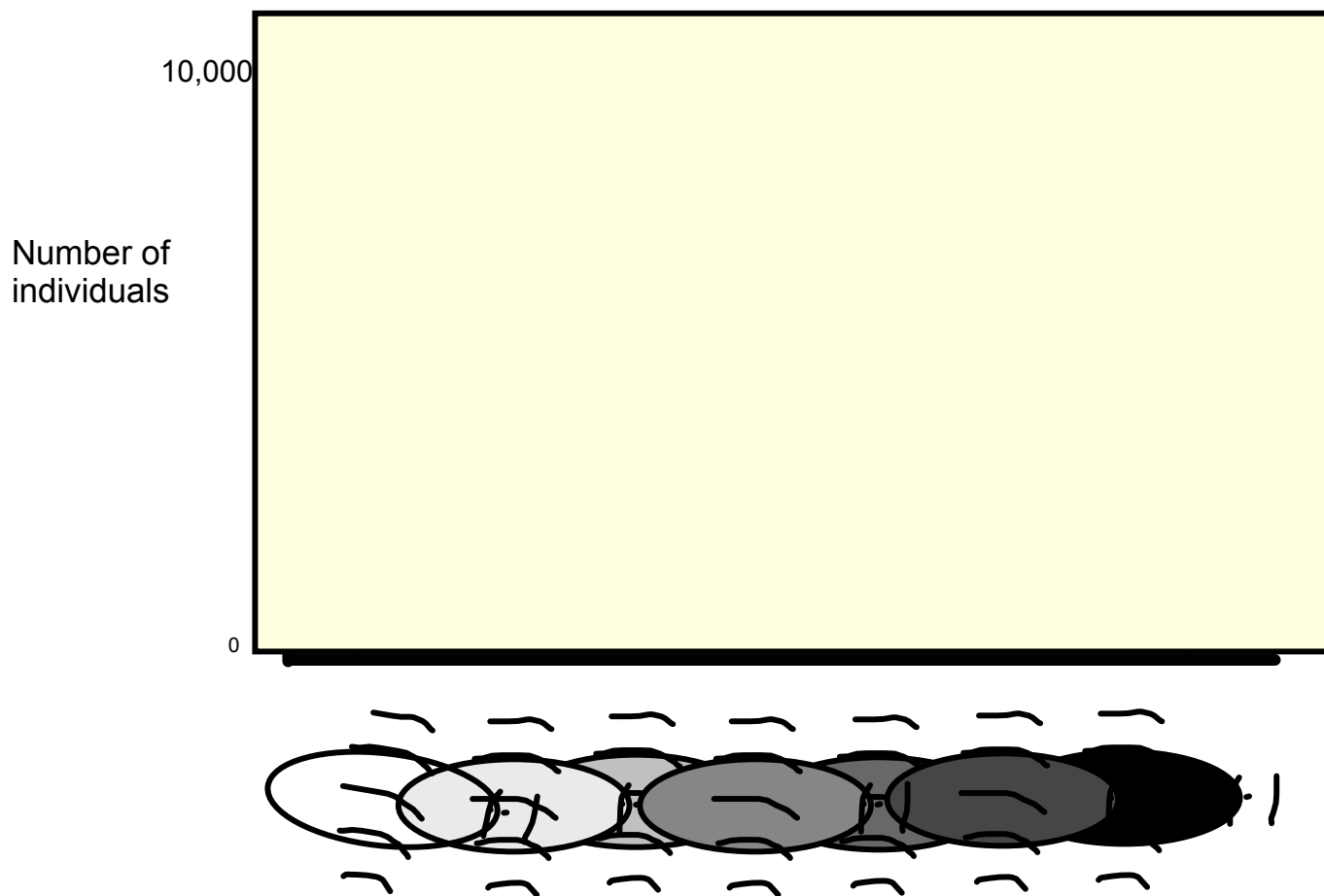
Roly Poly Selection

Imagine that this population has moved to an area where the soil is fertile and black. What would happen to this curve if we resampled the population 5 years later? There are many hungry birds that live in this area. Draw your prediction.



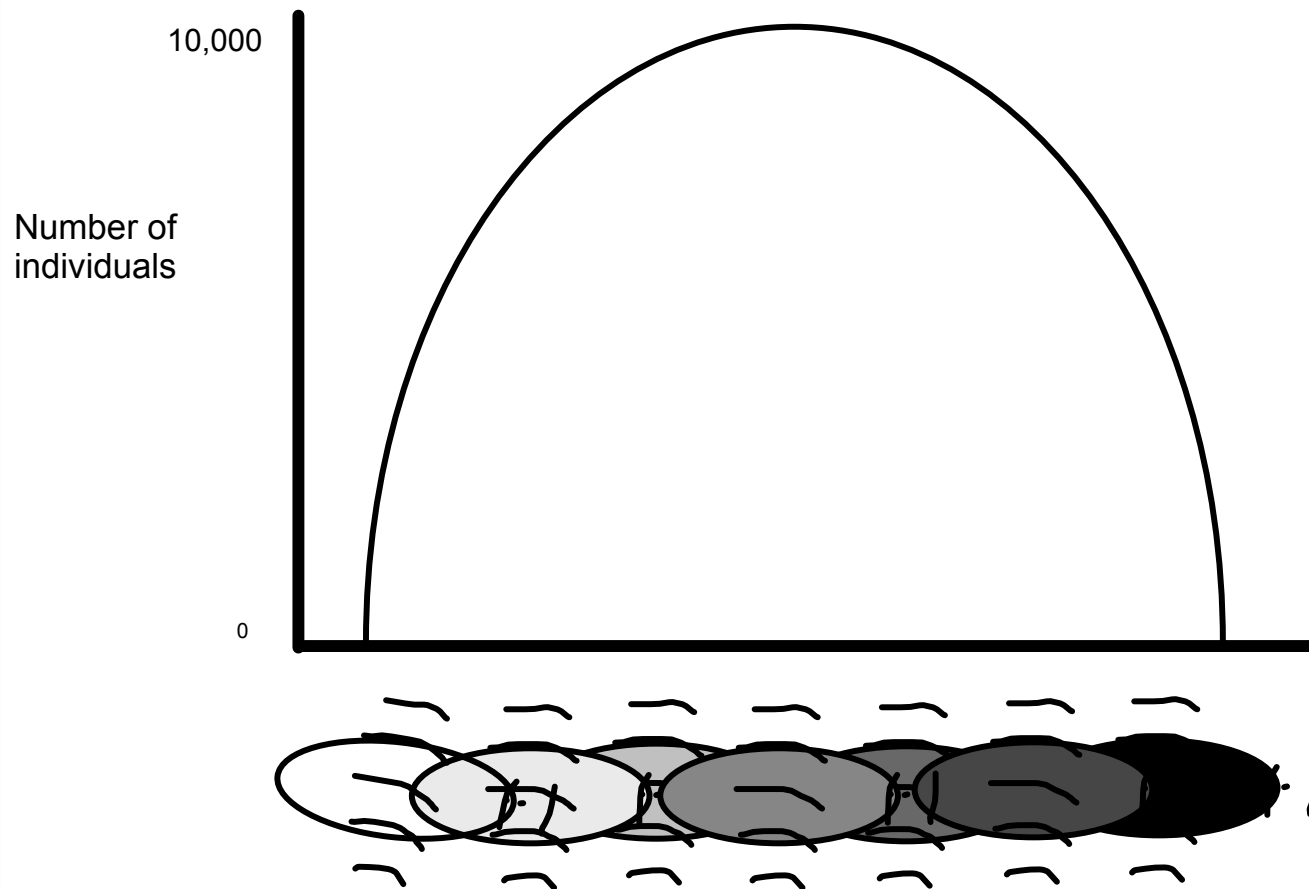
Roly Poly Selection

This is what the scientist observed. Birds ate mostly the lighter colored. In other words, the environment favored the camouflaged darker roly polys. This is called **directional natural selection**.



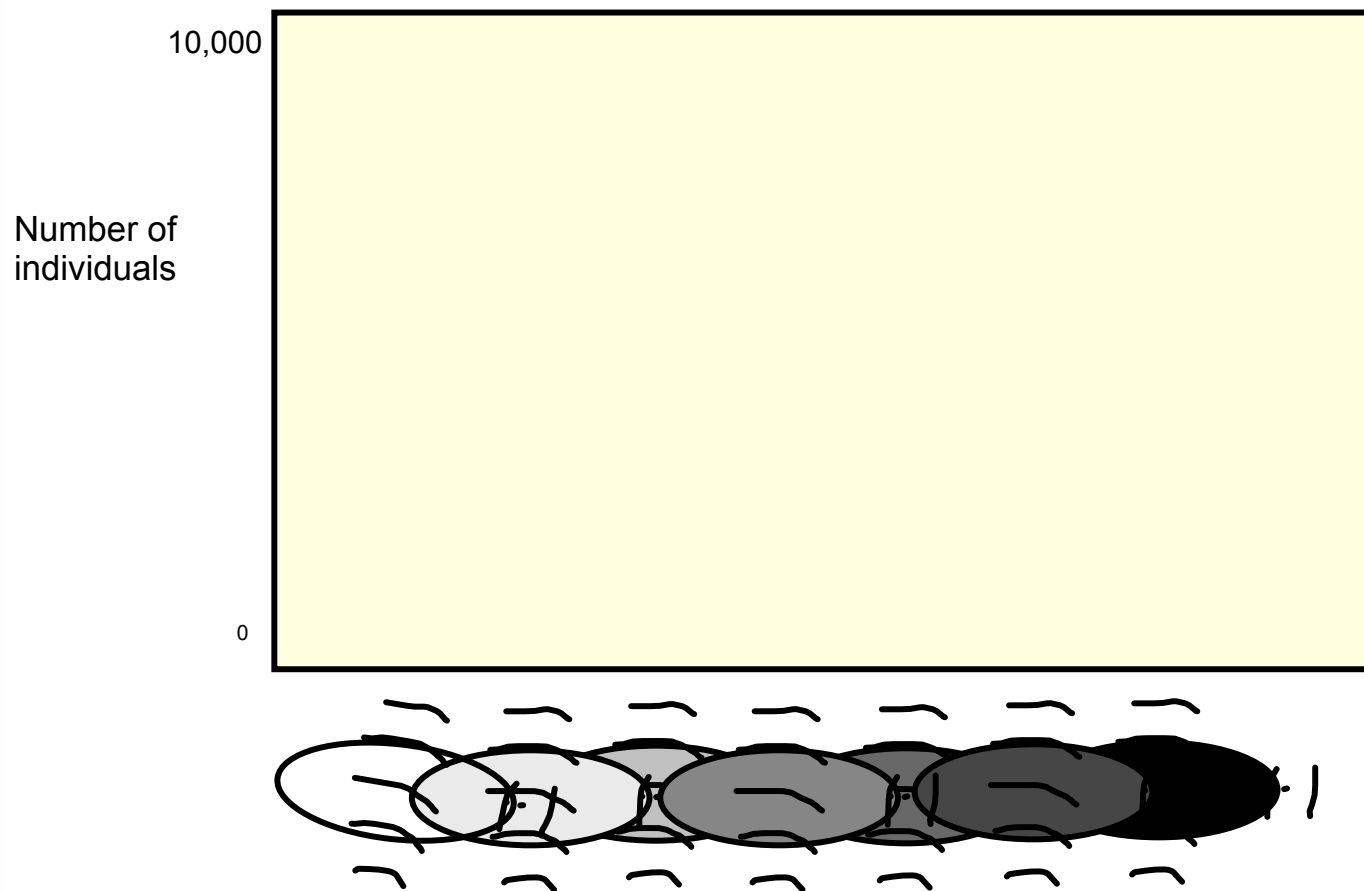
Roly Poly Selection

Now imagine this population has moved to an area that has ice on the ground year round (remember, fictitious). What would be the outcome? Draw your prediction.



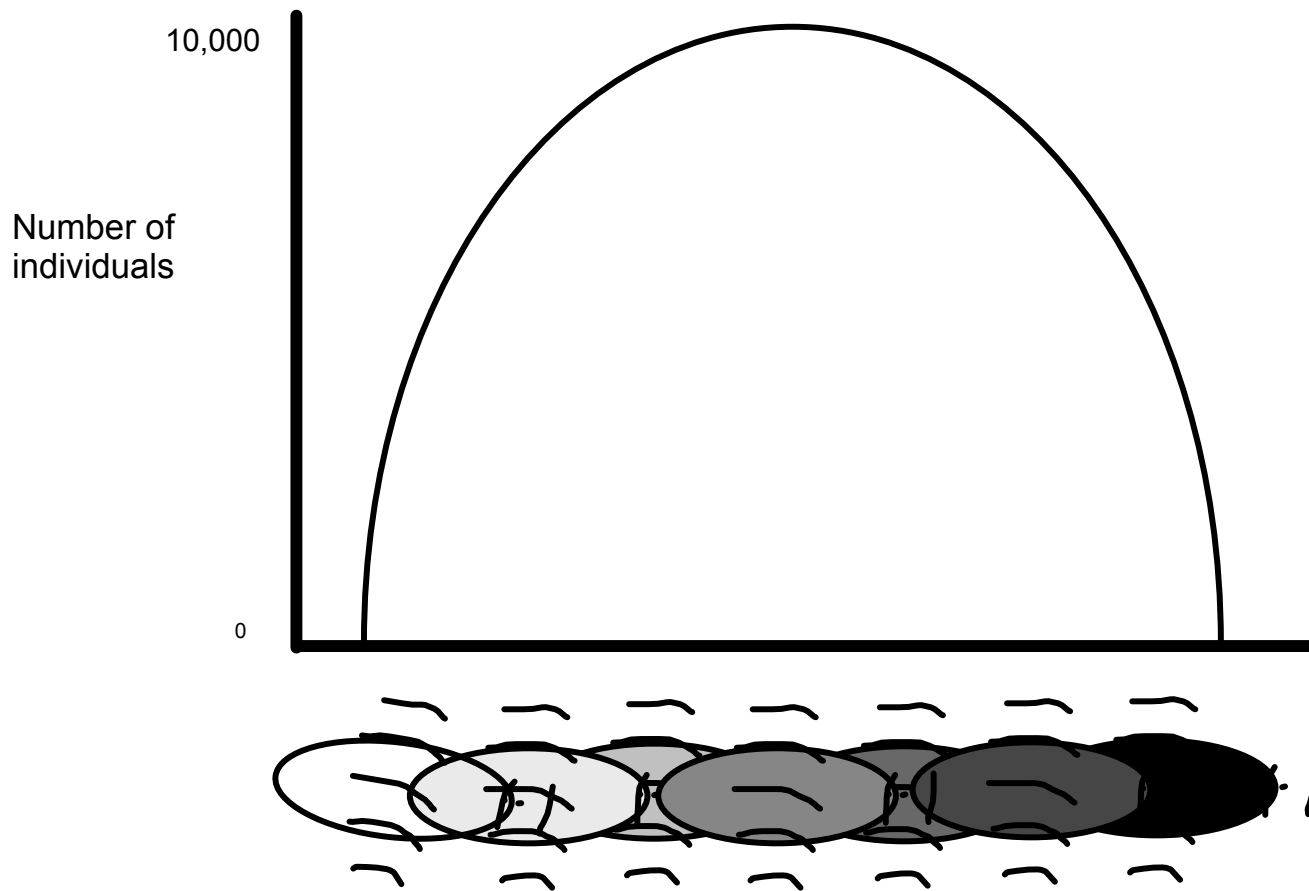
Roly Poly Selection

This is what the scientist observed. Birds ate mostly the darker colored. In other words, the environment favored the camouflaged lighter roly polys. Again, **directional natural selection** occurred.



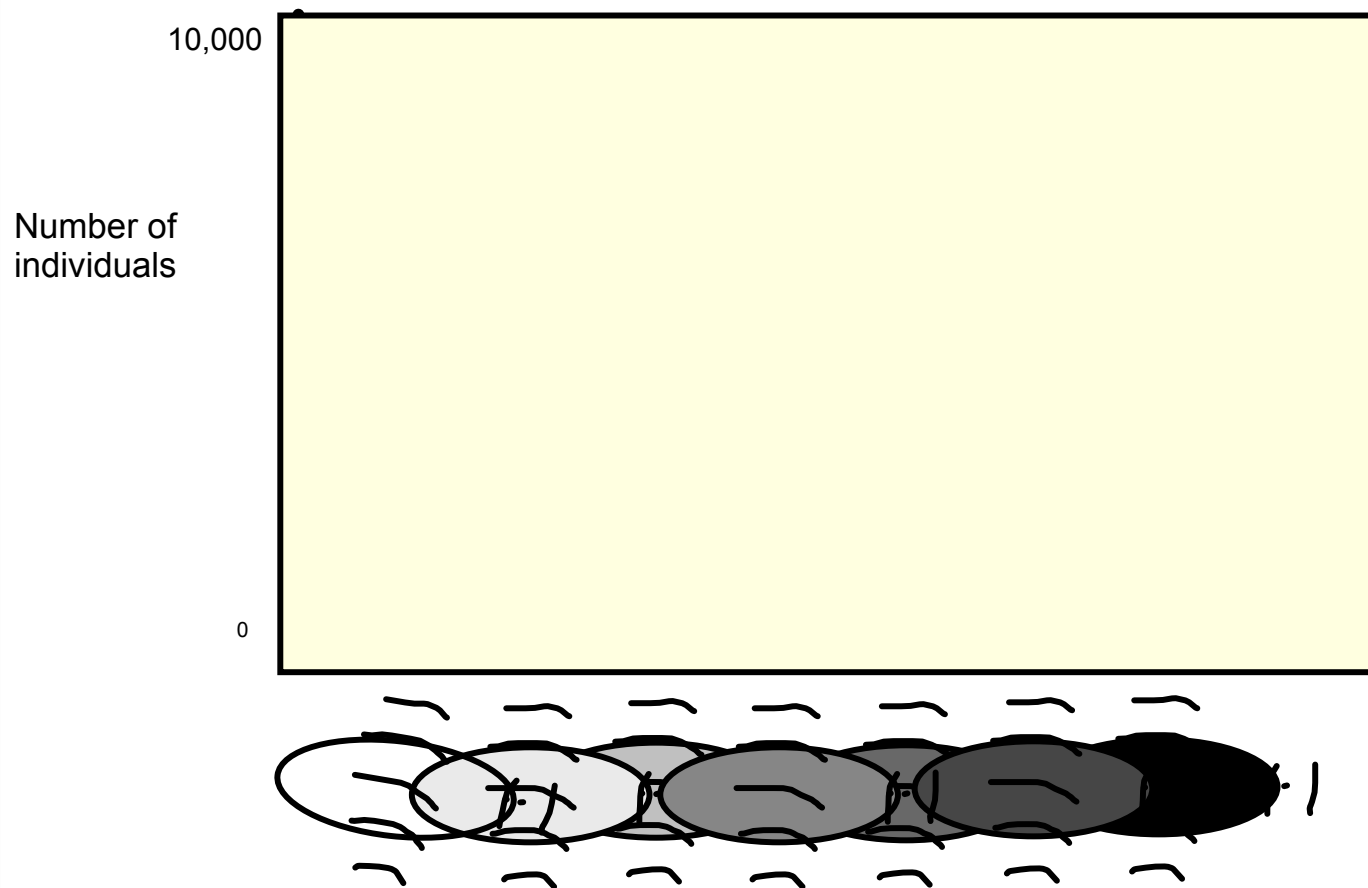
Roly Poly Selection

Now imagine this population has moved to an area where it is snowy in the winter and fertile soil in the summer. What would happen to the populations color distribution?



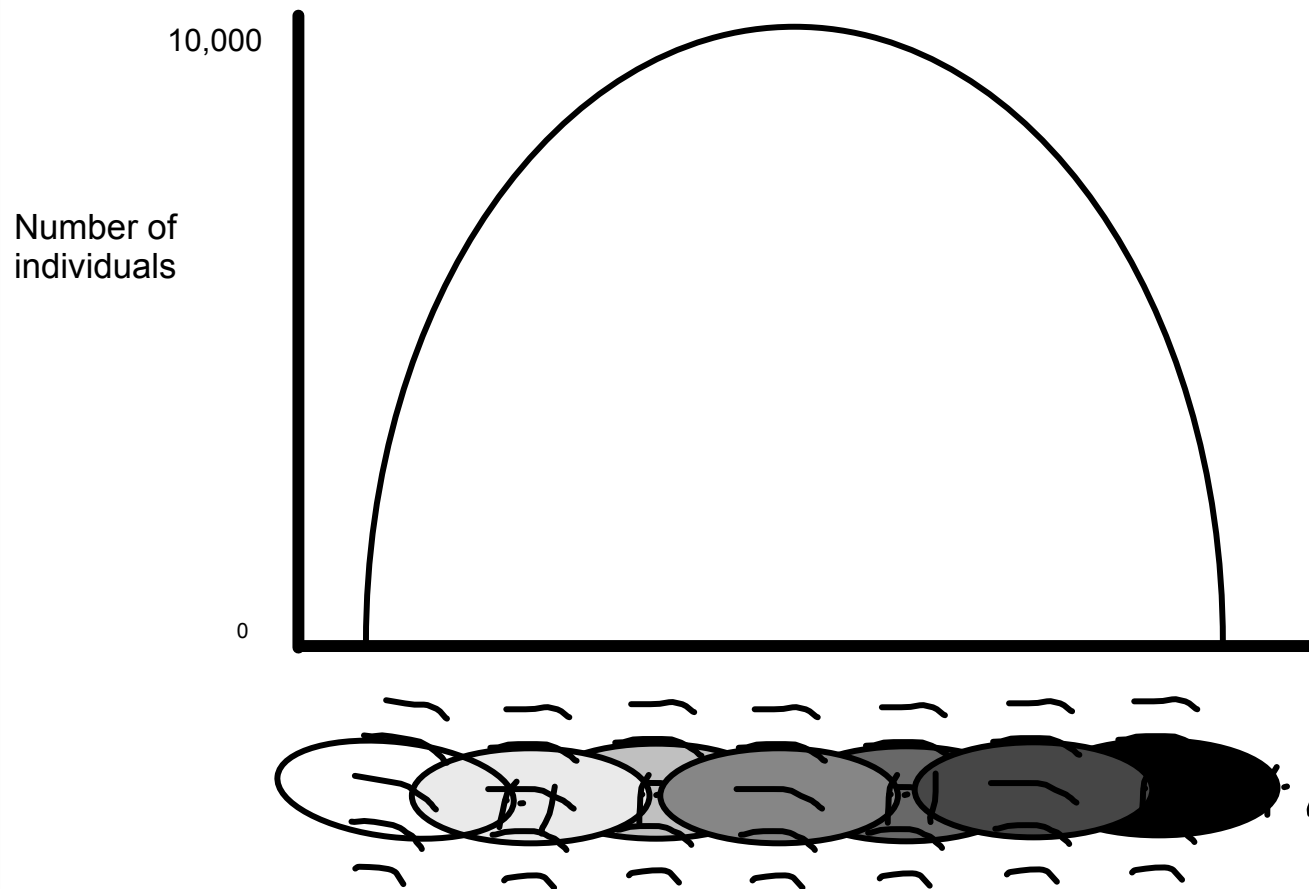
Roly Poly Selection

This is what the scientist observed. In the summer the dark were protected, in the winter the light were protected. through out the year the grey ones were visible so they were eaten year round. This is called **disruptive natural selection**.



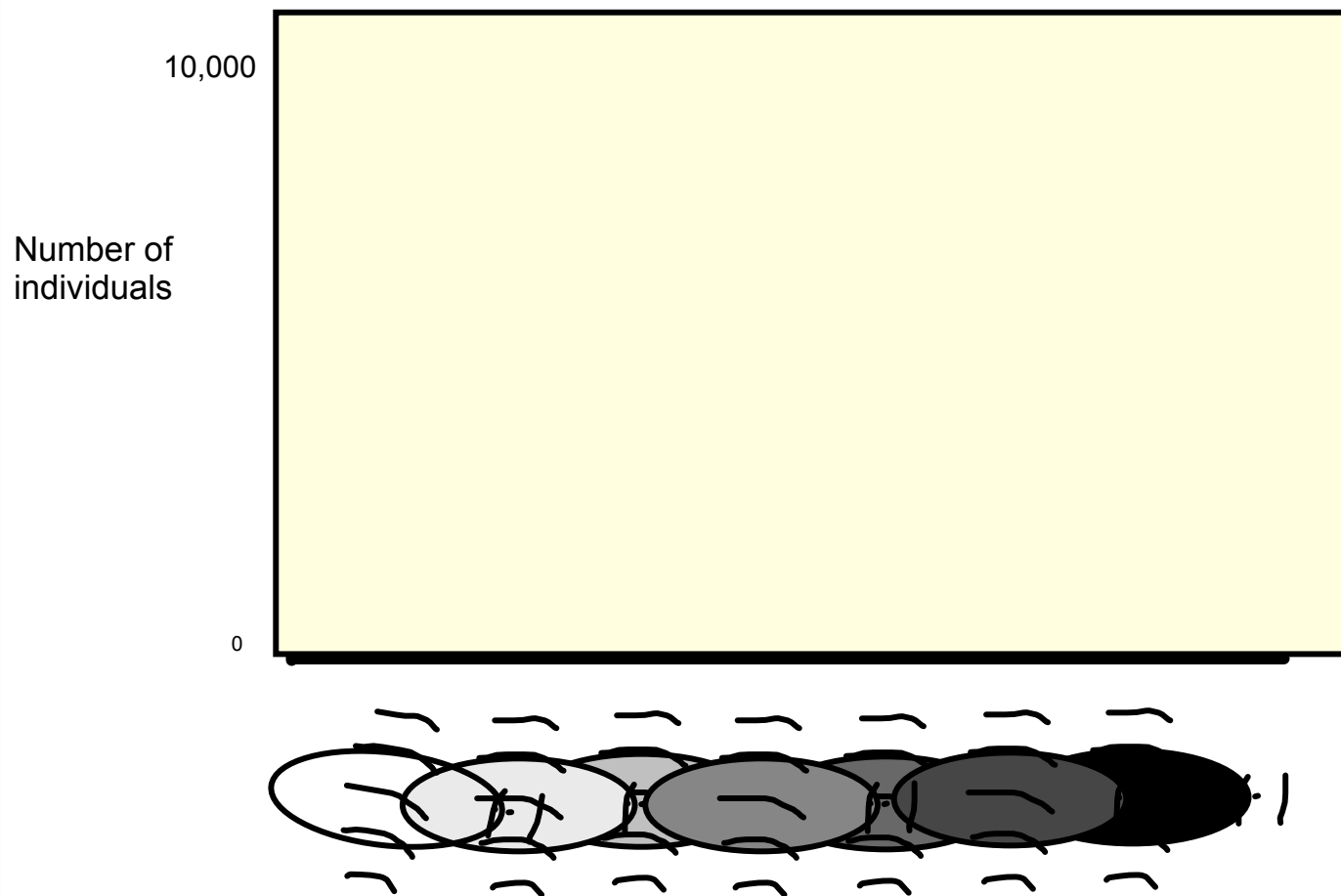
Roly Poly Selection

Now imagine this population has moved to an area where there is grey sedimentary rock all year. What will happen to the distribution? Draw your prediction.



Roly Poly Selection

This is what the scientist observed. The grey were protected year round and the darker and lighter ones were more easily seen by the hungry birds. This is called **stabilizing natural selection**.



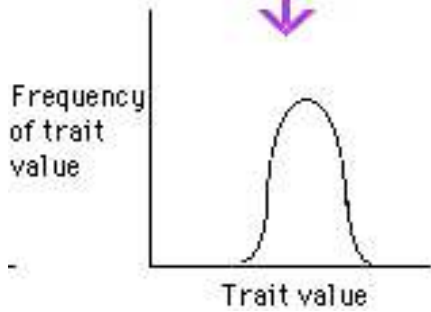
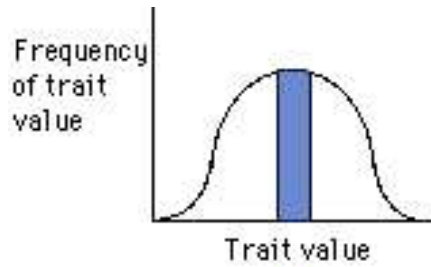
Natural Selection

In each subsequent generation, environmental factors play a role in which organisms are selected for or against. Those organisms that have the adaptations to better fit in the environment have increased fitness and have a better chance to survive and reproduce.

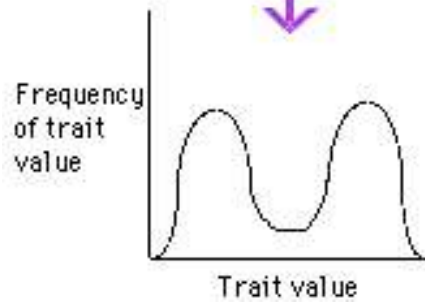
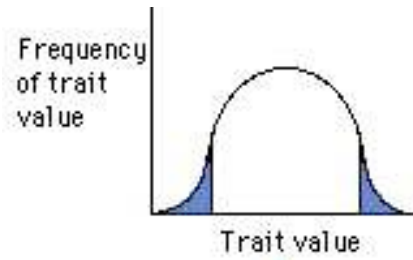
Increases in the frequencies of favored traits in a population from one generation to the next modifies the gene pool.

All of the genes in a population at any given time are referred to as the **gene pool** of that population.

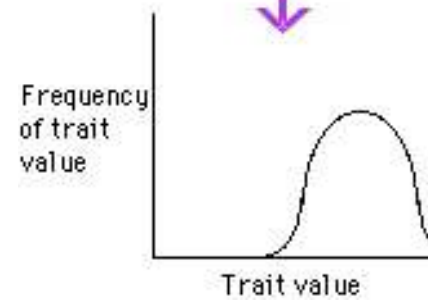
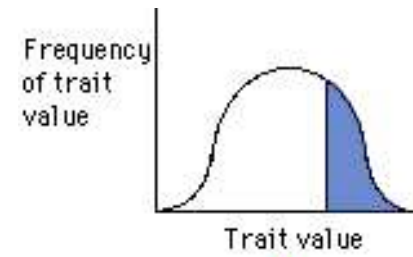
Natural Selection



Stabilizing



Disruptive



Directional

13 The smallest unit of evolution is

- A an individual organism.
- B a species.
- C a population.
- D a community.

13 The smallest unit of evolution is

- A an individual organism.
- B a species.
- C a population.
- D a community.

Answer

C

14 Over time giraffes have evolved long necks to reach food high up in trees. This is an example of which type of selection?

- A disruptive
- B directional
- C stabilizing
- D artificial

14 Over time giraffes have evolved long necks to reach food high up in trees. This is an example of which type of selection?

- A disruptive
- B directional
- C stabilizing
- D artificial

Answer

B

15 Low birth weight babies are more prone to illness. High birth weight babies are difficult to deliver through the pelvis. This indicates the birth weight is undergoing which type of selection?

- A disruptive
- B directional
- C stabilizing
- D artificial

15 Low birth weight babies are more prone to illness. High birth weight babies are difficult to deliver through the pelvis. This indicates that birth weight is being selected against, which type of selection is this?

- A disruptive
- B directional
- C stabilizing
- D artificial

Answer

C

Natural Selection

The following is a video about natural selection. The information within the video will be used to complete an activity. You should take notes on the important points.

[Click here to watch a video on Natural Selection](#)

[Click here for the printout of the activity.](#)

Teacher Note: Procedure 1-3 should be done first in class, then the video should be watched in class. The rest of the procedure and questions should be finished as homework or during the remainder of the class period.

Population Genetics

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Mutations

Mutations are how new alleles are introduced within a population. Small changes in the genetic code that produce favorable traits will survive in a population. Those mutations that produce unfavorable traits will perish with the individual that carries them.

Mutations

Mutations that cause new traits are the driving force behind evolution. Without them there would be no new variation for natural selection to create adaptations.

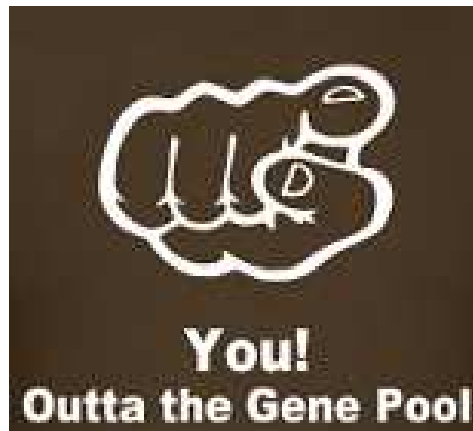


Population Genetics

A population's gene pool consists of all the genes in all individuals in that population.

Each variation of a gene has a **gene frequency** in the population. The gene frequency is the ratio of a particular allele to the total of all other alleles of the same gene in a population.

This frequency can be measured and then compared to its frequency in past or future generations. **If there is a change in gene frequency of the gene pool then the population is evolving.**



Non Evolving Populations

All of the examples given so far are of evolving populations because that is what we are trying to prove: populations evolve.

However, a good scientist knows that you have to look at the **Null Hypothesis (H_0)** as well as your hypothesis (H_1).

The null hypothesis is the opposite of your hypothesis.

Non Evolving Populations

In this case, we are saying that our hypothesis is:

H_1 = Populations evolve by descent with modification as proposed by Charles Darwin.

Our null hypothesis:

H_0 = Populations do not evolve by descent with modification as proposed by Charles Darwin.

Non Evolving Populations

Thinking about what you know about evolution, try to imagine what the conditions would have to be in order for a population to not evolve.

Remember, our contention is that if a gene pool changes the population has evolved. So how could you have a gene pool that **does not** change?

Try to come up with a list within your groups.

Sorry, this element requires Flash, which is not currently supported in PDFs.

Please refer to the original Notebook file.



Hardy-Weinberg Theorem

We use the Hardy-Weinberg Theorem to show what a non-evolving population would look like. It states that the parameters that would have to exist in order to stop a population from changing the frequency of genes in the gene pool. There are five parameters.

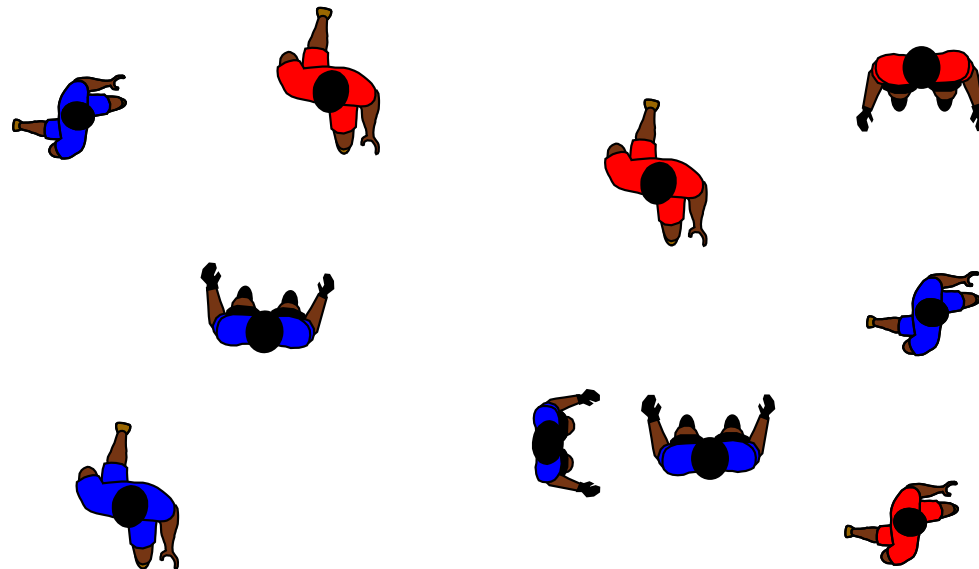
Condition #1: Large Population

Populations must be extremely large - in real life, populations tend to be smaller. They are localized in groups. The reason for the large size of the population is to ensure no genetic drift occurs and causes the gene frequencies to change.

.....in real life, this cannot hold true.

Condition #1: Large Population

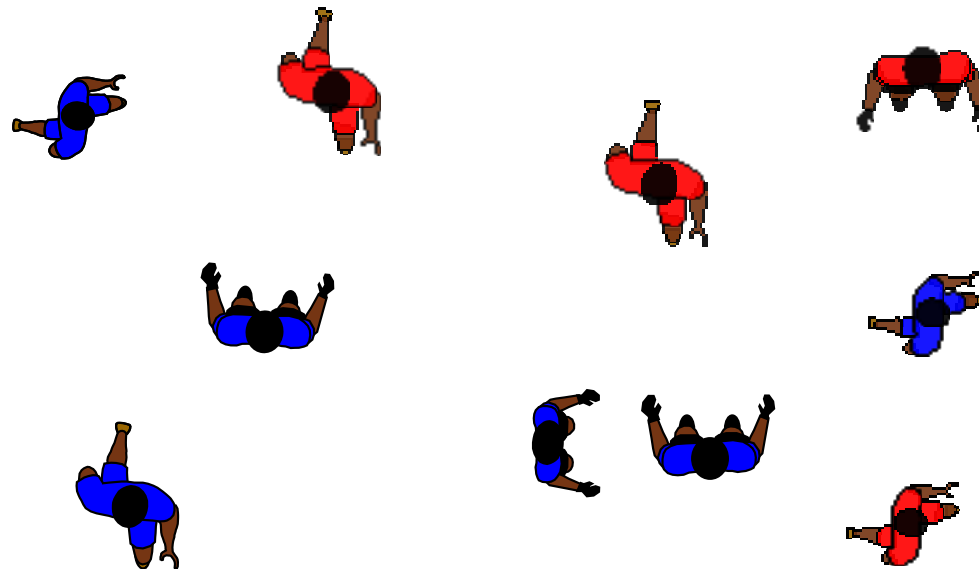
Imagine this pool of soccer players represents a small population.



60% Blue
40% Red

Condition #1: Large Population

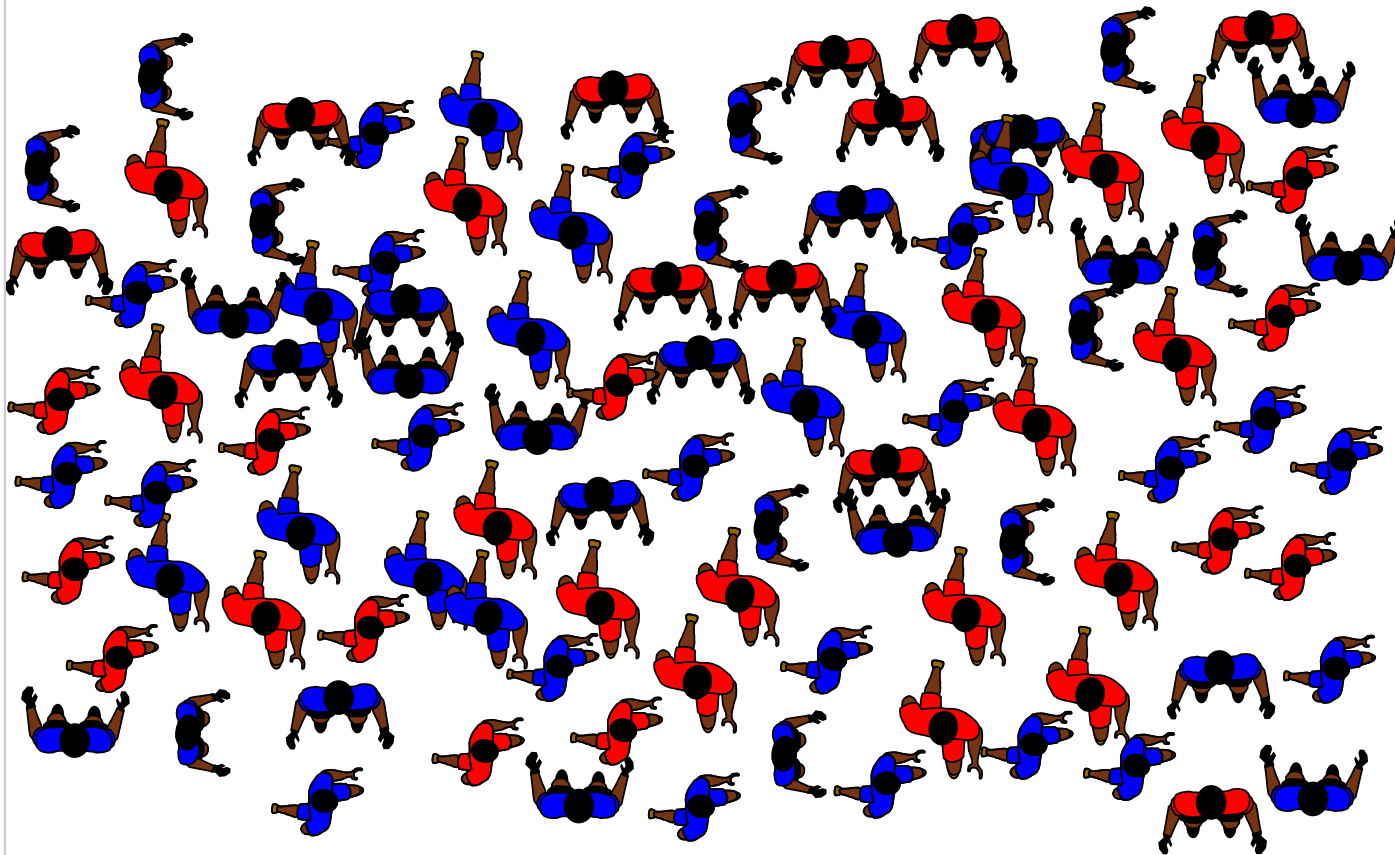
Unfortunately lightning strikes the field and randomly kills 5 of the players. The gene frequency has been changed so the population has evolved.



100%
Blue

Condition #1: Large Population

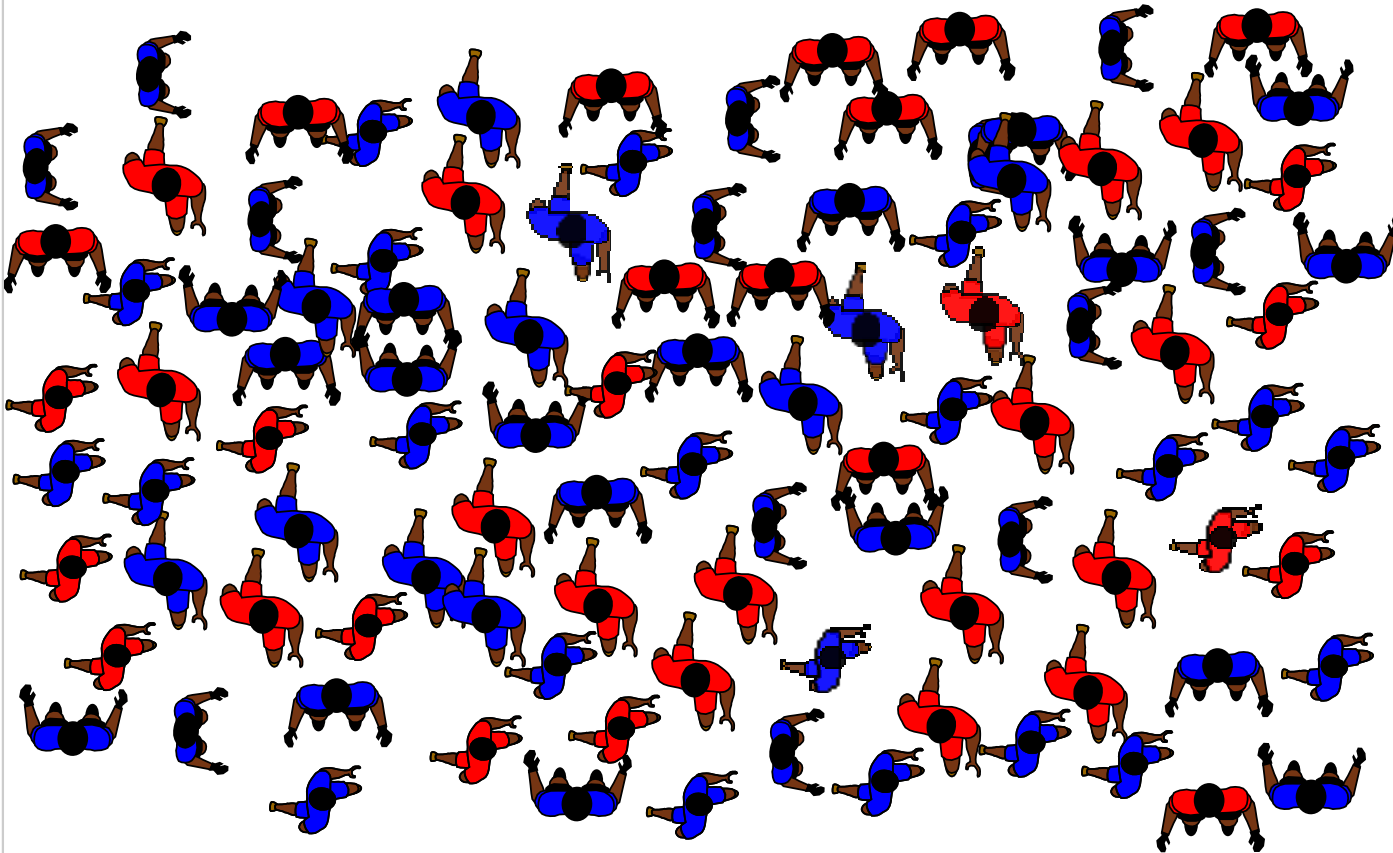
These soccer players represent a significantly larger population



60% Blue 40%
Red

Condition #1: Large Population

If 5 players are randomly killed in this population there is much less of a chance that it will effect gene frequency. The larger the population the less it is affected by environmental events.



60% Blue 40%
Red

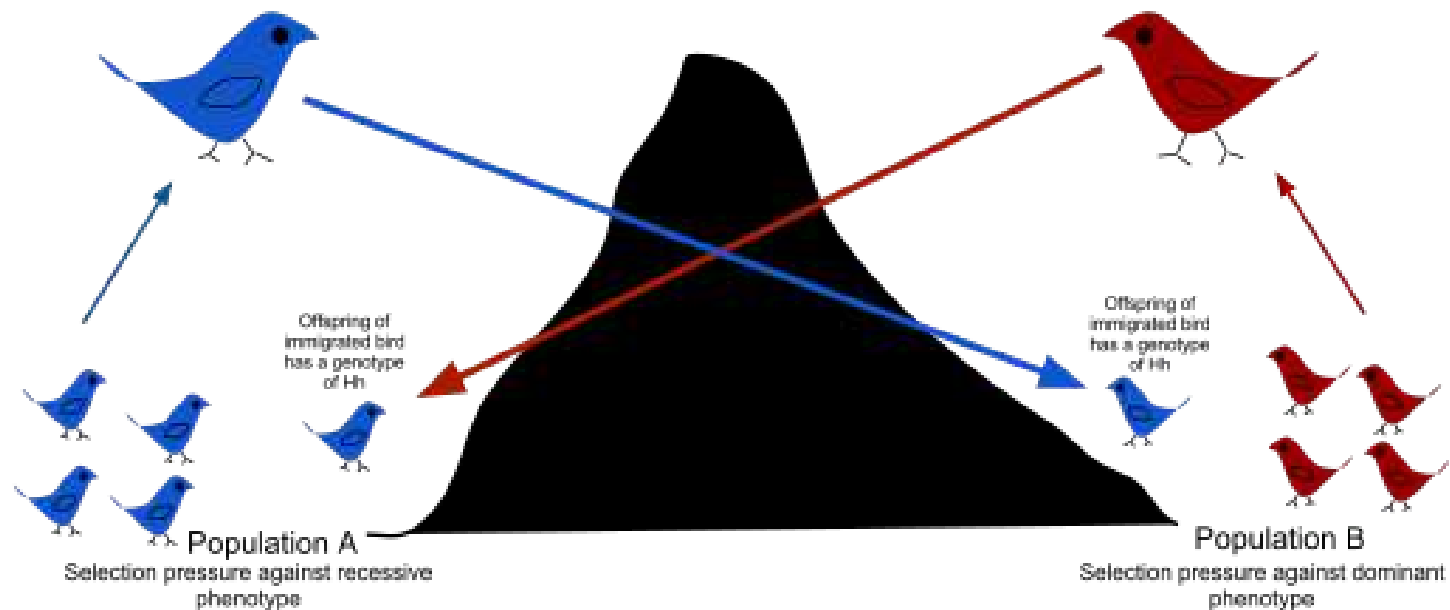
Condition #2 - No Gene Flow

No gene flow can occur in a population working within Hardy-Weinberg Equilibrium. Migration can not be occurring. In real life, you cannot stop organisms from migrating in and out of different populations. Real life populations do not have fences around them. You cannot stop the introduction of or taking away of genes (gene flow) in a population from happening.

.....in real life, this cannot hold true.

Condition #2 - No Gene Flow

In this example of gene flow: one of the birds from population A immigrates to population B and vice versa. Through mating they incorporate genes into the other population.



Condition #3 - No Mutations

Unfortunately, there is no way to ensure **no mutations** occur in a population. Species have built-in mutation rates that help them gain and keep genetic variability.

Mutations are caused by many factors in the environment. Simply being exposed to the sun can cause mutations to occur.



.....in real life, this cannot hold true.

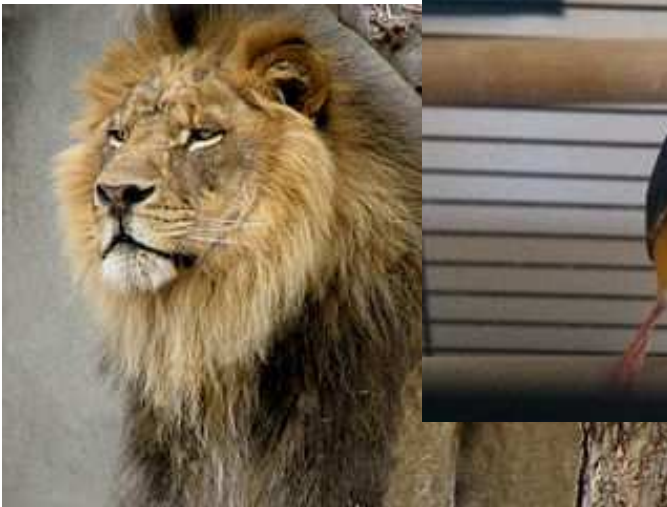
Condition #4 - Random Mating

In Hardy-Weinberg Equilibrium, **mating must be random**. This is the mating of individuals regardless of any physical, genetic, or social preference. In other words, the mating between two organisms is not influenced by any environmental, hereditary, or social interaction. Hence, potential mates have an equal chance of being selected.

.....in real life, this cannot hold true.

Condition #4 - Random Mating

Most organisms CHOOSE their mates. It is almost always the female that chooses. For example, males in the animal kingdom tend to be more ornate than females. Having ornate features sends a signal to the female that this male has good genes, and he is a good partner for producing offspring. Therefore, the female will mate with the male who is most attractive.



<http://topnews.in/people/david-beckham>

Condition #5 - No Natural Selection

No Natural Selection - in real life how can you stop the environment from choosing the best fit and best adapted organisms? You can't...

There is no way to stop the environment from changing. There will always be floods, drought, volcanos, infections, fire, deforestation, competition, climate change, ...

.....in real life, this cannot hold true.

16 If a sexually reproducing population's size is 350,000 individuals, then the total gene pool (number of alleles) for a single gene trait within the population is_____.

16 If a sexually reproducing population's size is 350,000 individuals, then the total gene pool (number of alleles) for a single gene trait within the population is _____.

Answer

700,000

17 Which of these are conditions that must be met in order to keep a population from evolving? (Select all that apply.)

- A Large population
- B Small population
- C Non-random mating
- D Random mating
- E Gene flow
- F No gene flow
- G No mutations
- H Mutations
- I No natural selection
- J Natural selection

17 Which of these are conditions that must be met in order to keep a population from evolving? (Select all that apply.)

- A Large population
- B Small population
- C Non-random mating
- D Random mating
- E Gene flow

Answer

A,D,F,G,I

Hardy-Weinberg Equation

[Click here for a review of the Hardy-Weinberg Equation](#)

If further review is needed, please see NJCTL's first year biology course.

[Evolution and Population Genetics First Year Course](#)

Hardy-Weinberg Equation

Hardy-Weinberg Equilibrium can be calculated using the following equation:

$$p^2 + 2pq + q^2 = 1$$

where:

p^2 = frequency of the homozygous dominant genotype
(p = frequency of dominant allele)

$2pq$ = frequency of the heterozygous genotype.

q^2 = frequency of the homozygous recessive genotype
(q = frequency of recessive allele)

and: $p + q = 1$

The Peppered Moth

One of the most studied examples of Natural Selection and adaptation is the *Biston betularia* (aka the Peppered Moth).

Watch the following video to see the history of this species and why it is a great example of natural selection taking place in a population.

[Click here for a video of Evolution of the Peppered Moth](#)

[Click here for a Peppered Moth evolution simulation activity print out](#)

Population Genetics

To practice the concepts of population genetics try to explain the observations below.

In 1932 a large pine tree forest in upstate New York suddenly began to die. Scientists identified a disease microbe that was responsible but could not find a cure. In 5 years 96% of the original population perished.



Population Genetics

A scientist noticed that some of the trees were unaffected and began to record data. He observed the trees that survived the epidemic began to produce new trees quickly.

Within 50 years the pine tree forest returned to its original population size.



Population Genetics

Suggest a reason as to why a small number of trees survived this epidemic.



Population Genetics

In 2005 a few trees had perished in the same forest. Fearing the worst, biologists tested the dead trees and found the disease had returned. However, by 2010 only about 10% of the trees perished.

In terms of our modern understanding of biology, suggest a hypothesis for the change in death rate for exposure to this disease. Then briefly outline a procedure for testing your hypothesis.

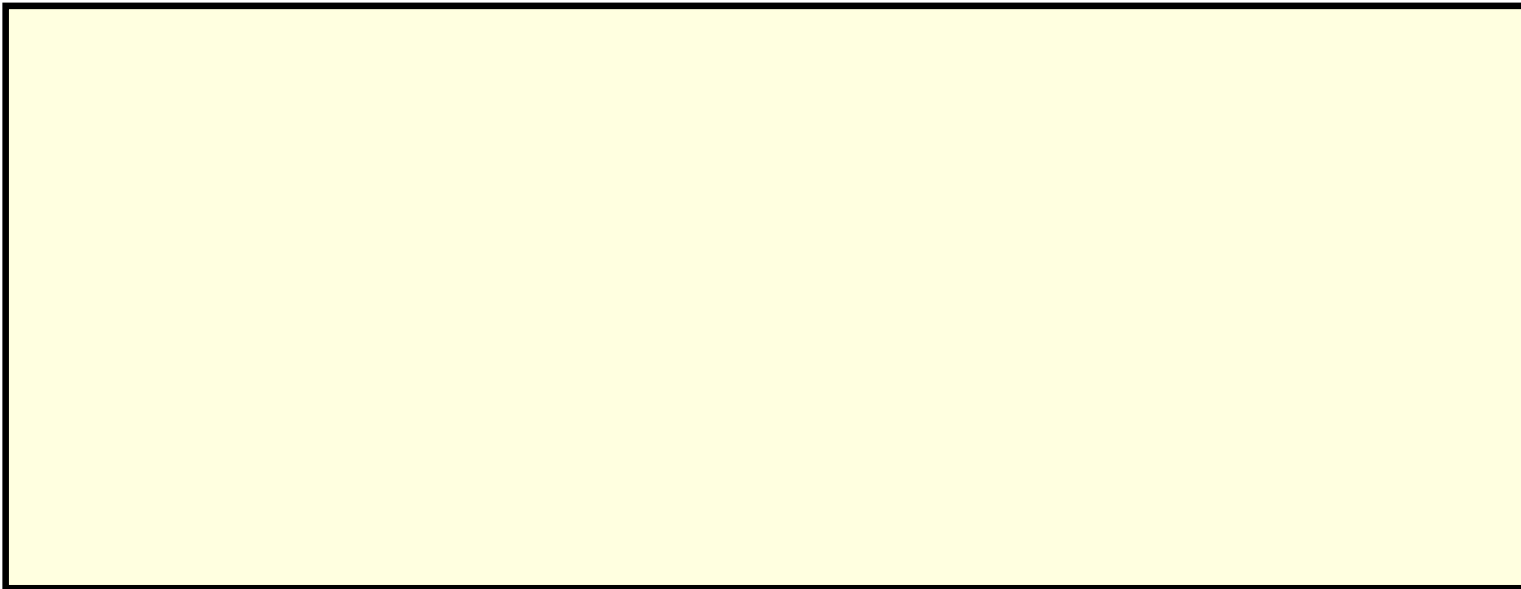
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Population Genetics

Click below to compare your ideas to the real story.



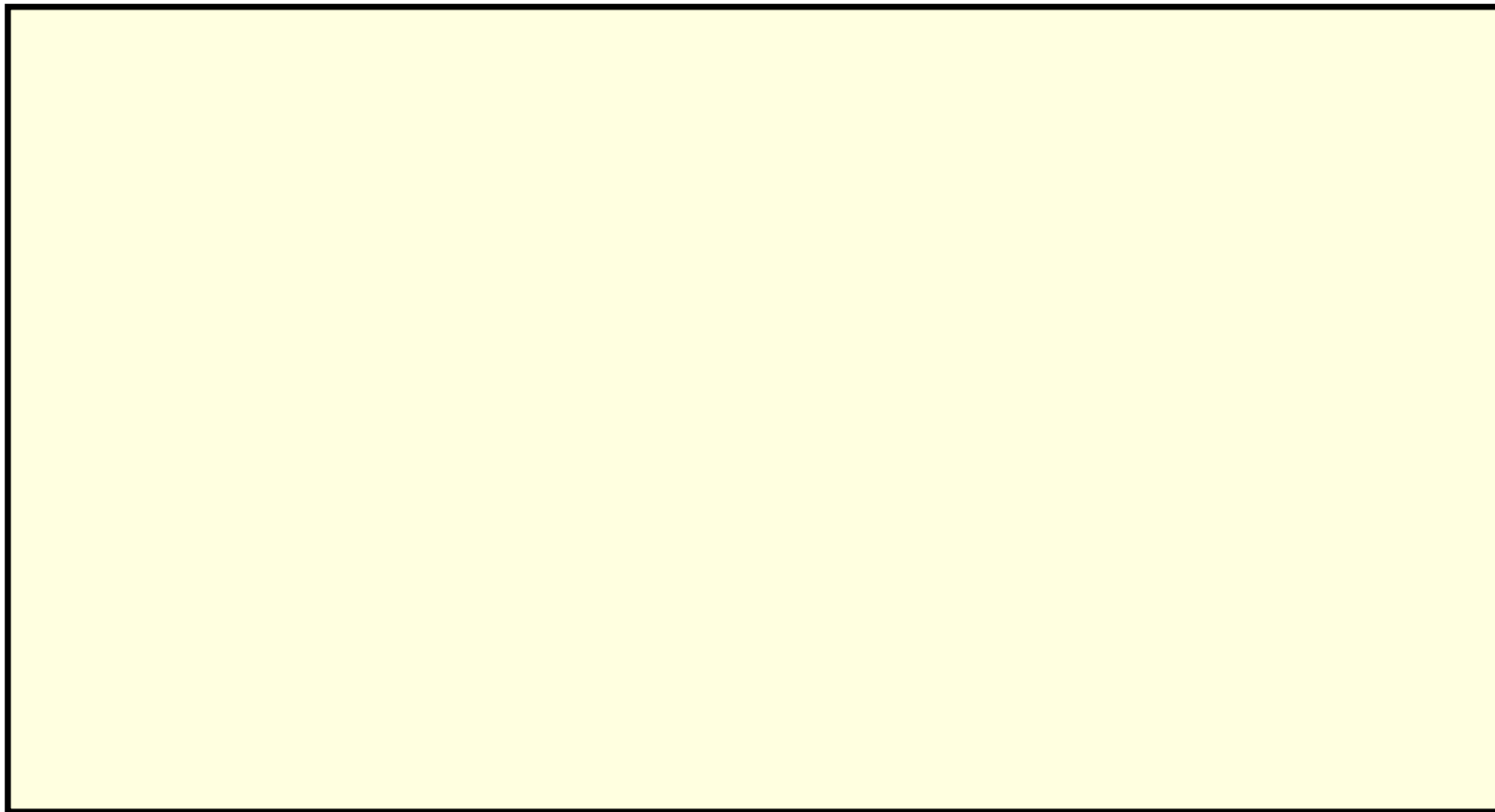
Population Genetics

The researchers labeled the alleles D+ for having the mutation that causes immunity, and D- for no immunity. Curious to know why some of the trees died even though all of them are descendants from immune trees, the biologists did controlled test crosses.

Suggest a hypothesis for why some trees still die from the disease and suggest test crosses that will help support or refute your ideas.

Population Genetics

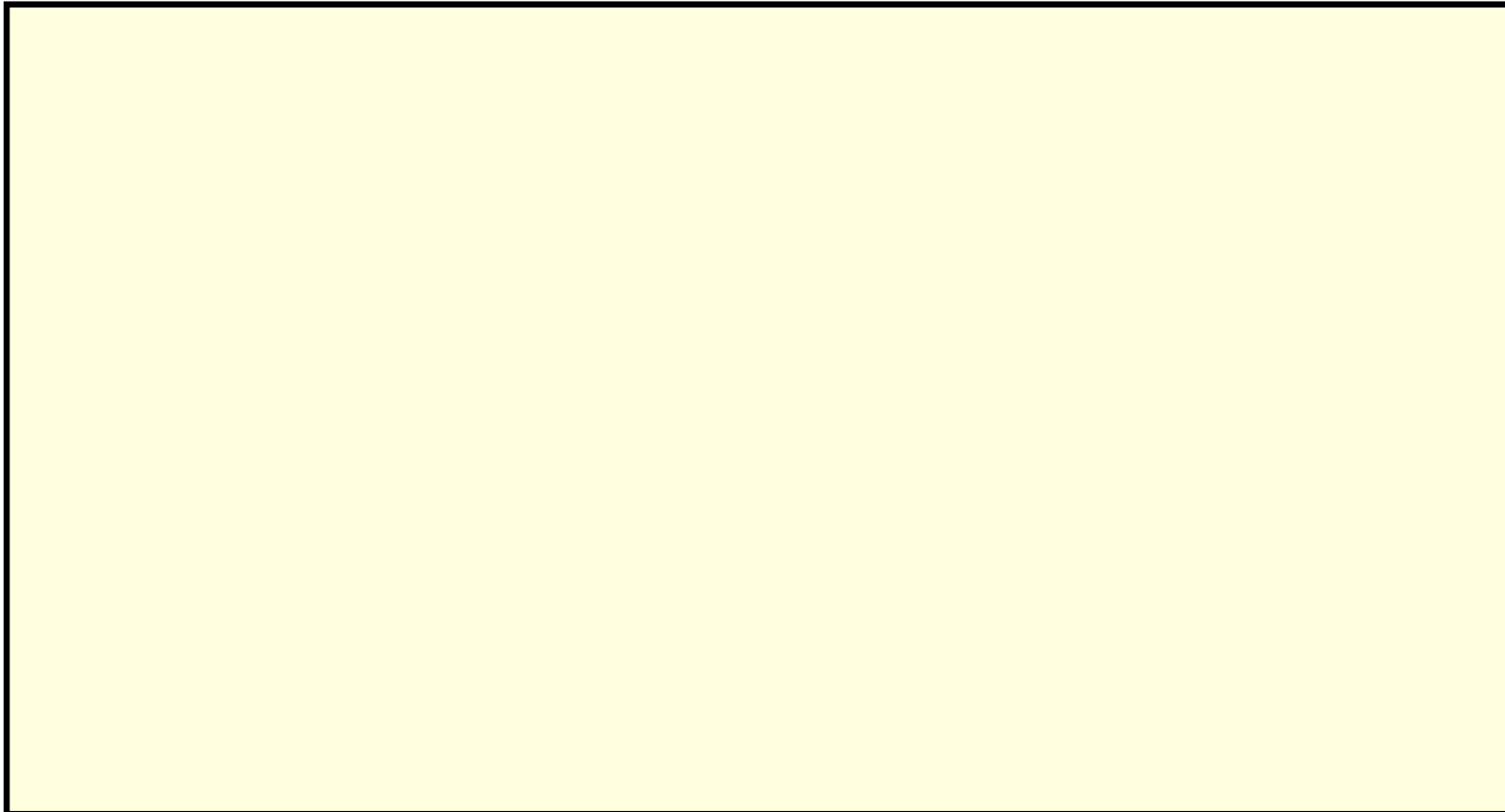
Click below to compare your ideas to the real story.



continued...

Population Genetics

Click below to compare your ideas to the real story.



Population Genetics

That same year, 2010, a forest fire ripped through the ill fated pine lot. In 2012 the same researcher returned to test what effect the fire had on the immunity gene of the population. He tested the immunity of over 1,000 individual saplings.



Population Genetics

He used the Hardy - Weinberg equation to see if the population had evolved.

Remember:

- Changes in allelic frequency of a population means that the population has evolved.
- The population is considered a whole so it equals 1
- p = the allelic frequency of the dominant allele (D+)
- q = the allelic frequency of the recessive allele (D-)
- p^2 = the proportion of individuals who are homozygous dominant (D+D+)
- $2pq$ = the proportion of individuals who are heterozygous carriers (D+D-)
- q^2 = the portion of individuals who are homozygous recessive (D-D-)
- The first equation: **$p^2 + 2pq + q^2 = 1$ (whole population)**
- The second equation: **$p + q = 1$ (whole population)**

Population Genetics

The data collected about the forest (Table A):

Year	sample size	number of non immune
1932	unknown	96% of total
2010	3,375	283
2012	1,112	178

Before proceeding to the questions on the next slides, prepare a data table that will allow you to compare the allelic frequency of the immunity gene when the calculations are done (Table B).

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18 What proportion of the population in 1932 was homozygous recessive?

18 What proportion of the population in 1932 was homozygous recessive?

Answer

0.96

19 Calculate the allelic frequency of D- and D+ in the 1932 population ?

19 Calculate the allelic frequency of D- and D+ in the 1932 population ?

Answer

$$p = 0.02$$
$$q = 0.98$$

20 Using data Table A calculate the proportion of the population that was homozygous recessive in 2010.

20 Using data Table A calculate the proportion of the population that was homozygous recessive in 2010.

Answer

0.085

21 Calculate the allelic frequency of D- and D+ in the 2010 population.

21 Calculate the allelic frequency of D- and D+ in the 2010 population.

Answer

$$p = 0.71$$
$$q = 0.29$$

22 Using data Table A calculate the proportion of the population that was homozygous recessive in 2012.

22 Using data Table A calculate the proportion of the population that was homozygous recessive in 2012.

Answer

0.16

23 Calculate the allelic frequency of D- and D+ in the 2012 population.

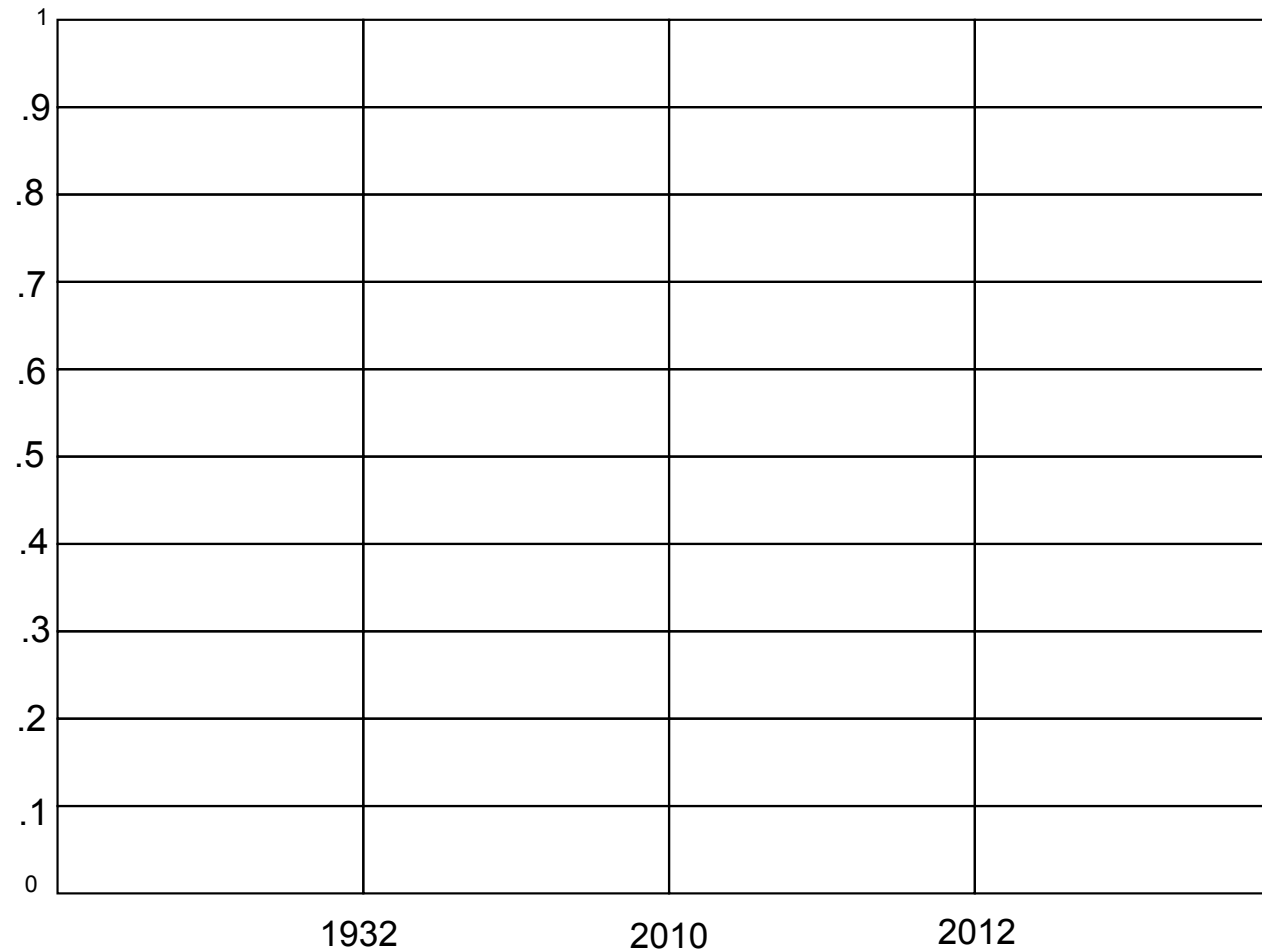
23 Calculate the allelic frequency of D- and D+ in the 2012 population.

Answer

$$p = 0.6$$
$$q = 0.4$$

Population Genetics

Create a point graph the data for allelic frequency against years of catastrophic events to compare the changes after each:



Population Genetics

Has this population evolved?

Write a statement that summarizes the evolution of the immunity gene in this population over time.

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supported in PDFs.

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Notebook file.



Population Genetics

Just when the researcher thinks he is done studying this forest, a colleague asks if she can use the data for her study.

She is studying the heterozygosity of traits in pine trees in areas around New York and thinks your data can predict how many trees in this population are heterozygous for the immunity trait.

24 An estimate was done and the total individual trees in the pine forest was 50,000. How many heterozygous trees are in this population for 2012?

24 An estimate was done and the total individual trees in the pine forest was 50,000. How many heterozygous trees are in this population for 2012?

Answer

24,000

Macroevolution

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What About Macroevolution?

The Hardy-Weinberg equation mostly accounts for evolution within a species, or microevolution.

Macroevolution is when a gene pool becomes so diverse that members of its population become new species.

A species is defined as an interbreeding population capable of producing viable offspring.



← Bulldog bat
and
Leaf nosed bat →

closely related but
not the same
species



What About Macroevolution?

The separation of a population into 2 distinct species comes about because the allelic variation becomes so great that contradicting behavior begins and portions of the population become reproductively isolated from one another.

This can be because:

- geographic barrier/location/habitat preference
- diverse mating rituals cause females to choose mates for different, consistent reasons
- a new food source produces opportunity that only a portion of the population takes advantage of.

Many other reasons can apply. Ultimately there is a separation in the gene pool that makes up the population

What About Macroevolution?

Choose one of the species below to use to plan an experiment to test the concepts of speciation.



← Lab Rats
Fruit Flies →
Pea plants ↓



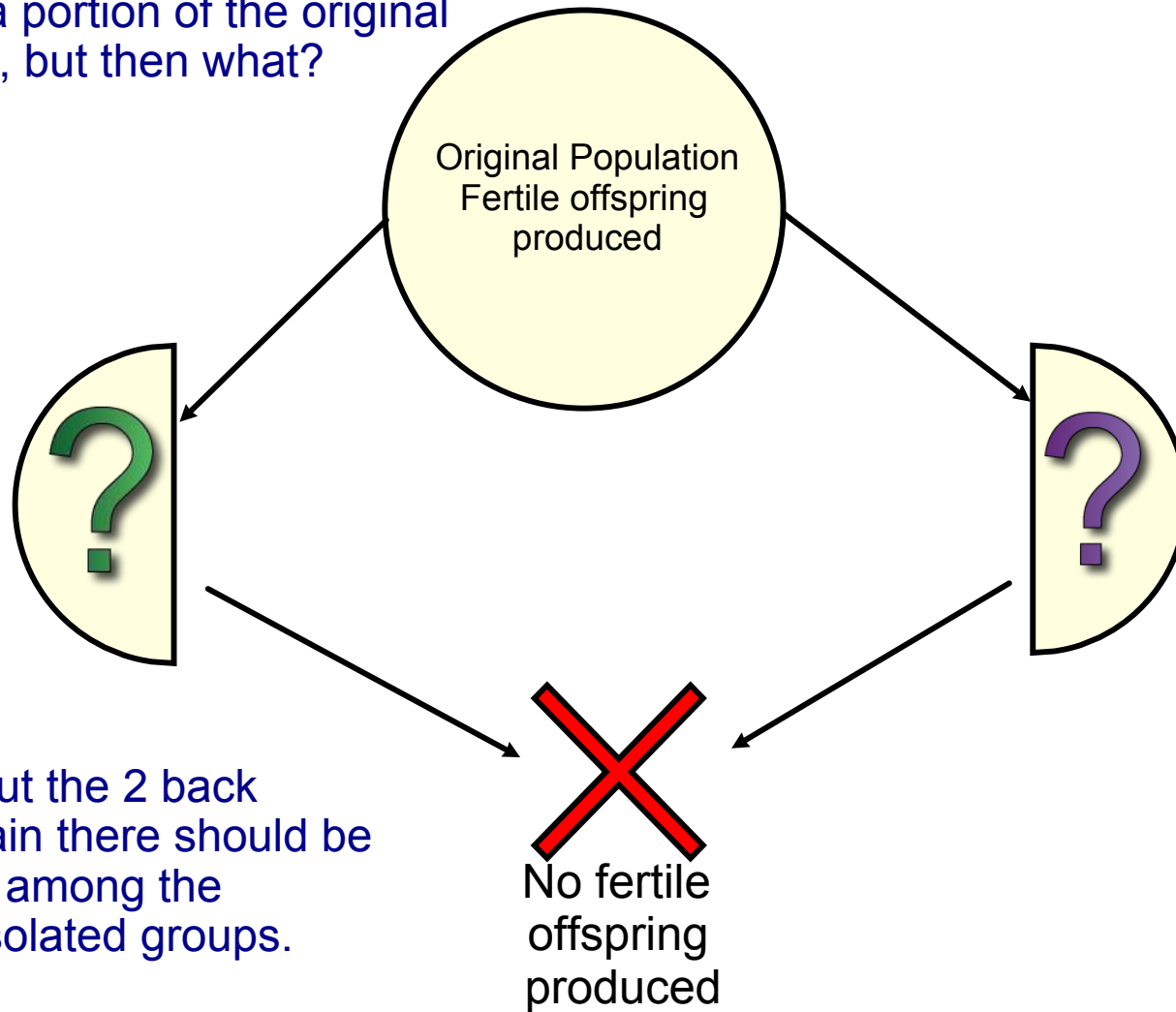
What About Macroevolution?

You are given a population of your organism of choice, a fully equipped lab, and all the time you need. You want to see if you can coax your existing population into two separate, non breeding populations.



What About Macroevolution?

You realize your first step will be to isolate a portion of the original population, but then what?



When you put the 2 back together again there should be no breeding among the previously isolated groups.

What About Macroevolution?

Consider the factors that separate gene pools in nature and design your experiments.

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supported in PDFs.

Please refer to the original
Notebook file.



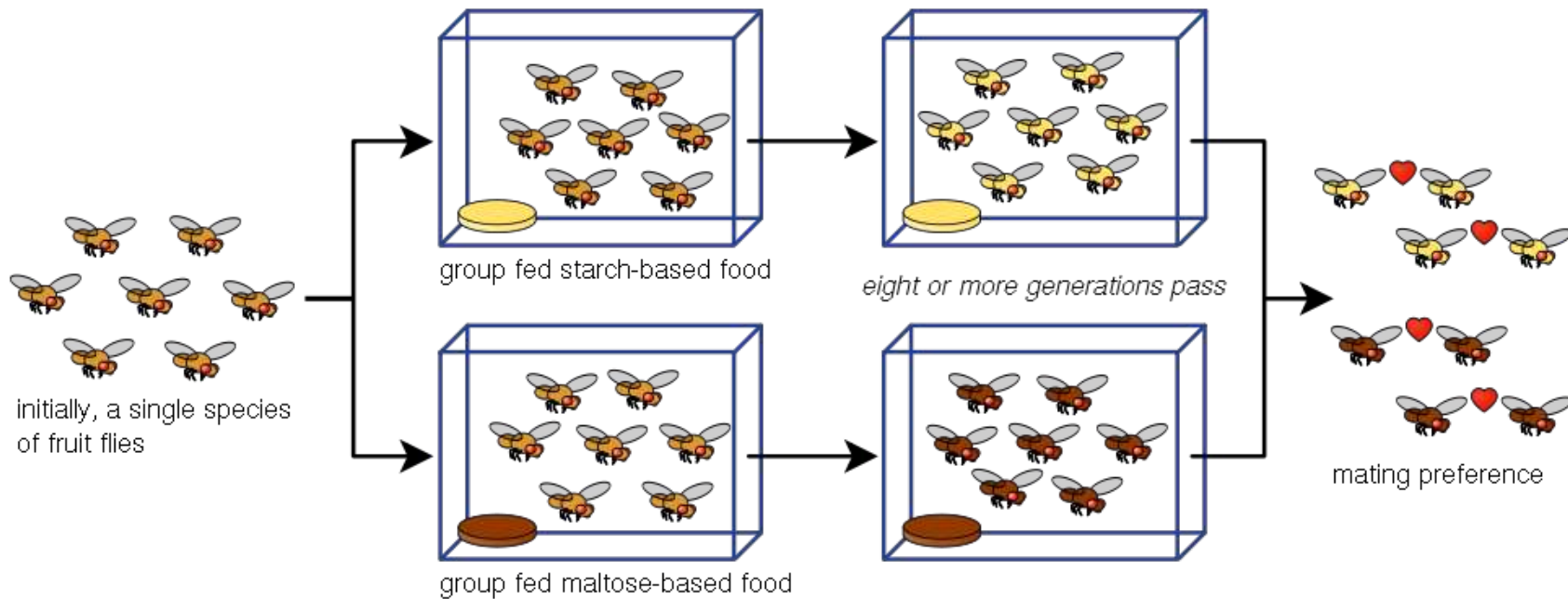
Dodd's Fruit Flies

An experiment demonstrating allopatric speciation in the fruit fly was conducted by Diane Dodd.

A single population of flies was divided into two, with one of the populations fed with starch-based food and the other with maltose-based food.

After the populations had diverged over many generations, the groups were again mixed; it was observed that the flies continued to prefer mating with others from the same original population.

Dodd's Fruit Flies



Consider that if these 2 groups no longer have sex or offspring, their separate gene pools will no longer be sharing mutations or the microevolutionary changes we have seen. Eventually their genetics will no longer be similar enough to produce offspring.

Allele Frequency is Influenced by Many Factors

We have seen many examples of a population evolving because the allele frequency is affected by some environmental influence.

However, we have just scratched the surface of possible factors that can change a population. Let's look at a few more to be sure that we get a big picture of how evolution drives unity and diversity.

Predator vs Prey

Most defenses and weapons that are found in nature exist because of **predation**, one species using another as food.

The impala has become faster over time because it is constantly hunted by big cats. Big cats have evolved speed, stealth and claws for grabbing to counter the improved speed of the impala.



Predator vs Prey

Take a moment and write down a paragraph that explains the evolution of the features of impalas in terms of alleles, gene pools and populations. Share your explanation with your group.

Remember:

If you are writing about the impala population then the cat is an environmental factor that selects alleles, this is known as a **selective pressure**. When writing about the cat population the impala is the selective pressure.



Genetic Drift

Genetic Drift happens when the allelic frequencies in a population change due to chance. The smaller the population is, the greater the impact of genetic drift.

With a small population, it might only take a few generations before they are all the same color (for example). Genetic drift thus tends to eliminate variation more quickly in small populations; large populations will tend to have greater genetic diversity.



Bottleneck Effect

The **Bottleneck Effect** is a type of genetic drift that occurs when most of the population is killed off due to a chance event such as fire, flood, volcano, or earthquake.

As a result, all of the alleles carried by these individuals are lost. Because there are so few individuals left, there is decreased genetic variability. Once alleles are lost in a population, it is extremely difficult to get them back. No matter how many times these individuals mate in different combinations with one another, they will not gain genetic diversity.

Founder Effect

A large population of fish live in a lake in western Oregon. These fish are usually blue in color, but a mutation causes a new allele (B⁺) leading to pink color.

Over time B⁺ is passed to future generations and a small group of these fish are pink.



Founder Effect

A pet supply company finds out about the new kind of fish and is interested in selling them to the public. They take a sample of this population of fish but only take the pink variety.

In an isolated man-made tub, these fish are bred to produce fish that they can sell.

25 Does this new gene pool have the same allele frequencies as the original one in the Oregon lake?

Yes

No

25 Does this new gene pool have the same allele frequencies as the original one in the Oregon lake?

Yes

No

Answer

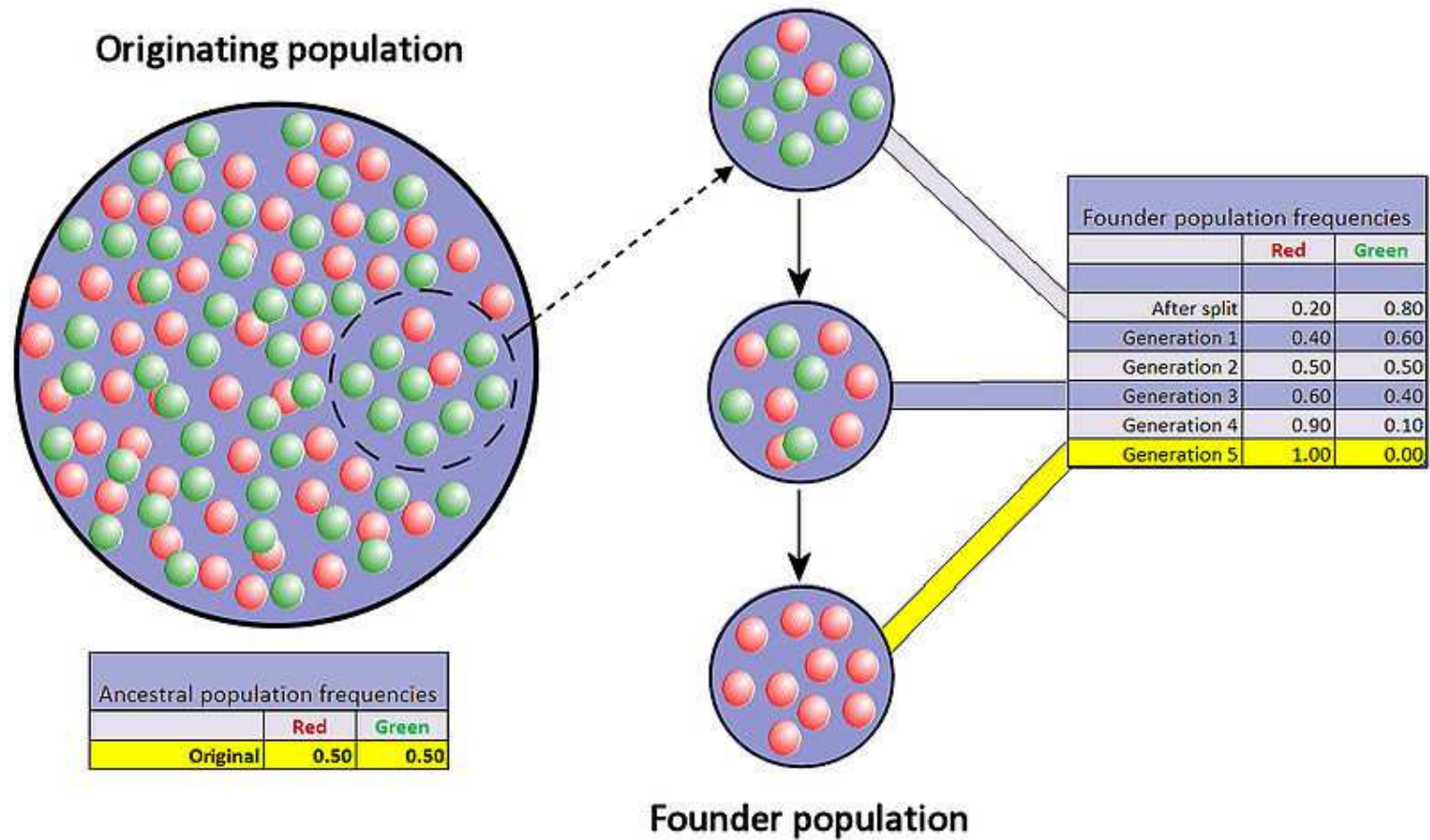
NO

Founder Effect

The Founder Effect occurs when a very small group of individuals are a new group (in a new area) and are the "founders" of the new population.

Because there are so few individuals, there is decreased genetic variability. Once alleles are lost in a population, it is extremely difficult to get them back.

Founder Effect



Importance of Genetic Variation

What if a population lost all its genetic variation? This means they only have one form of every gene. No matter how many times their chromosomes cross over in meiosis, they will not gain the other alleles back.

At this point, a population is in extreme danger of **extinction**. If organisms in a population are all alike, they can only be chosen *for* or *against* every time the environment changes.

It is probable that there will come a time when all of them will be chosen against.

26

- A it is random
- B it involves geographic relocation
- C it is a type of genetic drift
- D all of the above are true

26

- A it is random
- B it involves geogr
- C it is a type of ge
- D all of the above

Answer

B

27

- A the bottleneck effect
- B the founder effect
- C genetic drift
- D both B & C

27

- A the bottleneck effect
- B the founder effect
- C genetic drift
- D both B & C

Answer

D

Gene Flow Gets Interrupted

If gene flow of a population is interrupted for some reason and 2 or more new populations form in its place, it can lead to **speciation**. This is the beginning of a new **species**.

Species

According to the biological species concept definition...

A species is defined as a group of organisms capable of interbreeding and producing fertile offspring.

In other words, a group of organisms must have the ability to pass their gene pool on to future generations and individuals in the group must not be reproductively isolated from other individuals.

Reproductive Isolation

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Reproductive Isolation

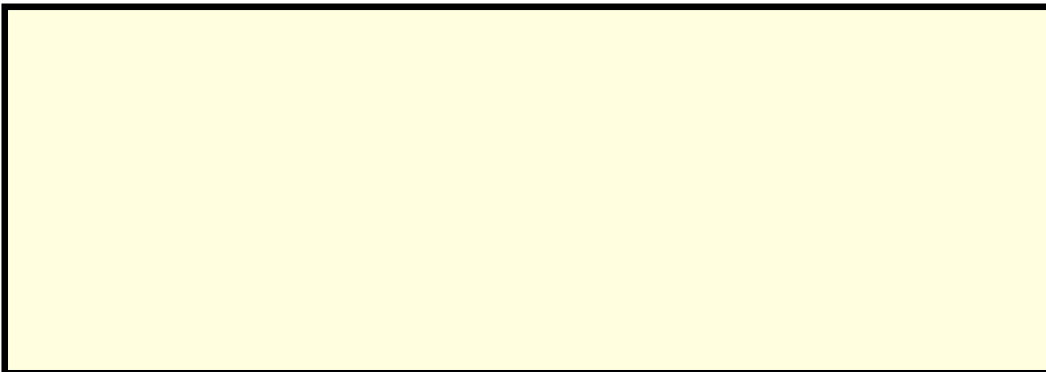
Reproductive isolation is caused by the existence of biological barriers that prevent members of two different species from producing viable, fertile hybrids.

The following slides are examples of isolations that will lead to reduced gene flow and, ultimately, a new species forming. See if you can point out the problem and the distinct new gene pools that will form.

Iguana Castaways

In the summer of 1995, at least 15 iguanas survived Hurricane Marilyn on a raft of uprooted trees. They rode the high seas for a month before colonizing the Caribbean island, Anguilla. These few individuals were perhaps the first of their species, *Iguana iguana*, to reach the island.

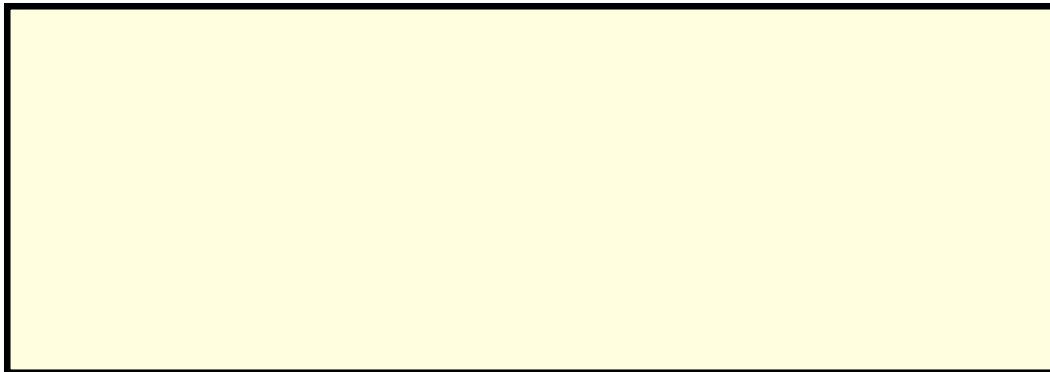
Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.



There Is A Season

In a mutation event, a few members of a flowering plant population begin to bloom a month after the rest of the population. Flowers are responsible for producing the sexual cells of plants.

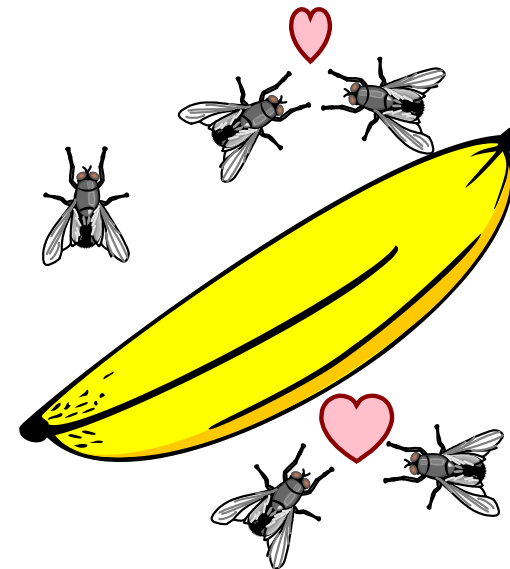
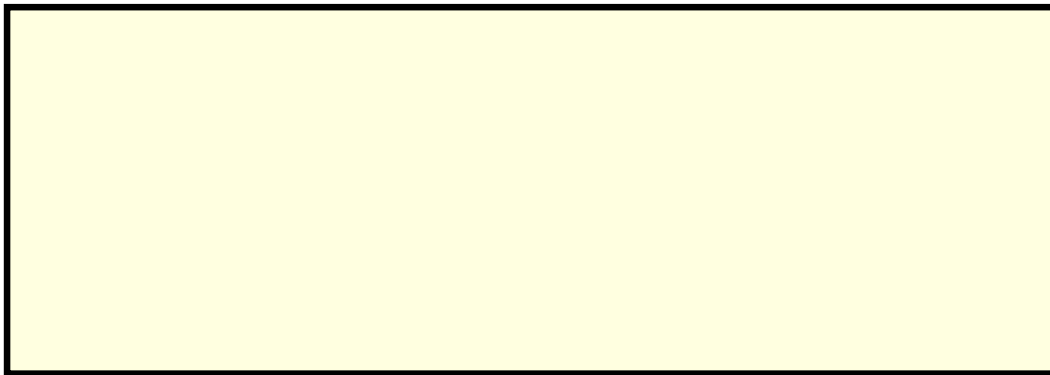
Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.



Flies on an Island

A population of fruit flies on an island has three food sources: mangos, oranges and bananas. Each fly shows a preference to one of the three foods. Because of this, flies that like bananas spend most of their time with other flies that have that preference. The same could be said for each of the other fruits.

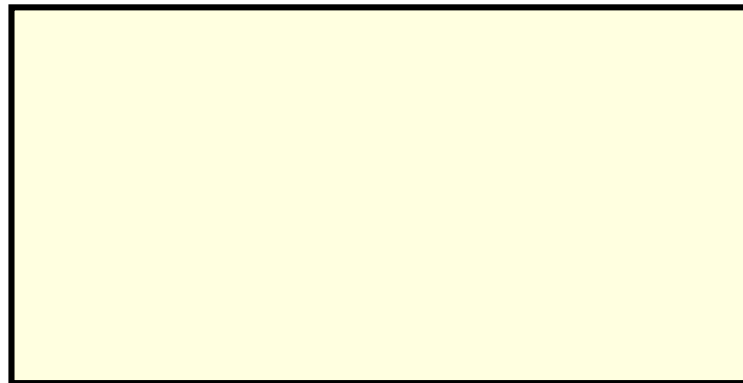
Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.



Puppy Love



Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.



Clammy

Giant clams reproduce by ejecting sperm and eggs into the open water in hopes that they will find each other. A mutation causes the sperm of some to reduce its ability to couple with some eggs.

Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.



Summary

1. **Habitat Isolation/Geographic Isolation** - Different species occupy different habitats in the same area and may never encounter each other.
2. **Temporal Isolation** - Different species breed at different times of the day or year so they would never mate with each other. e.g. Two plants that live in the same area produce pollen at different times of the year.
3. **Behavioral Isolation** - Different species have different mating rituals, dances, behavior. Females from one species will not respond to mating behavior of a male from another species.
4. **Mechanical Isolation** - Differences in structures of sex organs of different species make it impossible for fertilization to take place.
5. **Gametic Isolation** - Sperm from one species cannot survive in the female reproductive tract of another. Also, different species' eggs have different receptors on them so that sperm from another species cannot enter the egg.

28 A drought causes a food shortage among a primate population. As a result, a group of the individuals begins to look for alternate food sources. Some of the population remain in their native trees continuing to eat fruits, while another part of the population descends from the trees to look for bug larvae in stream beds. The two segments of the population wind up separated because their food source limits exposure to individuals looking for the other food source. This is _____ isolation.

- A Habitat
- B Temporal
- C Behavioral
- D Mechanical
- E Gametic

28 A drought causes a food shortage among a primate population. As a result, a group of the individuals begins to look for alternate food sources. Some of the population remain in their native trees continuing to eat fruits, while another part of the population descends from the trees to look for bug larvae in stream beds. The two segments of the population cause their food source living in the stream beds for the other food source isolation.

- A Habitat
- B Temporal
- C Behavioral

Answer

C

29 Fruit flies have sex for 10 minutes while in mid air. Because of this "The male fruit fly has a penis that resembles a medieval weapon, dotted with hooks and spines."- Discovery Magazine. A researcher's work showed that the configuration of hooks allows the male and female to couple for the duration of the act. He continued to show that males could only copulate with females that have genitalia compatible with his particular configuration of hooks. This is _____ isolation.

- A Habitat
- B Temporal
- C Behavioral
- D Mechanical
- E Gametic

29 Fruit flies have sex for 10 minutes while in mid air. Because of this "The male fruit fly has a penis that resembles a medieval weapon, dotted with hooks and spines."- Discovery Magazine. A researcher's work showed that the configuration of hooks allows the male and female to couple for the duration of the act. He continued to show that males could only copulate with females that have genitalia compatible with his particular configuration of hooks

- A Habitat
- B Temporal
- C Behavioral

Answer

D

30 A male song bird uses calls to attract females. These songs are very complex and only certain females respond to certain songs. A particular male only sings for two hours per day in the mid afternoon. This is _____ isolation.

- A Habitat
- B Temporal
- C Behavioral
- D Mechanical
- E Gametic

30 A male song bird uses calls to attract females. These songs are very complex and only certain females respond to certain songs. The male sings for two hours per day. This is an example of _____ isolation.

- A Habitat
- B Temporal
- C Behavioral

Answer

B & C

31 A large group of *Homo neanderthalensis* (homonids) separate from their population for an extended hunting trip to search out new game areas. They go through a canyon that allows them passage through a large mountain range. Before they can return a earthquake creates a massive landslide closing the passage and permanently separating them from their original population. This is _____ isolation.

A Habitat

D Mechanical

B Temporal

E Gametic

C Behavioral

31 A large group of *Homo neanderthalensis* (homonids) separate from their population for an extended hunting trip to search out new game areas. They go through a canyon that allows them passage through a large mountain range. Before they can return an earthquake creates a massive landslide that permanently separates the population. This is an example of _____.

- A Habitat
- B Temporal
- C Behavioral

Answer

A

Pre-Zygotic Barriers

The previous slides explained barriers that would be considered **pre-zygotic**. This is because they prevent a **zygote** from forming. A zygote is the term for the cell that is produced from the combining of sperm and egg. In other words, no fertilized egg can be produced because of the barrier.



Post-Zygotic Barriers

Post-Zygotic Barriers occur after fertilization. A zygote has been formed, however the offspring is infertile or unviable.

These barriers are the final stages of gene pool isolations. The genetic makeup of the isolated groups becomes so different that if an attempt at breeding is made, the genetics prevent a viable offspring from being produced.

Post-Zygotic Barriers

Reduced viability of zygote

The gene of the different parent species may interact and impair development of the hybrid offspring. Most of the hybrids do not complete development but those that do are very frail.

Post-Zygotic Barriers

Reduced fertility of offspring

Even if a strong offspring is produced, it may be sterile. If the parental chromosome number is different in the two parents, the offspring will not produce normal gametes and they cannot mate with either of the parental species and genes cannot flow freely between the species.

Horse



X



Donkey



A mule is a sterile animal it cannot produce offspring. So horse and donkey are separate species.

Post-Zygotic Barriers

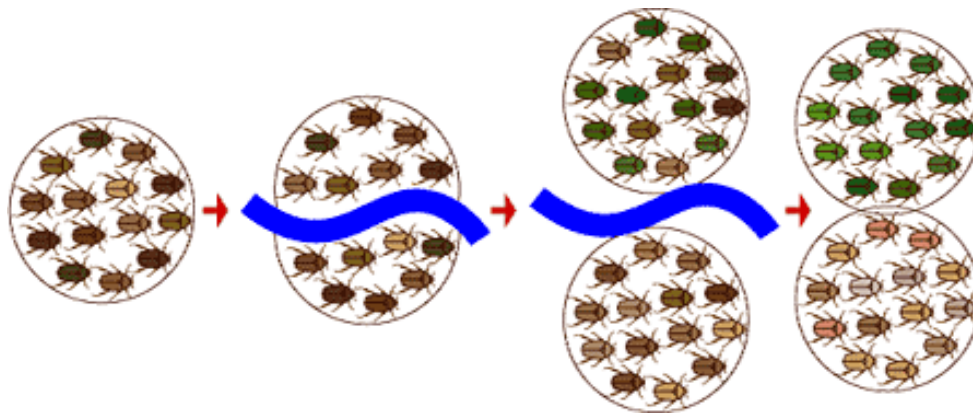
Offspring Breakdown

These offspring are fertile, but when they try to mate with the parental species or with one another, their offspring are feeble or sterile.

Allopatric Speciation

If a population becomes split into two separate populations due to some type of geographic barrier, this can lead to allopatric speciation. Since the two groups of the original population have become isolated from one another, gene flow between the two is interrupted.

Name some examples of how this can occur.



Allopatric Speciation

Once a geographic barrier has divided a population into two distinct populations and gene flow does not take place between the two, what has actually happened is that the original gene pool has been divided into two separate gene pools now.

These two gene pools can each change independently of each other due to all the different mechanisms that we have already spoken about and over time, each population becomes a new species.

Speciation due to geographic separation is referred to as **vicariance**.

Speciation due to a vicariance event

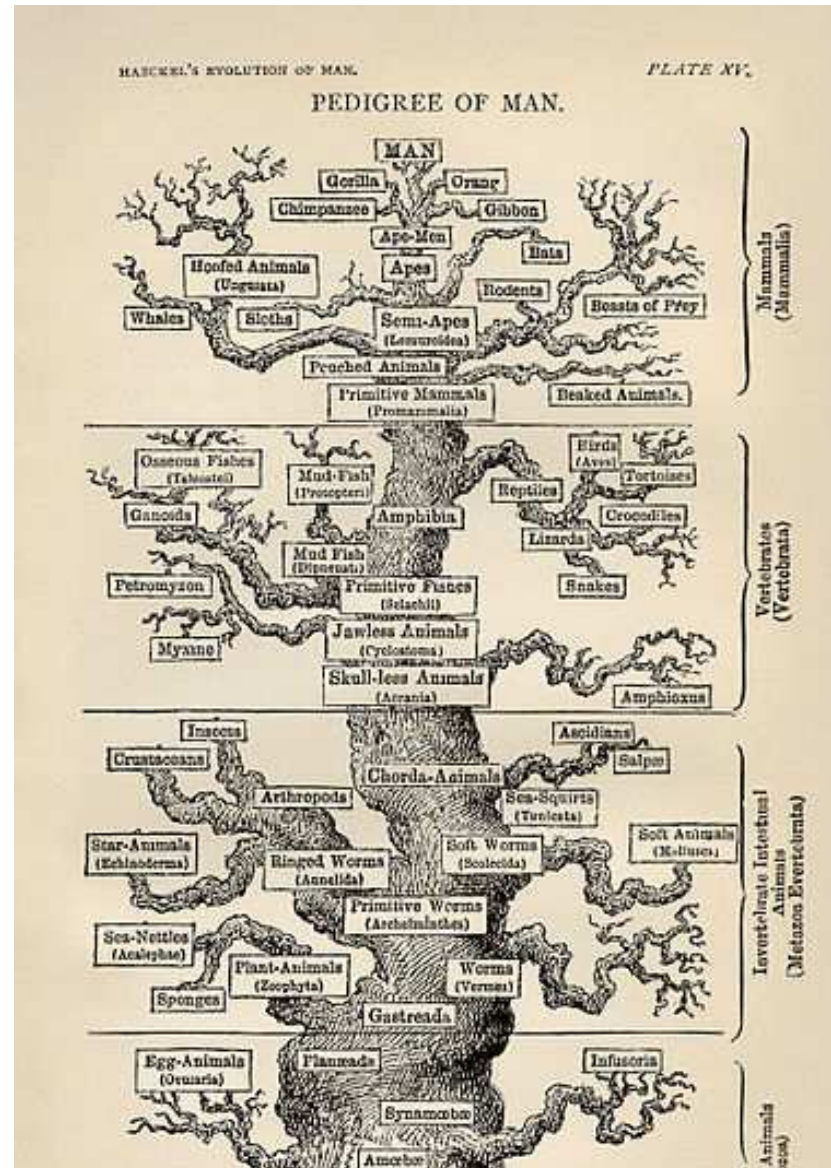
Sympatric Speciation

In sympatric speciation, there is no geographic barrier that separated a population; therefore, the members of a population remain in contact with one another.

If the members of the population remain in contact with one another, how do they evolve into different species? What mechanisms can play a role in this occurring?

Darwin's Tree

Life has progressed this way for billions of years. New species coming into existence, other species going extinct. Each contributing to the diversity of organisms on Earth that Darwin termed the **Tree of Life**.



Phylogenetics

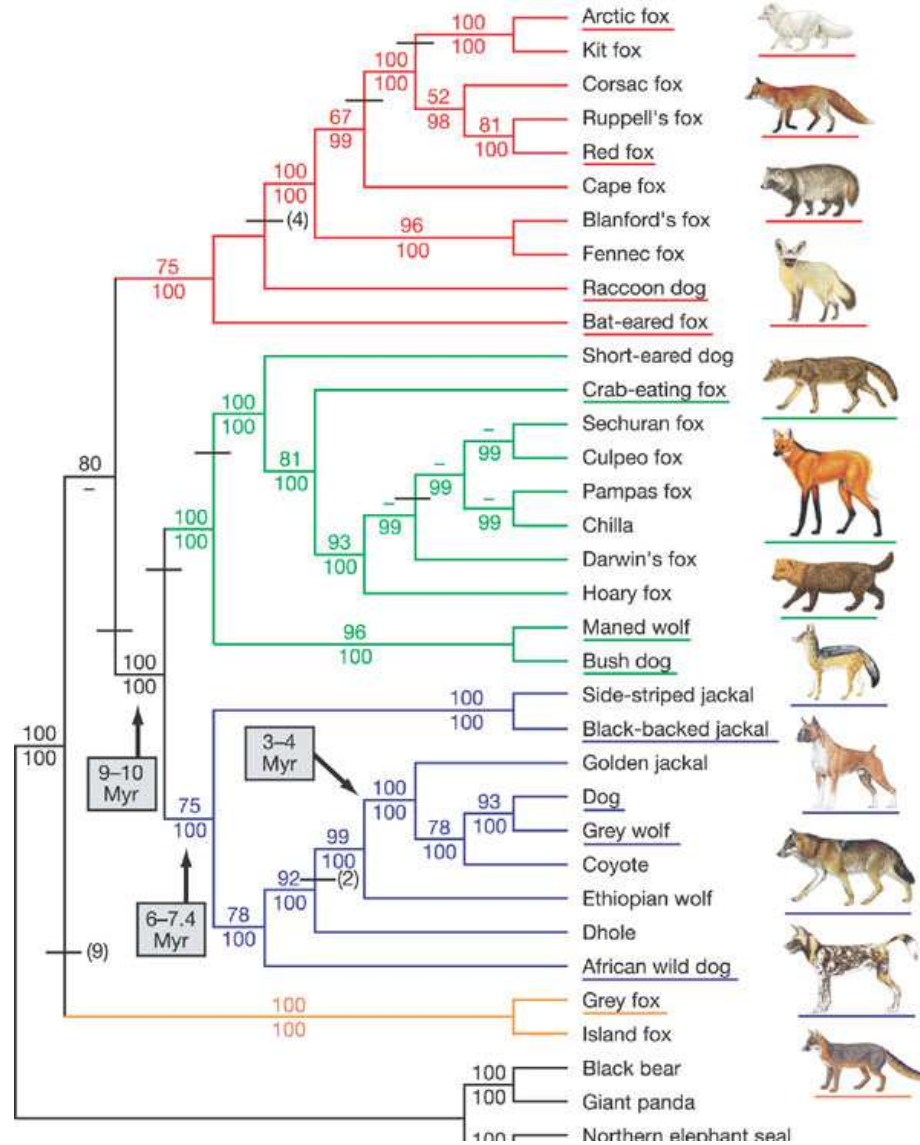
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Phylogeny is Classification

As phylogeny shows history it also shows the relatedness of certain species to other species.

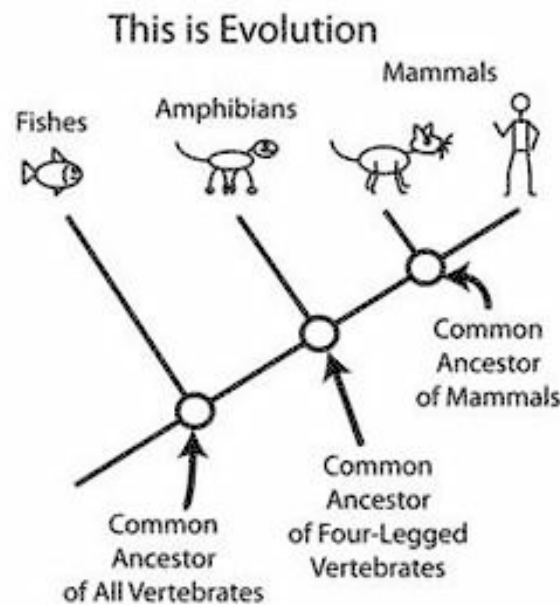
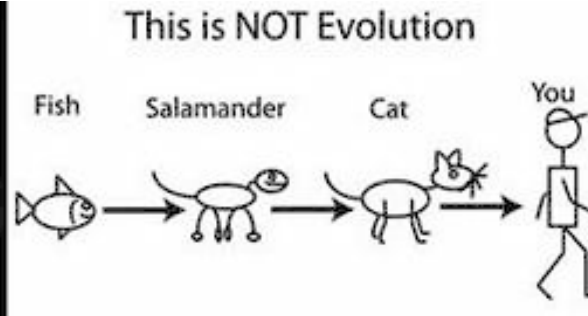
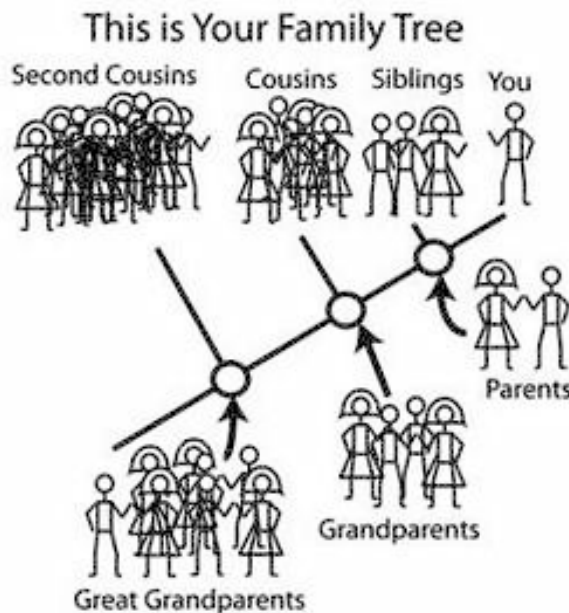
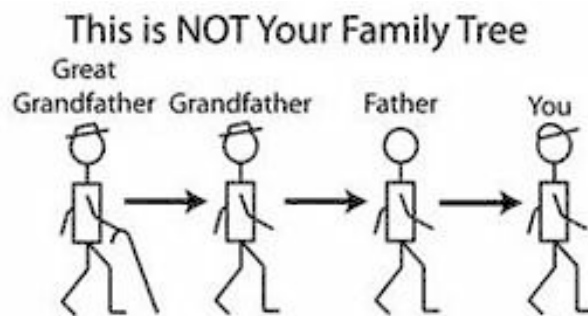
The closer two species are in a phylogeny the closer they are related.

This is a **clade** of the Family Canidae, which includes meat eating, dog-like mammals.

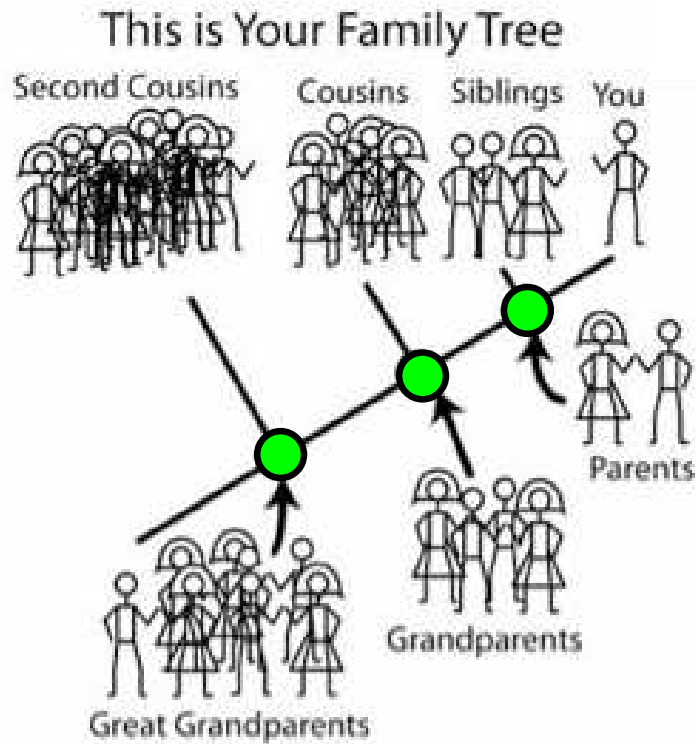


Phylogenetic Tree is a Family Tree

Phylogenetic trees can be viewed similar to family trees.



Phylogenetic Trees



Each **node** on the tree is representative of a common ancestor.

Your grandparents are a common ancestor between you and your cousins.

You share the most traits with your siblings, then your cousins, and then your second cousins.

How are we all connected?

[Click here for a video of "Discovering the Greatest Tree of Life"](#)

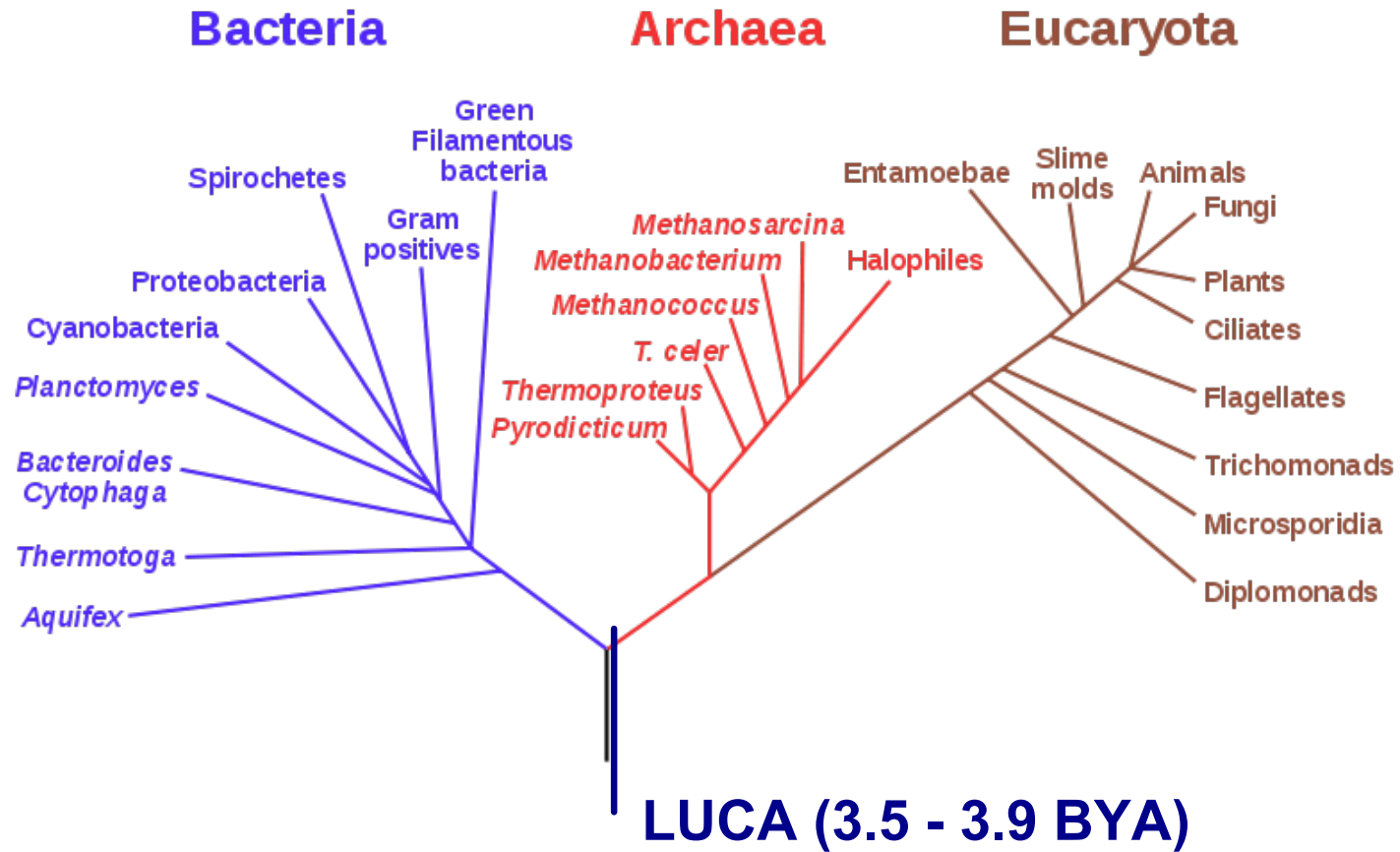
Phylogenetic Tree

Phylogenetic trees allow us to trace the evolutionary history of a species back farther and farther to common ancestors and related species.

They are produced through comparison of traits and the genetic code between modern day organisms and/or fossils.

Phylogenetic trees are constantly changing to fit in the new information that scientist learn.

Phylogenetic Tree of Life



Phylogenetic Tree of Life

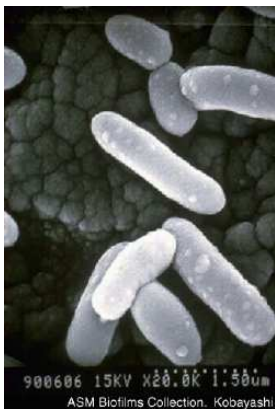
This tree represents the analytical approach to classifying the **diversity** of life. In doing so it also points out the organisms that show **unity** in particular groups.

The study of evolutionary relationships between species and the construction of phylogenetic trees is called **systematics**. It uses pieces of evidence provided by all the different disciplines we have talked about in Big Idea 1: homologies in structure and molecules, fossils in the record, biogeography, etc.

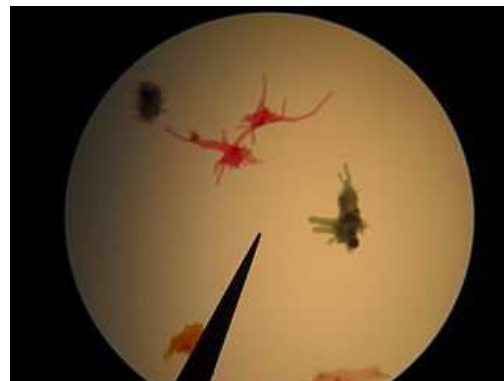
Phylogenetic Tree of Life

As a start to this tree... prokaryotic cells exist on the planet, they begin to mutate, become varied and replicate based on those variations (natural selection).

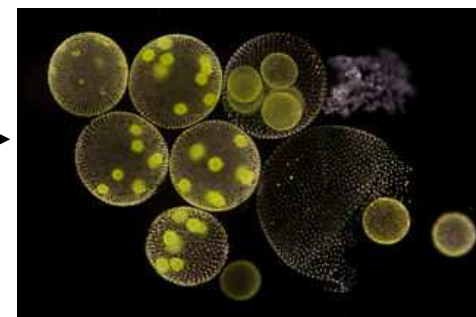
After billions of years of evolution more complex features arise. **Eukaryotes** which are defined by their large amount of genetic material contained in a nucleus, evolve even further to become multicellular organisms.



Prokaryotes



Single celled eukaryotes

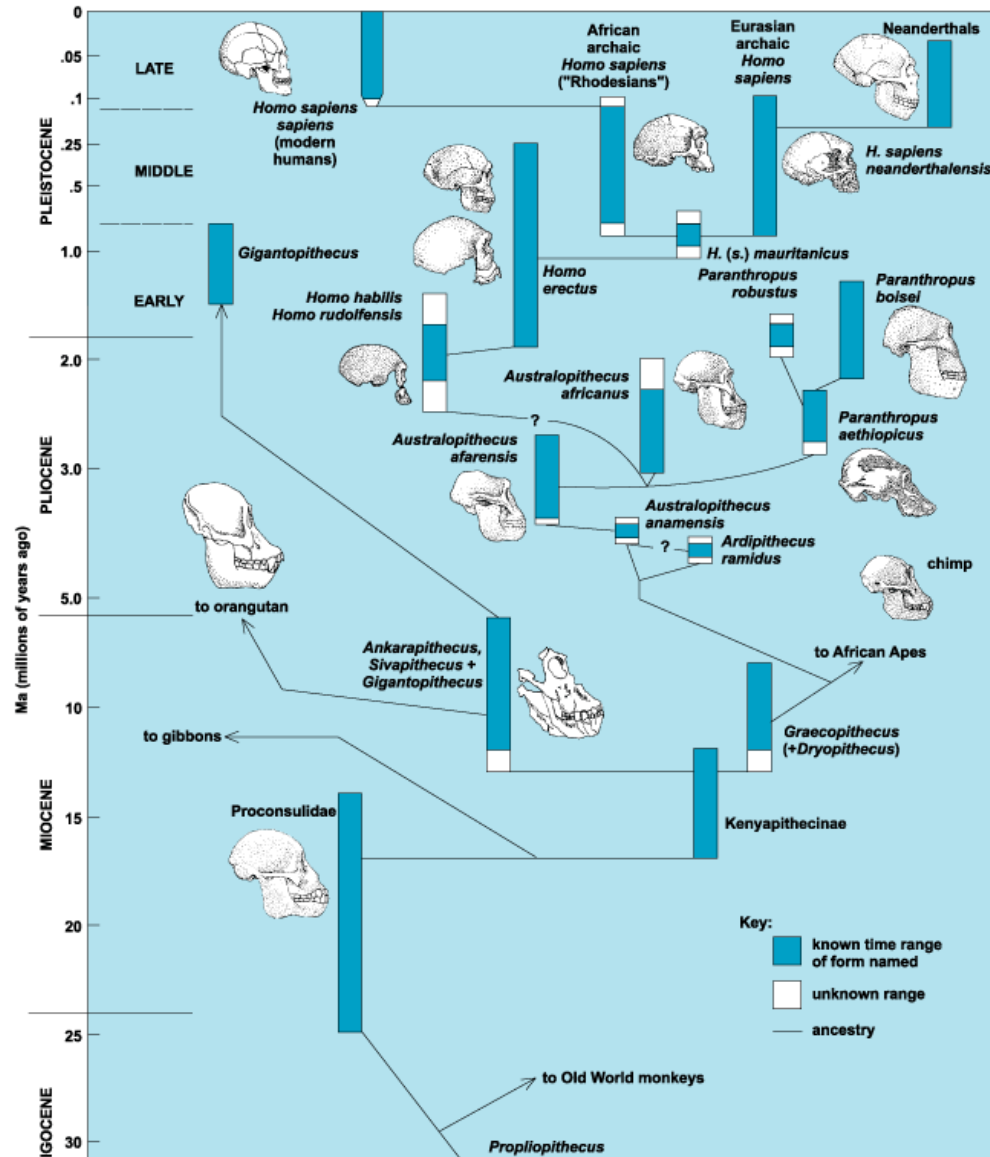


Multicelled Eukaryotes

Phylogeny is History

As a phylogenetic tree comes together it shows the heredity of species from the past and present.

This shows the relationship of hominid species as they evolved through time.



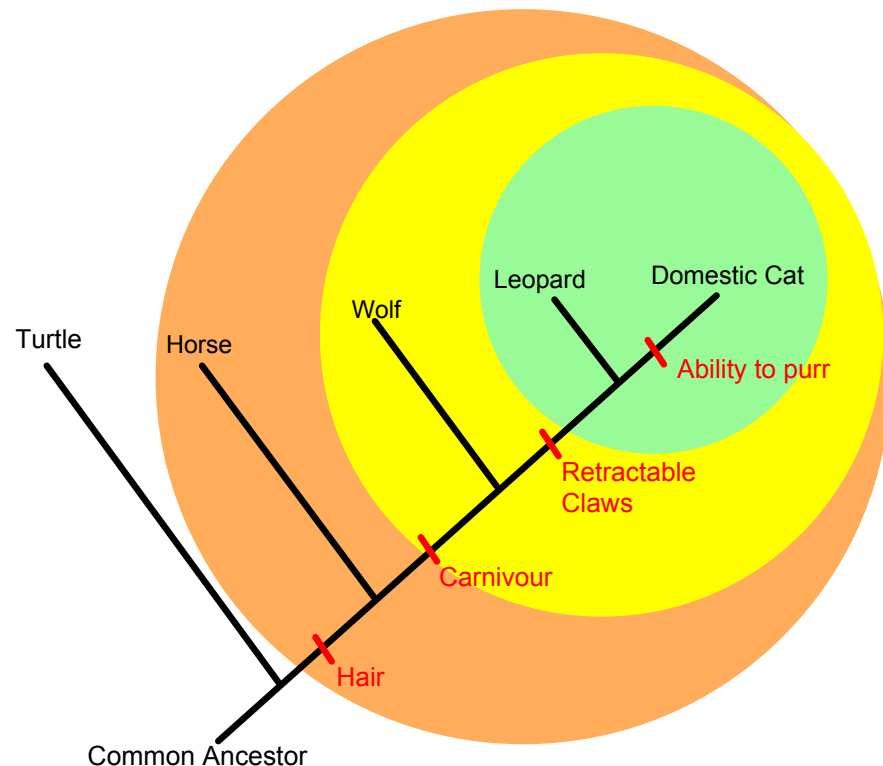
"Fossil humans." McGraw-Hill Encyclopedia of Science and Technology. The McGraw-Hill Companies, Inc., 2005. *Answers.com* 16 Aug. 2012. <http://www.answers.com/topic/fossil-humans>

Clade

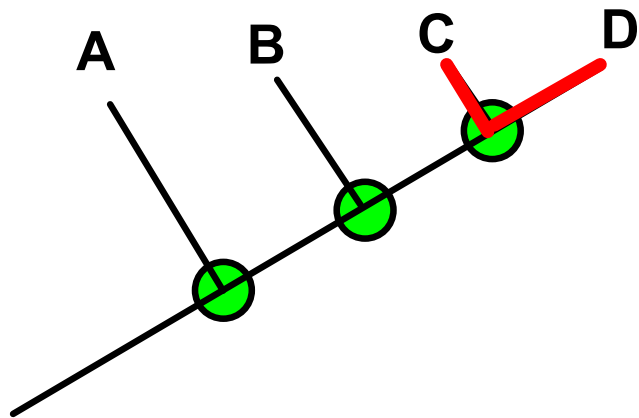
Sometimes the term clade is used to refer to smaller groups within a cladogram or phylogenetic tree.

A clade is representative of a group of organisms and all of its common descendants.

The colored highlighting is representative of 3 different clades within this 1 cladogram.



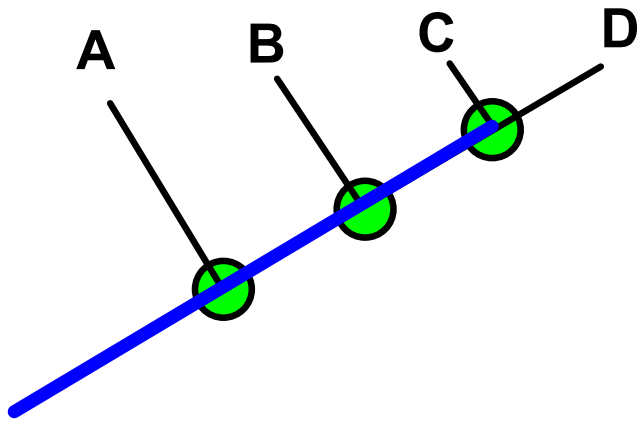
Phylogenetic Trees



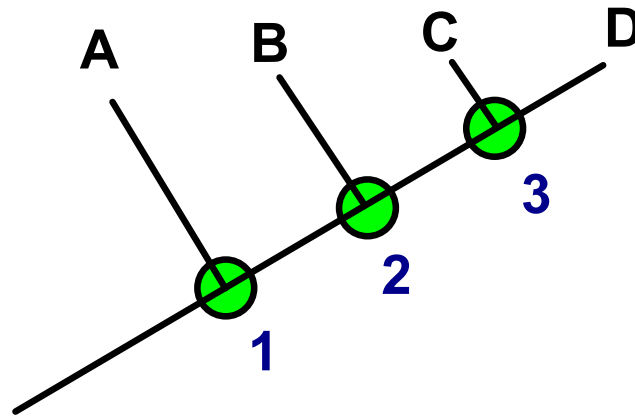
Each organism has a distinct history.

Phylogenetic Trees

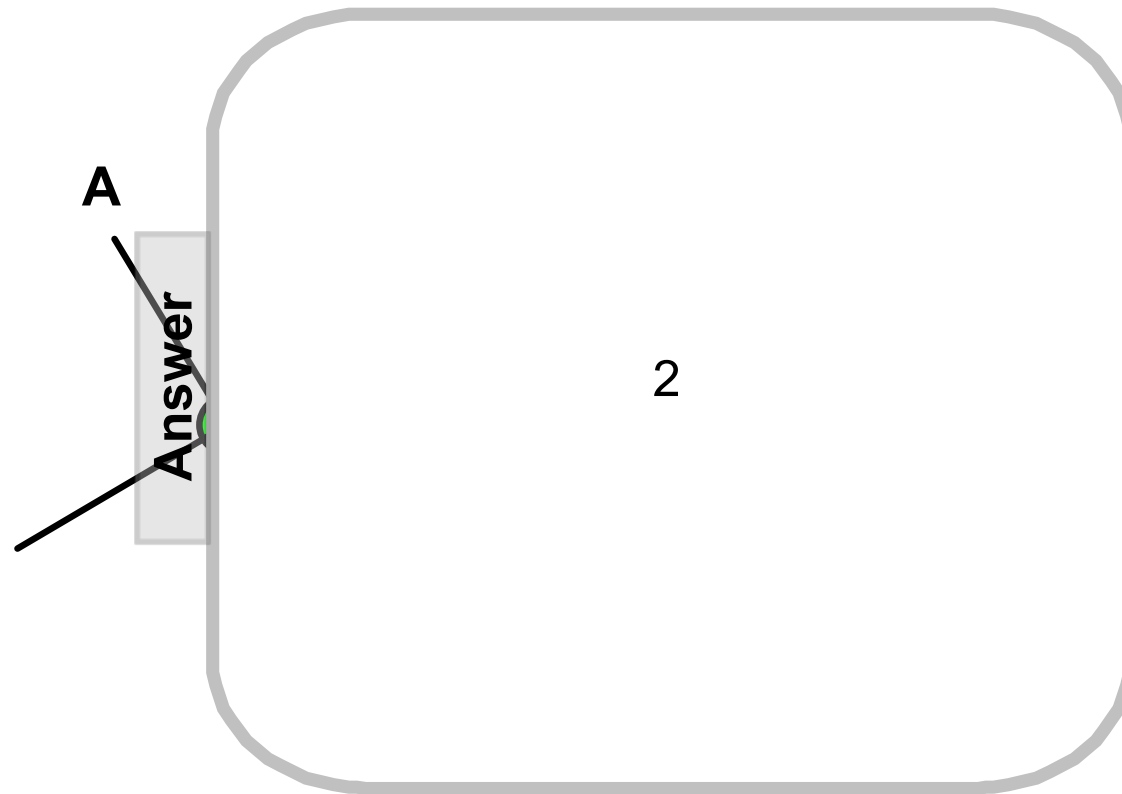
They also have shared histories.



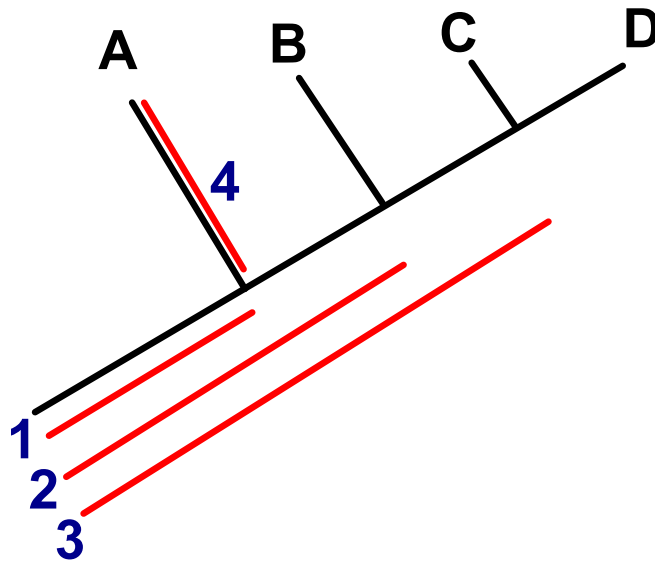
32 Which number node represents the most recent common ancestor between organism B and C?



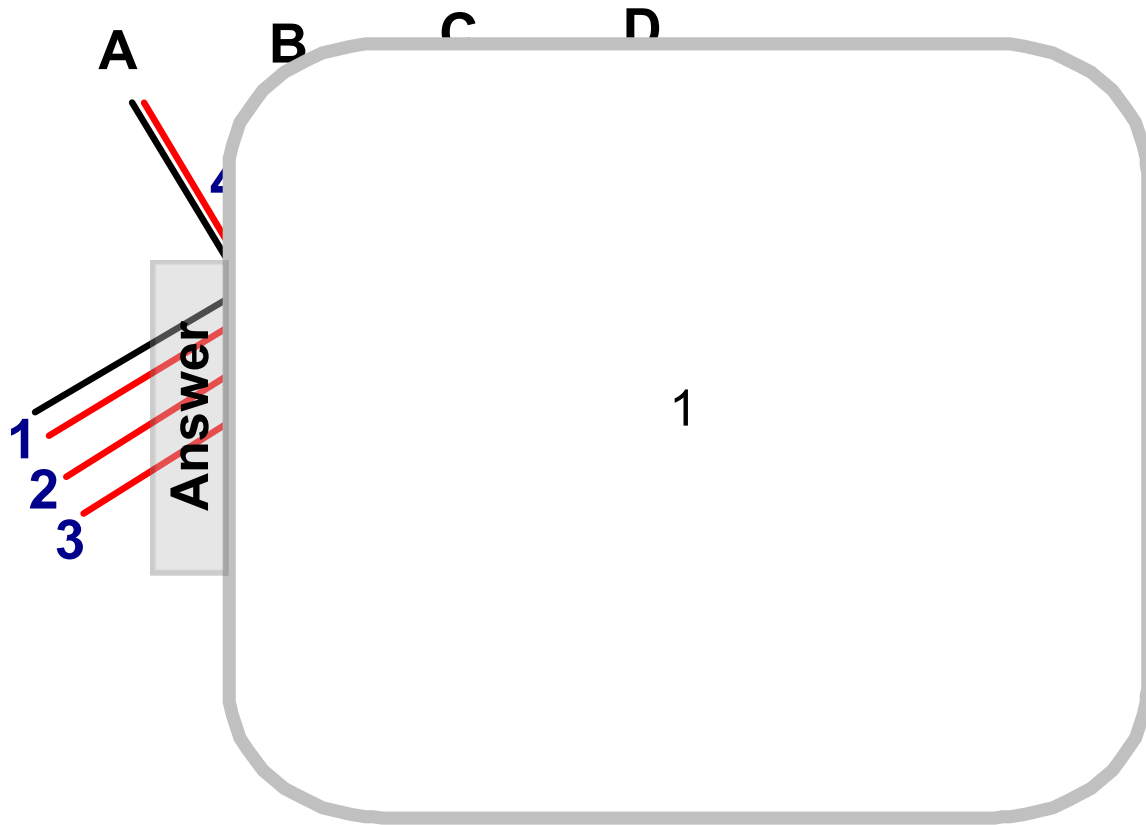
32 Which number node represents the most recent common ancestor between organism B and C?



33 Which number location represents the shared history between organism A, C, and D?



33 Which number location represents the shared history between organism A, C, and D?

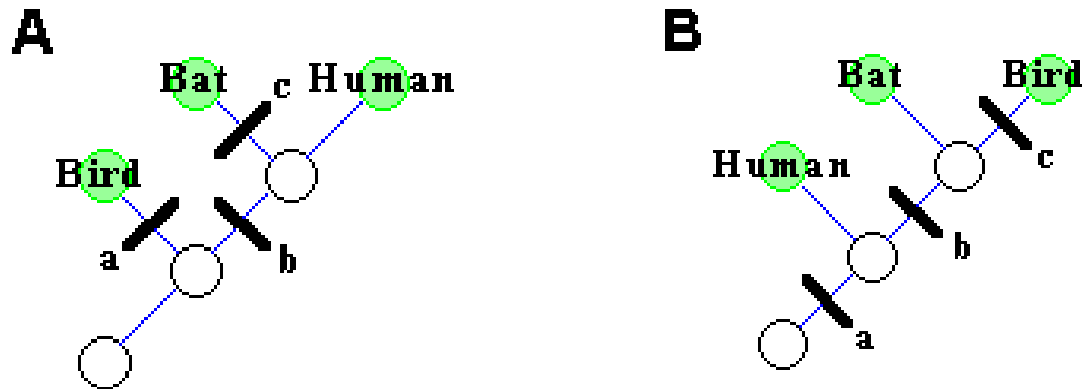


Maximum Parsimony and Likelihood

Phylogeny relies on factual data being interpreted to produce a reasonable conclusion. In some cases the data could be interpreted in different ways. When this happens the principal of **maximum parsimony**, which states the simplest explanation that is consistent with the facts is more likely to be true.

This is then combined with the principal of **maximum likelihood** which states a tree should be made that reflects the most likely sequence of evolutionary events. This can be determined using what we already know about DNA and how it changes over time.

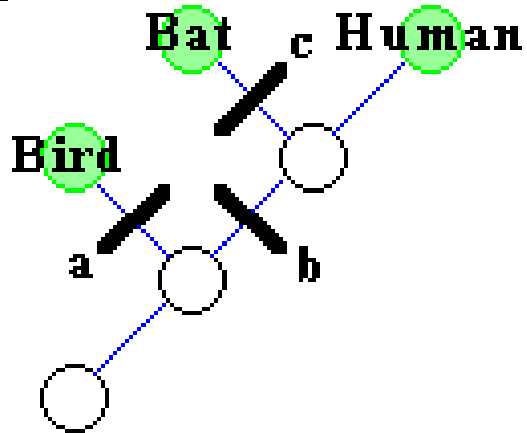
Maximum Parsimony and Likelyhood



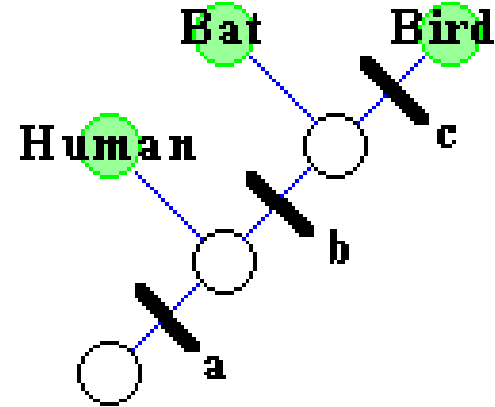
	Cladogram A	Cladogram B
Evolutionary event a	wing structures feathers	hair mammary glands
Evolutionary event b	hair mammary glands	wing structures
Evolutionary event c	wing structures	loss of hair mammary glands feathers

Maximum Parsimony and Likelihood

A



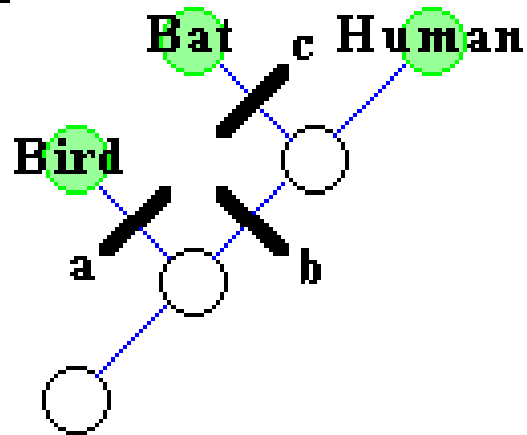
B



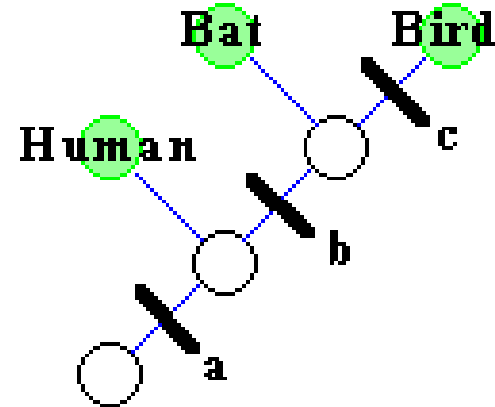
Cladogram A requires five evolutionary steps while cladogram B requires six. Because cladogram A requires fewer evolutionary steps it is the simplest, and parsimony dictates that this is the preferred cladogram.

Maximum Parsimony and Likelihood

A



B



The combination of the loss of hair, mammary glands and the evolution of feathers in one event would require that the laws of logic and DNA behavior must be ignored in order to allow cladogram B to be true.

Cladogram A does adhere to scientific logic, making it the parsimonious and likely cladogram.

Understanding Cladistics: What Did T.rex Taste Like?

The following question slides are adapted from the <http://www.ucmp.berkeley.edu/education/explorations/tours/Trex/navigation.html>.

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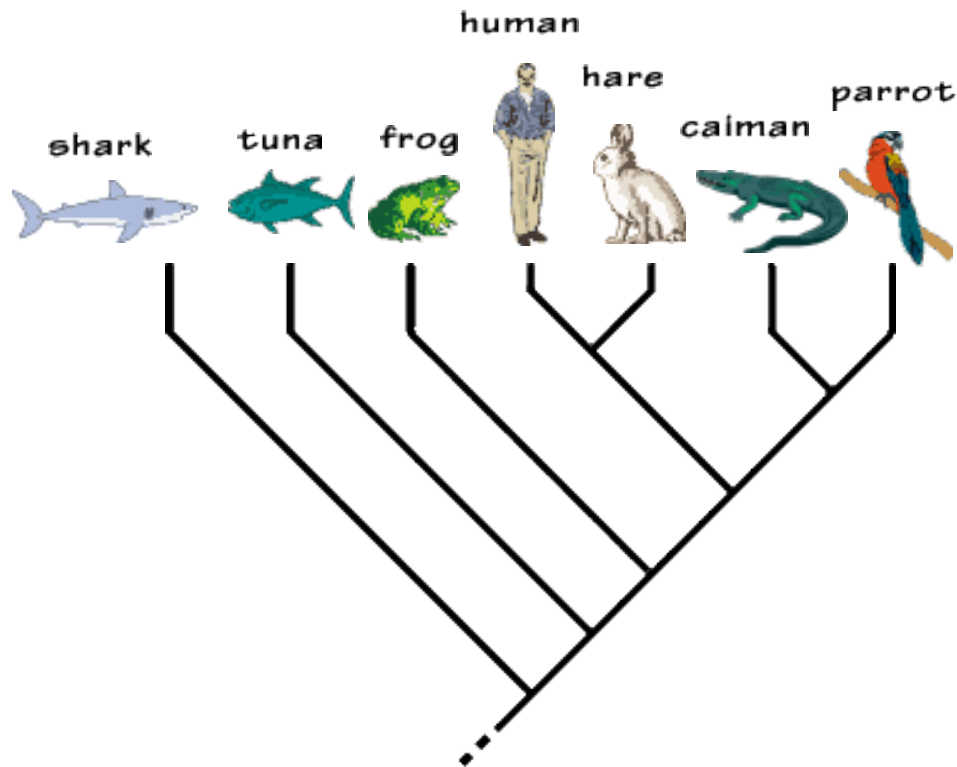
Teacher Note: You will proceed through folder 3 of the activity as a class. Anytime there is a question on the website, you should return to the notebook and allow students to use Smart Response to give their answers. Then put the class answers into the website activity to see if they are correct.

[Click here for the activity: What did T.rex taste like?](#)

34 Which are more closely related to caimans?

A Hares

B Parrots

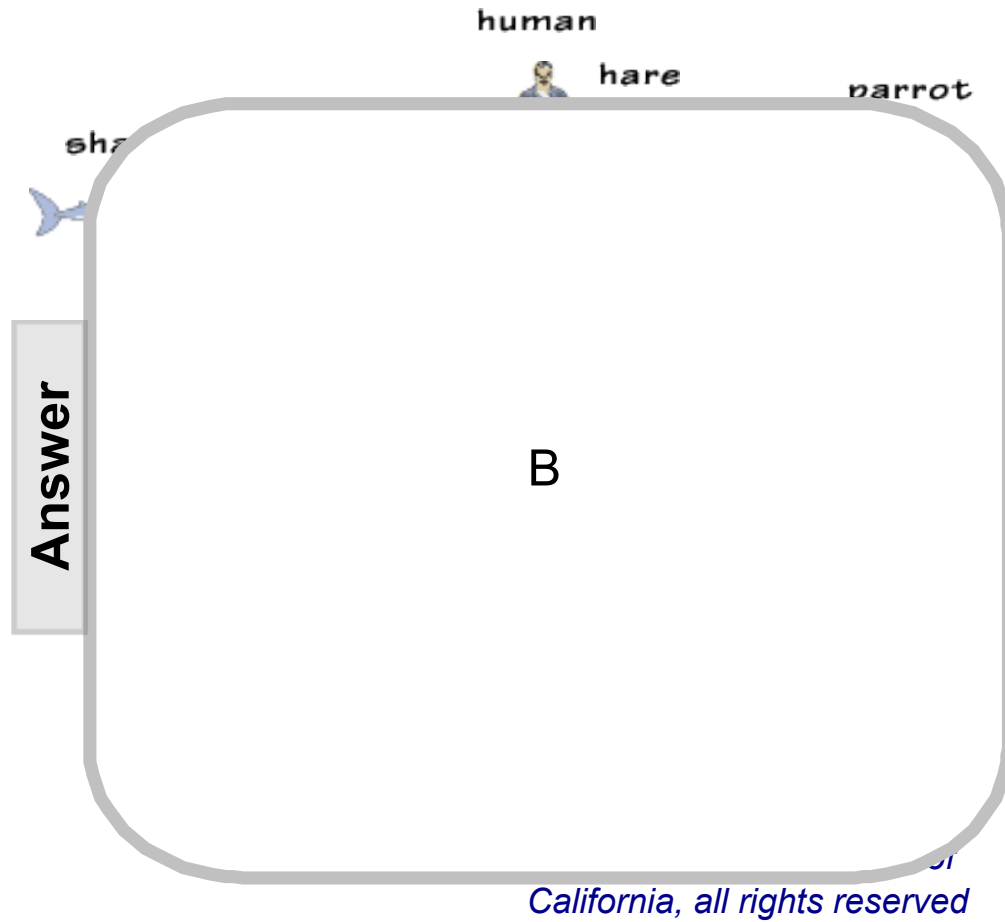


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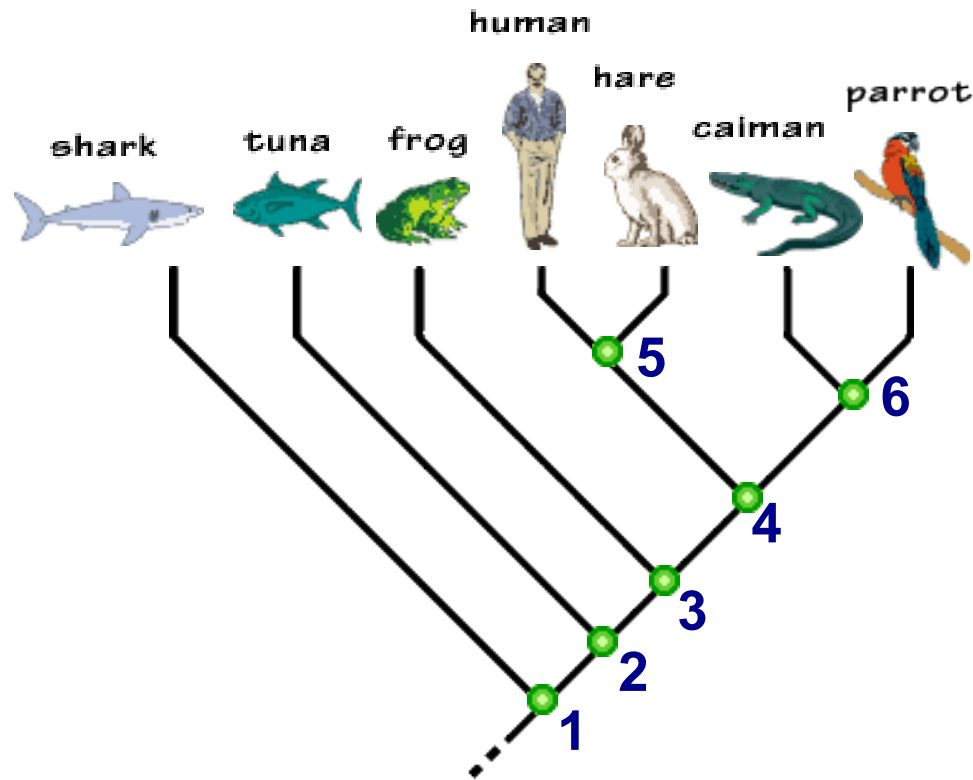
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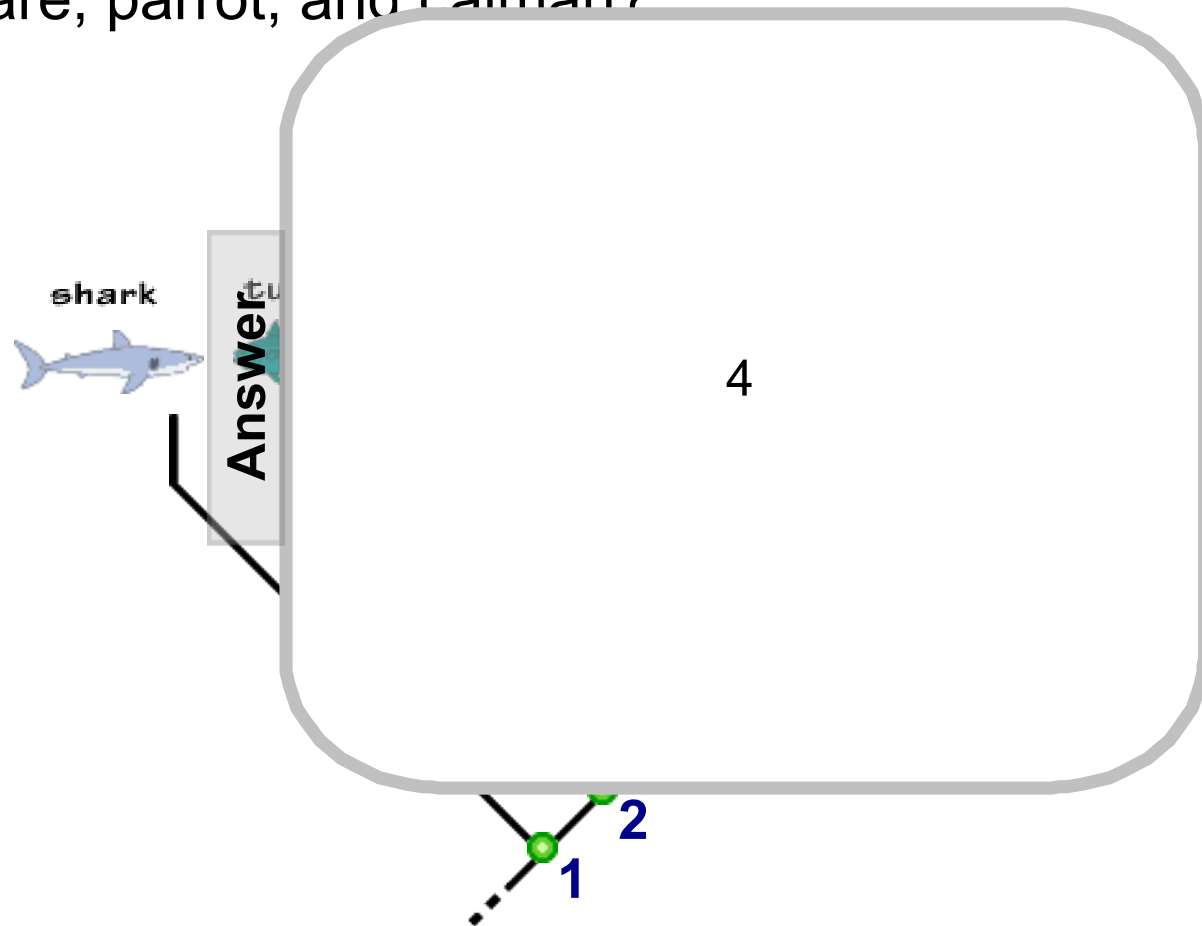


35 Which green dot best represents the common ancestor to the hare, parrot, and caiman?



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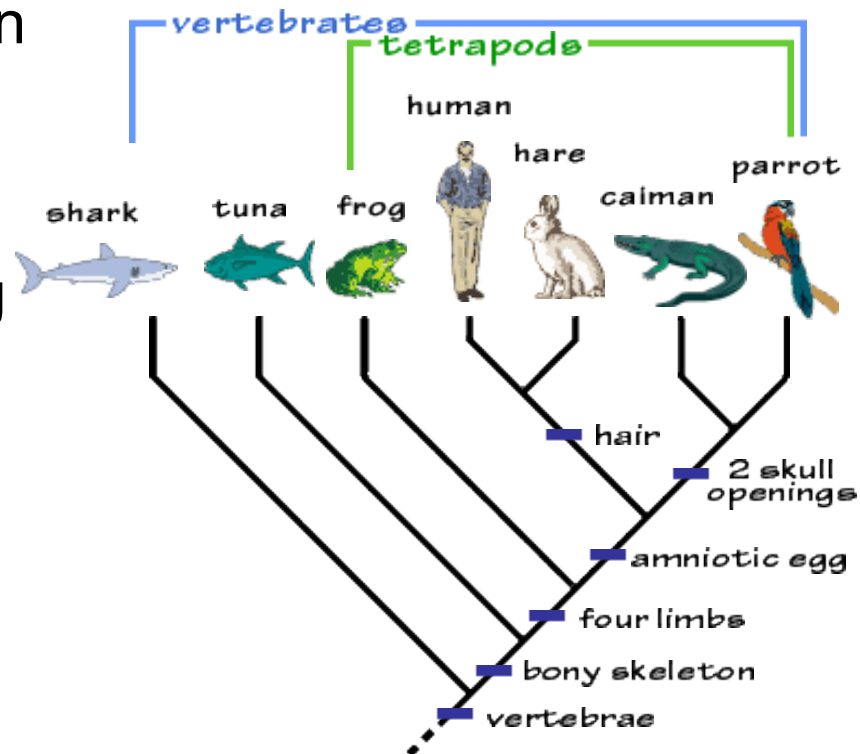
35 Which green dot best represents the common ancestor to the hare, parrot, and caiman?



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36 Which feature do humans, hares, caimans, and parrots share that the other three lineages did not inherit?

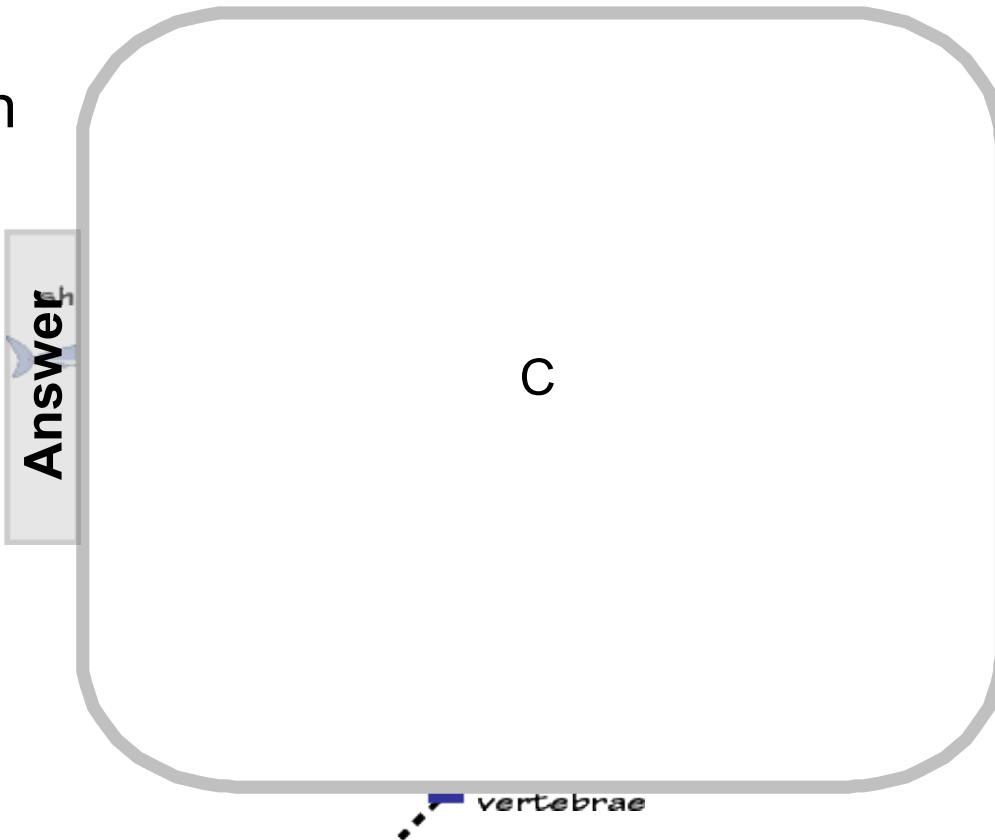
- A Bony skeleton
- B Hair
- C Amniotic egg



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36 Which feature do humans, hares, caimans, and parrots share that the other three lineages did not inherit?

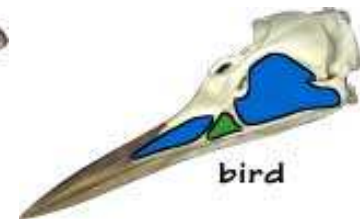
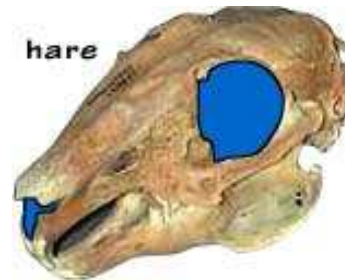
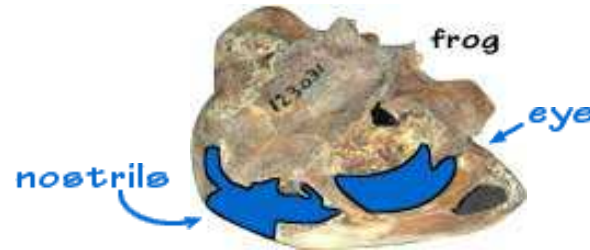
- A Bony skeleton
- B Hair
- C Amniotic egg



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37 Which of the tetrapods have a skull opening in front of the eye?

- A Hare and crocodile
- B Bird and crocodile
- C Frog and hare



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37 Which of the tetrapods have a skull opening in front of the eye?

- A Hare and crocodile
- B Bird and crocodile
- C Frog and hare

Answer

B



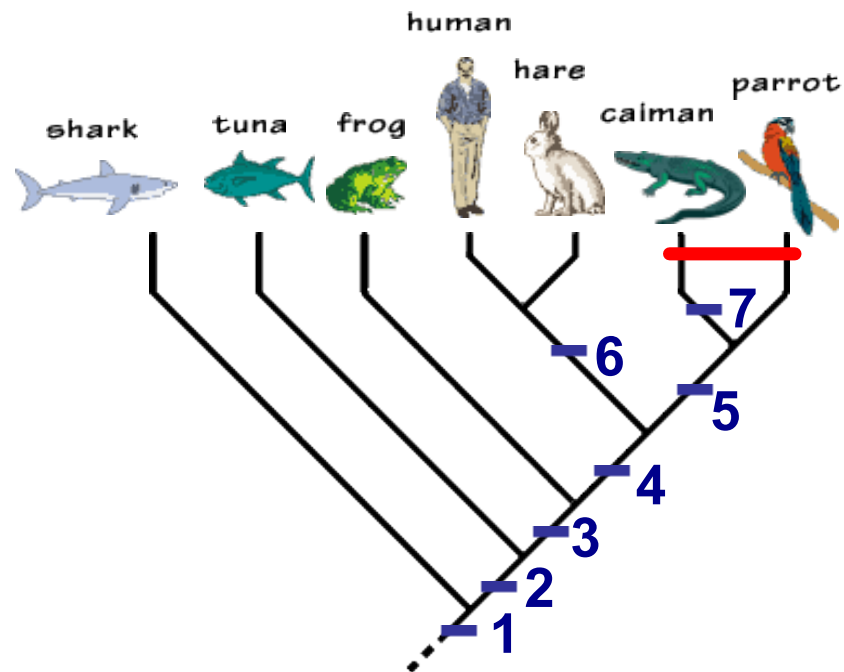
fossil crocodile



bird

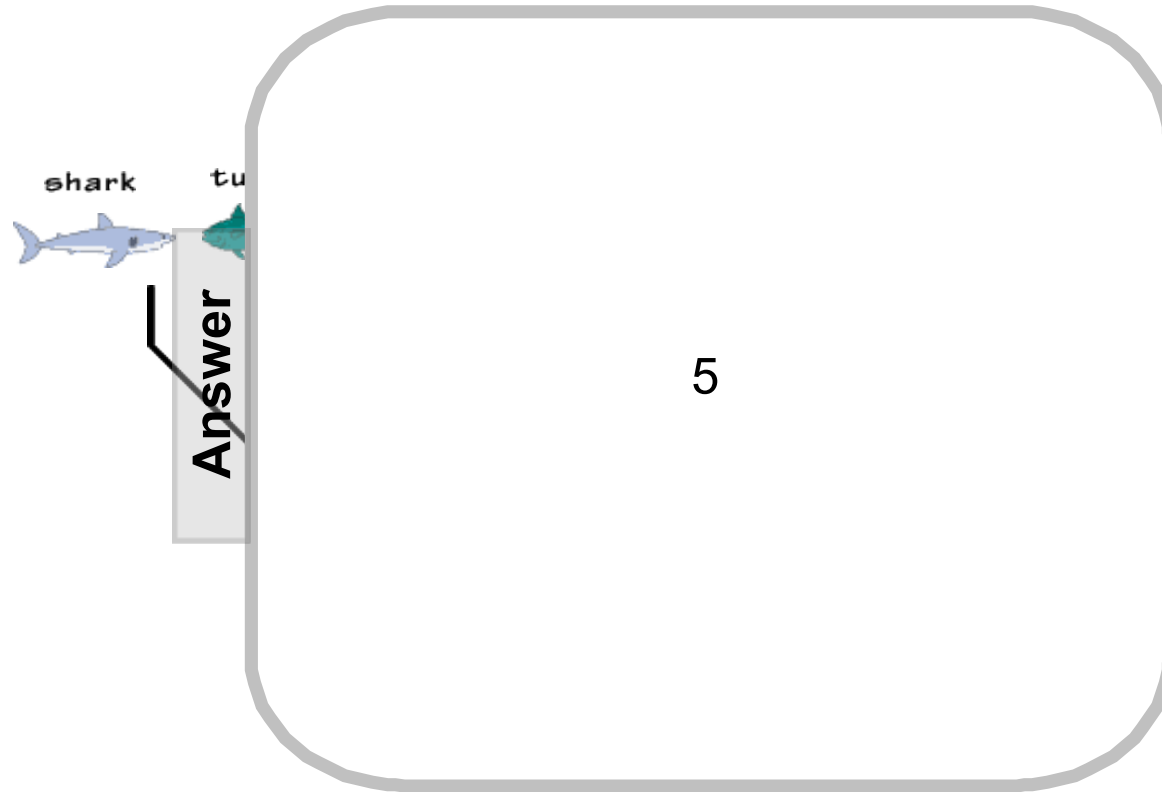
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38 Which number blue bar best represents when the skull opening in front of the eye evolved?



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38 Which number blue bar best represents when the skull opening in front of the eye evolved?



What Did T.rex Taste Like?

Teacher Note: Students will now complete the folders 4 & 5 of the activity working with a partner. Each pair of students will need a computer and the appropriate handouts.

[Click here for "What did T.rex taste like?" folder 4.](#)

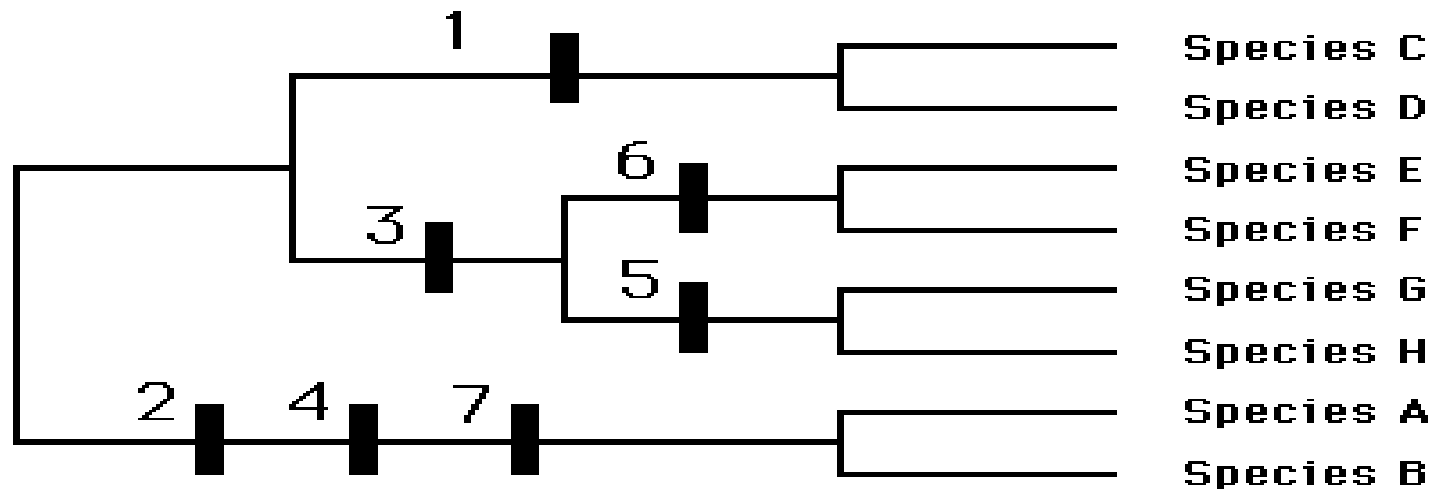
Ideas to Remember When Looking at Phylogenetic Trees

- **The trees are works in progress** - as new evidence arises updates are made.
 - The 3 Domain system we use today was introduced in 1990. It replaced a system known as the 5 Kingdom system that did not include Domains.
- **The diversity of organisms arose through evolution-** phylogeny is the history of life and its changes over time
- **All organisms exhibit characteristics similar to their ancestors-** All of the successful traits we see in life today have been fine tuned from traits that arose in the past

DNA Sequencing

Phylogeny looks at the differences of specific DNA sequences in living organisms and their extrapolated changes over time to confirm the relationship of species at a genetic level.

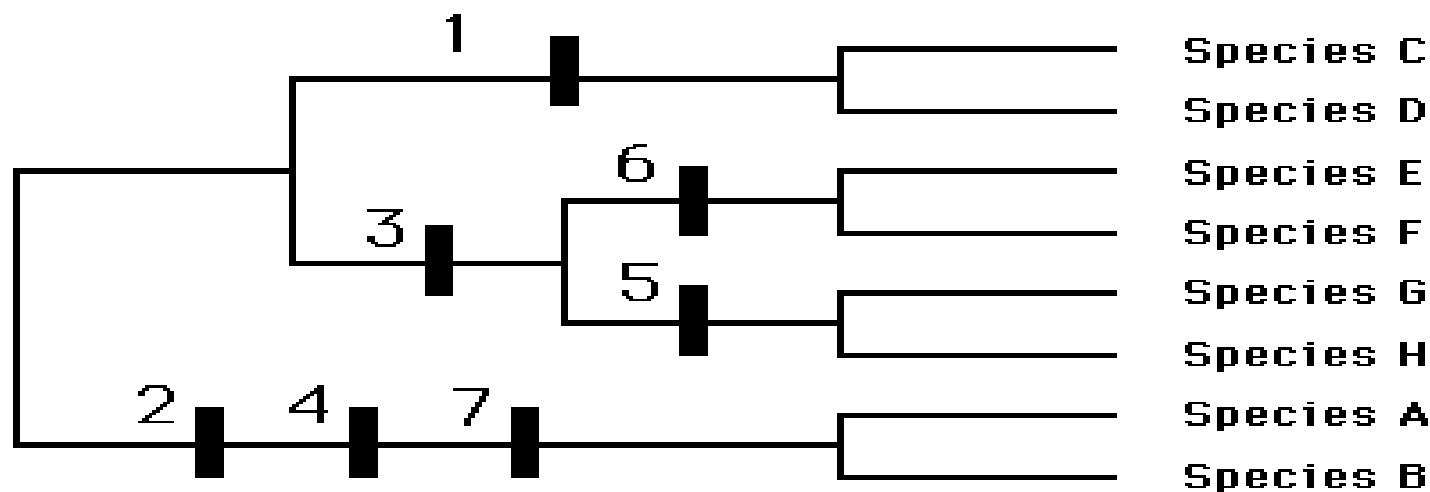
	1	2	3	4	5	6	7
Species A	ACCAGCCTGTGCATCGATG A CGACTAAGTGATACCATAAA A GACT						
Species B	ACCAGCCTGTGCATCGATG A CGACTAAGTGATACCATAAA A GACT						
Species C	AC G AGCATGTGCATCGATG C CGACTAAGTGATACCATAATGACT						
Species D	AC G AGCATGTGCATCGATG C CGACTAAGTGATACCATAATGACT						
Species E	ACCAGCATGTGT T ATCGATG C CGACTAAGTGATACC A AAATGACT						
Species F	ACCAGCATGTGT T ATCGATG C CGACTAAGTGATACC A AAATGACT						
Species G	ACCAGCATGTGT T ATCGATG C CGACTAAGTG C TACCATAATGACT						
Species H	ACCAGCATGTGT T ATCGATG C CGACTAAGTG C TACCATAATGACT						



DNA Sequencing

The numbers below represent mutations that have happened in a group of species since their divergence from a common ancestor.

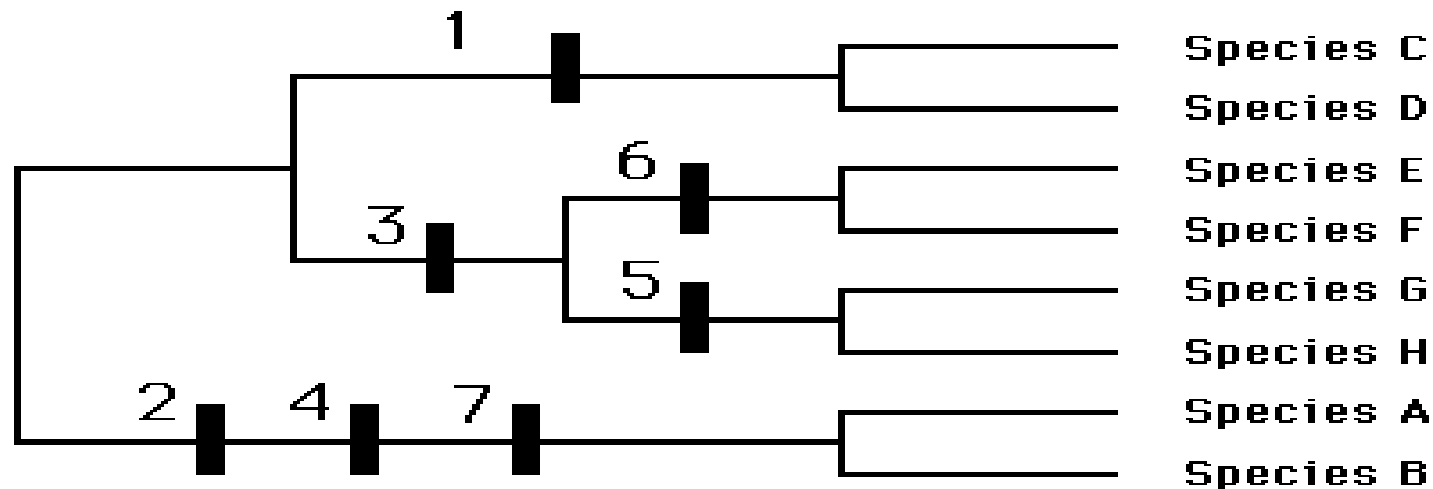
	1	2	3	4	5	6	7
Species A	ACCAGC C TGTGCATCGATG A CGACTAAGTGATACCATA A AGACT						
Species B	ACCAGC C TGTGCATCGATG A CGACTAAGTGATACCATA A AGACT						
Species C	AC G AGCATGTGCATCGATG C CGACTAAGTGATACCATA A ATGACT						
Species D	AC G AGCATGTGCATCGATG C CGACTAAGTGATACCATA A ATGACT						
Species E	ACCAGCATGTG T ATCGATG C CGACTAAGTGATACC A AAATGACT						
Species F	ACCAGCATGTG T ATCGATG C CGACTAAGTGATACC A AAATGACT						
Species G	ACCAGCATGTG T ATCGATG C CGACTAAGTG C TACCATAATGACT						
Species H	ACCAGCATGTG T ATCGATG C CGACTAAGTG C TACCATAATGACT						



DNA Sequencing

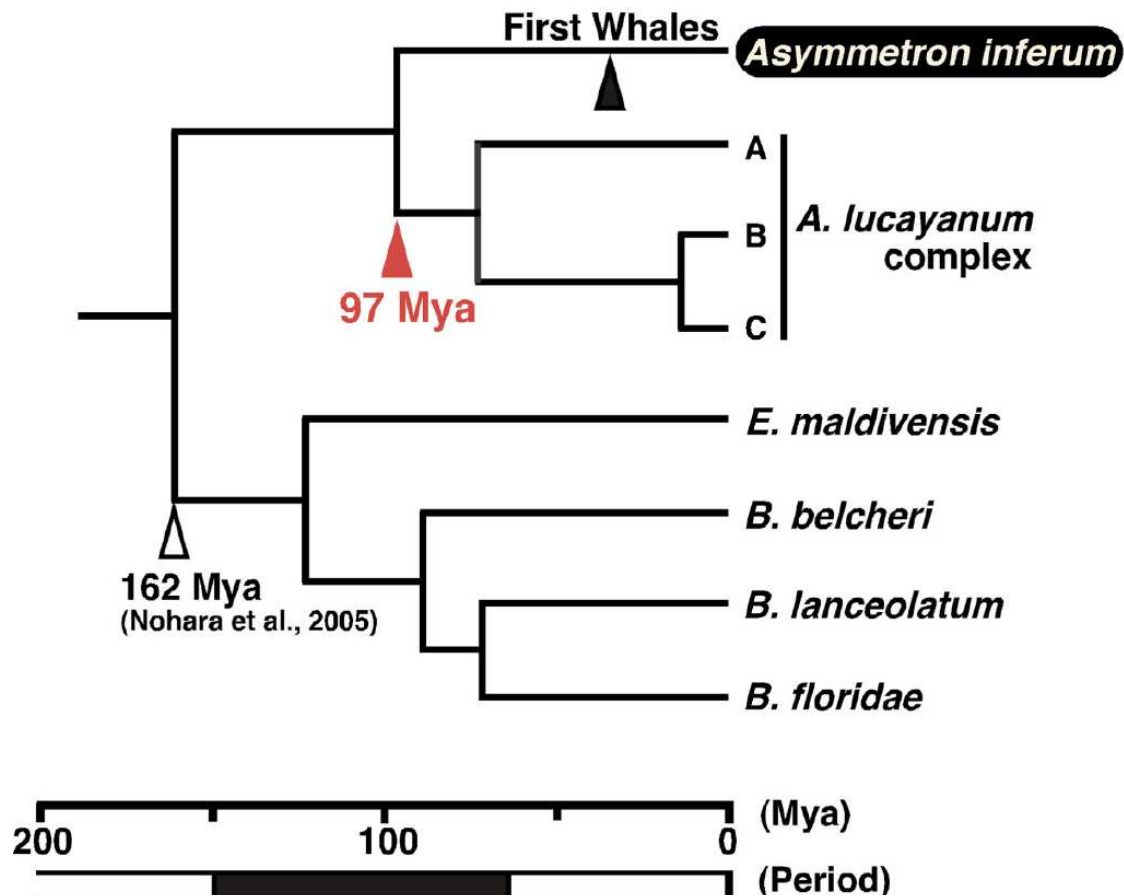
The mutations present in each of the species are compared and ordered to create a phylogenetic tree that represents the evolution of the group.

	1	2	3	4	5	6	7
Species A	ACCAGCCTGTGCATCGATG Δ CGACTAAGTGATACCATA Δ AGACT						
Species B	ACCAGCCTGTGCATCGATG Δ CGACTAAGTGATACCATA Δ AGACT						
Species C	AC G AGCATGTGCATCGATG C CGACTAAGTGATACCATAATGACT						
Species D	AC G AGCATGTGCATCGATG C CGACTAAGTGATACCATAATGACT						
Species E	ACCAGCATGTGT T ATCGATG C CGACTAAGTGATACC AAA ATGACT						
Species F	ACCAGCATGTGT T ATCGATG C CGACTAAGTGATACC AAA ATGACT						
Species G	ACCAGCATGTGT T ATCGATG C CGACTAAGTG C TACCATAATGACT						
Species H	ACCAGCATGTGT T ATCGATG C CGACTAAGTG C TACCATAATGACT						



Ultrametric Trees

Combining time scale with changes in derived traits creates an ultrametric tree. The lines in this type of tree represent an amount of time from one divergence to another. (Mya = Millions of years ago)



Why Study the Tree of Life?

[Click here for a video explanation](#)

