Evolution

Vocabulary

- adaptation
- adaptive radiation
- allelic frequency
- apoptosis
- behavioral isolation
- biogeography
- bottleneck effect
- coevolution
- comparative anatomy
- comparative embryology
- convergent evolution
- directional selection
- disruptive selection
- divergent evolution
- epigenetics
- evolution
- founder effect
- gene conservation
- gene pool
- genetic drift
- geographical isolation
- homologous structure
- macroevolution
- mechanical isolation
- microevolution
- molecular homology
- natural selection
- population
- population genetics
- punctuated equilibrium
- speciation
- species
- stabilizing selection
- temporal isolation
- vestigial structure

Evolution Unit Topics

- Adaptations
- Theories of Evolution
- Natural Selection & Speciation
- Population Genetics
- Genetic Drift & Patterns of Macroevolution
ALL LIVING THINGS - from a tiny amoeba, to a massive redwood tree - share common characteristics.

- Order
- Adaptations
- Response to the environment
- Regulation
- Energy processing
- Growth and Development
- Reproduction

The most reasonable explanation that ALL LIFE uses the exact same genetic code is that the code was in place before life branched out. The common features of life on Earth are so profound that all life must have evolved from a single ancestor.

Evolution is the process by which modern organisms have descended from ancient organisms over time. Time is the critical element in seeing how life could have developed from simple chemicals to the complex world we see around us today.

Earth is approximately 4.6 billion years old. Our first records from human history are about 10,000 years old. The process of developing life started about a million times further back in time than that.
Why Evolve?

The Earth is a dynamic, continuously changing environment.

Groups of living things must adapt, adjusting to these changes in order to survive and pass on their genes to their offspring.

Adaptations

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.

Competition

Organisms that share an environment compete with each other to obtain necessities like water, food, and living space.

An organism with an adaptation specific to its environment that helps it obtain resources has a better chance of survival and reproduction than the other organisms in its environment.

Evolution Leads to Diversity

A species is a group of individuals that can actually or potentially interbreed, producing viable offspring. It is estimated that there are 8.7 million species of organisms currently living on Earth.

In some cases, two closely related yet different species can interbreed, producing sterile offspring.

1. Apes and chimpanzees are different species because...
   - A they live in different environments
   - B they have different physical features
   - C they cannot produce offspring together
   - D they eat different foods

2. Which of the following is not a characteristic of all life?
   - A adaptations
   - B energy processing
   - C movement
   - D reproduction
Theories of Evolution

Jean-Baptiste Lamarck

Recall Lamarck’s Inheritance of Acquired Characteristics theory. This idea stated that traits present in parents are modified, through use, and passed on to their offspring in the modified form.

Inherited vs. Acquired Characteristics

During Lamarck’s time, there was no notion of DNA or genes; no knowledge of chromosomes or how inheritance happened.

Today we know Lamarck was wrong because characteristics acquired over a lifetime do not usually change the DNA and, therefore, are not passed on to the offspring.

An organism can only exhibit traits coded for by its inherited DNA.

Epigenetics

While the environment cannot change the inheritance of traits, biologists and geneticists are now discovering that non-genetic factors from an organism’s environment can influence the way genes are expressed.

Epigentics is the study of how environmental factors - including chemical signals in the cell triggered by stress and nutrition - regulate gene expression.

3 Lamarck suggested that if an organism does not use the structures they are born with, they will

- A develop different structures they can use
- B lose those structures in the next generation
- C acquire different structures from other organisms
- D stop evolving

4 Lamarck argued for which of the following ideas?

- A Life evolves towards perfection and organization and this can be traced
- B Life has consisted of creations and catastrophies
- C Species evolve through development of characteristics individuals use throughout their lives
- D Environments spontaneously produce species fitted to it
5 What is epigenetics the study of?
- A the environment's impact on gene expression
- B the inheritance of certain traits
- C the evolution of eukaryotes
- D the adaptive value of traits

Charles Darwin
The scientist who contributed most to our current understanding of evolution was Charles Darwin.

Upon graduation from university, Charles Darwin took a position as a naturalist on a ship called the H.M.S. Beagle. The main purpose of the Beagle was to map out the coastline of South America.

Darwin was on board the Beagle from 1831 to 1836 to record all natural and geological characteristics of the landscape he saw.

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

Darwin Arrives in South America
Roughly one third of the way into the journey, Darwin spent most of his time inland collecting thousands of fossils, specimens, and living plants and animals from South America.

He sent all of his collection (thousands of specimens) back to England by ship while still on the journey.

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

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.

One Example: Marine & Terrestrial Iguanas
While in the Galapagos, Charles became fascinated with marine iguanas. He noted the differences in adaptations of both species:

Terrestrial iguana
Mainland S.America

Marine iguana
Galapagos
Marine & Terrestrial Iguanas

<table>
<thead>
<tr>
<th>Terrestrial iguana</th>
<th>Marine iguana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainland S.America</td>
<td>Galapagos</td>
</tr>
<tr>
<td>- round tail</td>
<td>- flat tail</td>
</tr>
<tr>
<td>- on land</td>
<td>- dove to the bottom of the ocean</td>
</tr>
<tr>
<td>- fear of man</td>
<td>- to eat algae on the rocks</td>
</tr>
<tr>
<td>- no swimming</td>
<td>- no fear of man</td>
</tr>
<tr>
<td>- smaller skin flaps on back</td>
<td>- large skin flaps on back</td>
</tr>
<tr>
<td></td>
<td>- longer and sharper claws</td>
</tr>
</tbody>
</table>

Physical Adaptations of the Marine Iguana

- Flat tail allows it to swim to get its food
- Large skin tags on its back provide more surface area to gain heat from the sun more quickly
- Blood vessels constrict when it is in the water to minimize heat loss
- Longer and sharper claws allow it to cling to the lava rocks when in the water so they don’t get carried out to sea
- Longer and sharper teeth allow it to scrape the algae off rocks

Darwin's Finches

While in the Galapagos, Darwin also studied small songbirds called finches. He studied their feeding habits and quickly realized there was a connection between the type of food they ate to the beak size and shape.

He saw that there were many varieties among the finches.

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

Finch Beak Size & Function

Each beak is adapted to eat a certain food type.

Some of Darwin's finches

Harriet the Galapagos Tortoise

One of the living animals he brought back to England with him was a young tortoise he named Harriet. She was only 5 years old.

Harriet lived with Darwin as a pet, then lived in an Australian zoo owned by Steve Irwin, “The Crocodile Hunter”.

Harriet died at the age of 176 years in 2006.

Darwin's Return to England

Upon Darwin’s return to England, his collections were hailed by the scientific community. Most scientists, let alone the general public, had never seen or heard of the organisms he brought back.

He immediately began to send out specimens to other scientists for examination. He needed help because of the sheer volume of what he had collected.

He started to piece together the evidence to determine the mechanism by which evolution happens.
Darwin's Evidence for Evolution

Darwin used 4 categories of evidence to develop his theory:

1. **Comparative anatomy**
   - Homologous structures
   - Vestigial organs
2. **Comparative embryology**
3. **Fossils**
4. **Biogeography**

**Comparative Anatomy**

Comparative anatomy is the comparison of different body structures in different species. Anatomical similarities give signs of common decent or that species are related through evolution.

The more similarities there are, the more closely related the 2 species must be in evolution.

**Homologous Structures**

Darwin noticed that animals have similar body plans and structures. He saw that the main differences amongst animals were in the forelimb and hind-limb areas.

However, forelimbs of different animals are made of the same exact bones, only the bones are modified to fit the environment of the organism. These are what is known as homologous structures.

**Vestigial Structures**

Vestigial structures are structures on 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.

**Vestigial Bones**

Whale

Snake

**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.

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.
6 Which of the following represents two homologous structures?

- A the wings of a bird and scales on a fish
- B the wings of a bat and the flipper on a whale
- C the legs on a fly and the wings of a bird
- D the antennae on an insect and the eyes of a bird

7 A vestigial structure is one that

- A is no longer necessary
- B has lost its function
- C has lost its form
- D all of the above

8 The wings of a penguin are vestigial structures.

- True
- False

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.

Apoptosis

Apoptosis (programmed cell death) occurs within the webbing of the hand 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.
The Fossil Record is the ordered array in which fossils appear in layers. Erosion of sand and silt cover the landscape and press down on the older layers, compressing them into hard rock. This takes millions of years.

When organisms die, their remains get trapped by the next layer of sediment caused by erosion. The fossil forms and gets trapped inside a layer. Layers are laid down through time. The oldest layers are on the bottom, so they contain the oldest fossils.

9 Fossils form by which of the following processes?
- A remains of a dead organism are turned to stone when trapped in layers in the earth
- B non-organic material remains when bacteria cannot decompose an organism
- C organisms become exposed when ice melts
- D Animals are broken down by bacteria when they die

10 The webbing between the fingers of human embryos falls into which category of evidence for evolution?
- A comparative anatomy
- B comparative embryology
- C fossils
- D biogeography

11 Different size beaks amongst the finches of the Galapagos Islands is an example of which category of evidence for evolution?
- A comparative anatomy
- B comparative embryology
- C fossils
- D biogeography

Biogeography

Biogeography is the geographical distribution of species.

Darwin noted that the species on the Galapagos resembled the species on mainland South America more than species on other groups of islands.

Because of this evidence, Darwin proposed that the Galapagos species must have come from a common ancestor of the species on the mainland of South America or that the Galapagos varieties evolved from the mainland immigrants.

On the Origin of the Species

In 1859 Darwin published his observations and findings in a book called On the Origin of the Species

In his book he highlighted evidence gathered from comparative anatomy, comparative embryology, the fossil record, and biogeography, as well as meticulously documented examples of adaptations to conclude that all species alive today are descended with modifications from ancestral species, and proposed natural selection as the mechanism that drives evolution.

Darwin's Evolutionary Tree of Life
Evolution by Natural Selection

Natural selection is the process by which competition for resources and an organism’s ability to survive and reproduce in a given environment result in changes in groups of living things over time, generation by generation.

Natural selection results in adaptations that enhance an organism's ability to survive and reproduce within its environment.

Natural selection is based on inherited, rather than Lamarck's acquired, traits.

The Modern Synthesis

When Charles Darwin and Gregor Mendel died (1882 and 1884, respectively), Charles Darwin was virtually unaware of the details of inheritance worked out by Mendel.

Mendel had discovered the key to how populations gained variety and could evolve. Darwin died without knowing this.

The Modern Synthesis

However, in the decades following their deaths, scientists continued their work; specifically, to find an explanation for how populations evolve by natural selection.

The new movement fusing the principles of Darwin and Mendel came to be known as The Modern Synthesis.

Modern Evidence

Advances in the studies of molecular biology, geology, and physics have provided a number of additional ways to determine relatedness among living things. Molecular evidence demonstrates that organisms share:

- rRNA
- common genes
- common proteins
- molecular homologies

rRNA

Biologists now know ribosomal RNA mutates very rarely. The fact that it does not change through time can be used to link species through evolution.

If the rRNA is similar amongst species, then they must be closely related in evolution. They must have had a common ancestor.

Common Genes

The more genes organisms have in common, the more closely related species are. In fact, most genes in humans are not human genes! We have genes from every living thing that came before us in evolution including bacteria, yeast, reptiles, early mammals, etc.

This is called gene conservation.

- 50% of genes in humans and bananas are the same.
- 96% of genes in humans and chimpanzees are the same.
- 99.9% of genes in all humans are the same.
Common Proteins
Having common polypeptides also signals close relationships in evolution and common origin.

Example: the proteins controlling all color pigments.

Molecular Homologies
The same cell structure and common cell parts amongst all living things provides evidence that we are all related.

Cytochrome c is part of the cellular respiration chain down which electrons are passed to oxygen. Cytochrome c is found in the mitochondria of every aerobic eukaryote - animal, plant, and protist. The amino acid sequences of many of these have been determined, and comparing them shows that they are related.

12. Which of the following provides evidence that all animals evolved from a common ancestor?

- A Molecular biology
- B Homologous structures
- C Biogeography
- D Embryology
- E All of the above are correct

13. The Modern Synthesis combines Darwin's work with the work of...

- A Einstein
- B Lamarck
- C Mendel
- D Newton

Modes of Natural Selection
There are three modes of natural selection:
- Stabilizing selection
- Disruptive selection
- Directional selection

Natural Selection & Speciation

Return to Table of Contents
Stabilizing Selection
Stabilizing selection favors intermediate variations.
Stabilizing selection reduces variation in a population.

Example: Human Birth Weight
- Medium-size babies are healthiest
- Small babies get sick and lose heat easily
- Large babies are difficult to deliver

Directional Selection
Directional selection favors one of the extreme variants in a population.

Example: Peppered Moths
- If the tree bark is dark, natural selection favors dark moths over light-colored moths.

Disruptive Selection
Disruptive selection favors the extreme variations.

Example: Bird Seed and Beak Size
- If only small seeds and large seeds are available, natural selection favors members of the population with extremely small or extremely large beaks.

14 Polar bears are believed to have evolved from brown bears 600,000 years ago. Their white fur is an adaptation that allows them to better survive in their snowy environment. This is an example of which mode of natural selection?
- A stabilizing selection
- B directional selection
- C disruptive selection
- D artificial selection

15 A species of African butterfly ranges in color from reddish yellow to blue. The individuals that are at the extremes of the color range (very red-yellow or very blue) survive better because they mimic non-edible species of butterfly. This is an example of what mode of natural selection?
- A stabilizing selection
- B directional selection
- C disruptive selection
- D artificial selection

Punctuated Equilibrium
Most evolution is gradual - small changes over long periods of time. But in some cases, new species can appear or disappear suddenly. This type of evolution is known as punctuated equilibrium.

The "sudden" appearance or disappearance may not be as sudden as thought. Speciation may have occurred during time periods too short to be distinguished in the fossil layers.
Speciation
How do new species form?
Members of the same species share a common set of genes called a gene pool. This means genetic change in one individual can spread through the population, by interbreeding.

For a new species to form, members of a population must become genetically separated from one another until genes can no longer flow between them.

Causes of Speciation
How do populations become reproductively isolated from one another so that genes cannot flow between them?

- Behavioral Isolation
- Geographic Isolation
- Temporal Isolation
- Mechanical Isolation

Behavioral Isolation
Occurs when two populations are capable of interbreeding but have behaviors that prevent mating.

Some species of crickets are physically identical, but can be distinguished by the fact that females will only respond to the mating songs of males of their own species. Males of other species are ignored.

Geographic Isolation
Occurs when two populations are separated by geographic barriers like mountains or bodies of water.

Temporal Isolation
Occurs when two different populations mate at different times.
Two populations of plants may produce flowers in different seasons, making mating between the populations impossible.

Mechanical Isolation
Occurs when the sexual organs between members of closely related, yet different, species do not fit together.
For some different and physically incompatible species of fruit flies, interbreeding can result in injury or death.
16 Evolution is always a gradual process.
- True
- False

17 The American Toad and the Fowler's Toad are closely related species. While scientists have been able to mate them in the lab, they do not mate in the wild because the American Toad mates early in the summer and the Fowler's Toad mates in the late summer. This is an example of which mechanism of speciation?
- A geographic isolation
- B mechanical isolation
- C behavioral isolation
- D temporal isolation

18 Differences in mating seasons are to temporal isolation as differences in mating behaviors are to ____________.
- A geographic isolation
- B mechanical isolation
- C behavioral isolation
- D temporal isolation

19 A horse and a donkey can mate and produce offspring, a mule. Why are horses and donkeys considered separate species?
- A Because the mule does not closely resemble its parents
- B Because the mules can not reproduce
- C Because all mules are male
- D They are not considered separate species

---

**Population Genetics**

Scientists building on the research of Darwin and Mendel came up with a whole new branch of biology called population genetics.

Population genetics examines how the frequencies of alleles in populations change over time.

The inheritance patterns and principles found by Mendel explained how variation occurred in populations.

Natural selection explained why some alleles became more frequent in a population than others.
Populations

A population is a group of individuals of the same species living in the same area that mate and produce fertile young.

Genetic Variation

Populations having genetic variability can evolve by natural selection. Genetic variability allows populations to adapt to ever changing environments.

Populations with NO genetic variability face extinction (ultimately) because they are all alike. It is a 50/50 chance the population will survive any environmental change. If all cannot handle the change, all individuals will die.

Slide 87 / 137

20 What is a population?

- A all of the individuals in a species
- B a group of localized organisms
- C a group of localized organisms that can mate and produce FERTILE young
- D groups of species living in the same area

Hardy-Weinberg Equilibrium Theory

Two scientists independently worked out a way to measure evolution in populations.

G.H. Hardy and Wilhelm Weinberg came up with the "Hardy - Weinberg Equilibrium Theory" that mathematically measures gene frequencies in populations from generation to generation.

Allelic Frequencies

Hardy-Weinberg Equilibrium measures microevolution rather than large scale macroevolution. By measuring allelic frequencies (how often dominant and recessive alleles show up in populations) from generation to generation, the Hardy-Weinberg equation can be used to determine if a population is currently evolving.

*"micro" = small

Hardy-Weinberg Equation

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

\[ p^2 + 2pq + q^2 = 1 \]

where:

\[ p = \text{ frequency of the homozygous dominant genotype} \]
\[ (p= \text{ frequency of dominant allele}) \]
\[ 2pq = \text{ frequency of the heterozygous genotype} \]
\[ q = \text{ frequency of the homozygous recessive genotype} \]
\[ (q= \text{ frequency of recessive allele}) \]
Knowing this equation will help you determine if populations are evolving. The equation is equal to one because for any investigation, you can only look at one population.

All of the genotypic frequencies ($p^2$, $2pq$, $q^2$) always equal one full population. It does not matter if there is evolution or no evolution going on within the population.

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

21. In H-W Equilibrium, what is $p$?
   - A the recessive genotypic frequency
   - B the dominant genotypic frequency
   - C the recessive allelic frequency
   - D the dominant allelic frequency

22. What does $2pq$ represent in the H-W Equilibrium equation?
   - A the homozygous recessive allele
   - B the homozygous dominant phenotype
   - C the heterozygous genotype
   - D the heterozygous phenotype

23. In H-W Equilibrium, if AA represents the homozygous dominant genotype, what is $a$?
   - A the dominant allele
   - B the homozygous recessive genotype
   - C the recessive phenotype
   - D the recessive allele

24. When does the H-W Equilibrium equal 1?
   - A always
   - B only when there is evolution
   - C only when there is no evolution
   - D only when the population is in H-W Equilibrium

Solving Hardy-Weingberg Equilibrium Problems

1. First find $q^2$ - It is very easy to find because the recessive phenotypic frequency = the homozygous recessive genotypic frequency.

2. Find $q$ (using $#q$) the recessive allelic frequency.

3. Once you have $q$, you can find $p$ ($1 - q = p$).

4. Once you have $p$, you can calculate $p^2$ and $2pq$.

5. If you need the number of individuals at a particular frequency, just multiply the frequency by the total number of individuals in the population.
Hardy-Weinberg Equilibrium equation can help you determine five main things about any population:
- phenotypic frequencies in a population
- genotypic frequencies in a population
- allelic frequencies in a population
- how many individuals exhibit the different phenotypes and genotypes
- if a population is evolving

25. How do you find \( q \) (recessive allelic frequency) in a population, if it is not given.
   - \( A \) take the square root of the homozygous recessive genotypic frequency
   - \( B \) take the square root of the recessive phenotypic frequency
   - \( C \) take the square root of \( q^2 \)
   - \( D \) all of the above

26. Black wool color is a homozygous recessive trait in sheep. Out of 100 total sheep, 25 have black wool. Calculate the frequency of the total population that have black wool. This is \( q^2 \).
   - \( A \) 0.5
   - \( B \) 0.625
   - \( C \) 0.12
   - \( D \) 0.25

27. Take the square root of \( q^2 \) to calculate the frequency of the recessive allele.
   - \( A \) 0.5
   - \( B \) 0.25
   - \( C \) 0.625
   - \( D \) 0.15

28. The sum of the frequency of both alleles equals 1 (\( p + q = 1 \)). What is the frequency of the dominant, \( p \), allele within the population?
   - \( A \) 0.5
   - \( B \) 0.25
   - \( C \) 0.75
   - \( D \) 0.95

29. What is the frequency of the homozygous dominant genotype (\( p^2 \)) in the population?
   - \( A \) 0.45
   - \( B \) 0.75
   - \( C \) 0.25
   - \( D \) 0.625
2pq equals the frequency of the heterozygous genotype in the population. What percentage of the population is heterozygous?

A 25%  
B 50%  
C 75%  
D 95%

Conditions for Hardy-Weinberg

For a population to be able to fit into the Hardy-Weinberg Equilibrium Equation (meaning the population is NOT evolving) the following conditions MUST be met.

1. Populations have to be extremely large.
2. There is NO Gene Flow
3. There are NO mutations
4. Mating is random
5. There is NO natural selection

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 allele frequencies to change.

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

Condition #2 - No Gene Flow

No gene flow can occur in a population working within Hardy-Weinberg Equilibrium. Migration cannot 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 "gene flow" (the introduction or taking away of genes in a population) from happening.

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

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.

Remember mutations can be driven by the environment, a result of a copying mistake made by DNA or RNA enzymes, or inherited.

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

Condition #4 - Random Mating

In Hardy-Weinberg Equilibrium, mating must be random. However, in real life, most animals CHOOSE their mates. It is almost always the female that chooses. This is why males in the animal kingdom tend to be prettier and more ornate than females. Having ornate features sends a signal to the female that this male has good genes. and, therefore, the female will let mate with the male. Random mating can be considered in plant populations, but for the most part...

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

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

Used for Comparison

Therefore, no real-life population is ever found to be in Hardy-Weinberg Equilibrium. This is because real life populations are always evolving.

This might sound strange, but the reason for using Hardy-Weinberg is to set up conditions for fictional populations. By doing this, we can use it as a comparison to see the reasons for evolution in real populations.

Comparing Allelic Frequencies

Using the H-W equation, you will find the allelic frequencies (p and q) in a population, then compare those frequencies from one generation to the next. Two things can happen:

If the allelic frequencies (p & q) change from generation to generation: There IS evolution and the population is said to be OUT of H-W equilibrium

If allelic frequencies (p & q) do NOT change from generation to generation: There is NO evolution and the population is said to be IN H-W equilibrium

31 What is the purpose of Hardy-Weinberg Equilibrium?
- A to measure the number of individuals that are evolving in a population
- B to measure the amount of evolution based on all genes in the population
- C to measure allelic frequency change in populations and compare them from one generation to the next
- D to figure out specifically how the population is evolving

32 What does it mean if allelic frequencies CHANGE from generation to generation in a population?
- A it means there is no evolution
- B it means that the equation = 1
- C it means the population evolved
- D it means that the population will be IN of H-W equilibrium

33 Which of the following factors will affect Hardy-Weinberg equilibrium, leading to evolutionary change?
- A small populations
- B no gene flow
- C no natural selection
- D random mating
Exceptions to the Rule

A small number of real-life populations ARE in or close to H-W Equilibrium (they are either not evolving or only have slight microevolution).

The Galapagos Blue-Footed Booby is one of those populations in H-W. This is because the populations' alleles remain stable.

Populations like this are helpful to scientists that study them as a comparison to populations that are evolving.

Genetic Drift & Patterns of Macroevolution

Return to Table of Contents

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

The Founder Effect is a type of genetic drift that occurs when a very small group of individuals populate a new area. They form a new group and are the "founders" of the new population.

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.
34. Which of the following is not true about the bottleneck effect?

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

35. A flood occurs, leaving a small population of rabbits stranded on a new island. The evolution of this population is a result of:

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

---

**Cheetahs in Africa - An Example of a Homozygous Population**

Cheetahs used to be widespread throughout Asia and Africa.

Conservationists now estimate only about 9,000 cheetahs remain in Africa today, and none in Asia.

This number is tiny for an entire species.

---

**Current Range of Cheetahs in Africa**

Cheetahs are extremely endangered because of humans.

Loss of habitat to farming and game hunting have killed 96% of the cheetah population.

---

**Genetic Drift & Homozygosity**

Because most of the cheetah population has been killed off, the population has experienced Genetic Drift.

Zoos have a breeding programs where they return cheetahs to the wild. Unfortunately, both the wild cheetah and the zoo populations are nearly identically homozygous. The cheetahs have only one form of almost all their genes.

---

**The Only Hope: Random Mutations**

Mutations that would bring back the other allele on all genes need to happen.

The problem is for animals and plants, as stated earlier, mutation rates are extremely low. The cheetahs would die off before these much needed mutations could happen.
**Extinction**

The Founder Effect and the Bottleneck Effect lead to reduced genetic variation within a population that can make a species less able to adapt to changing environments, and, therefore, less likely to survive and reproduce.

Scientists estimate over 99% of all species that have ever existed are now extinct.

**Extinction**

Extinction can be caused by a variety of factors including predation, disease, competition, and degradation of habitat.

Mass extinctions have occurred frequently throughout Earth’s history, killing off multiple species at once. A mass extinction at the end of the Cretaceous Period 65 million years ago wiped out the dinosaurs.

**Patterns of Macroevolution**

- Adaptive Radiation
- Divergent Evolution
- Convergent Evolution
- Coevolution

**Adaptive Radiation**

Adaptive radiation is the emergence of numerous species from a common ancestor.

This generally occurs when organisms move to a distinctly new environment from the old one or when there is major change in the current environment.

**Divergent Evolution**

Adaptive radiation leads to divergent evolution, new species arising from another species.

Divergent evolution can arise from disruptive selection.

**Convergent Evolution**

Convergent evolution is when different organisms, arising from different ancestors, have similar characteristics because they adapted to similar environments.

Ex: The sugar glider and the flying squirrel.
Coevolution

Coevolution is when an evolutionary adaptation in one species affects the evolution of another species.

Coevolution requires the linkage of genetic change between the two species, such as between flowers and bumblebees.

The butterfly and flower are in a mutually beneficial relationship and have evolved complementary characteristics.


36 African moths are dependent on a certain species of flower for nectar, and the flower is dependent on the moths to spread pollen, allowing the flower to reproduce. This is an example of

- A Adaptive radiation
- B Divergent evolution
- C Coevolution
- D Convergent evolution

37 The ability of birds, bats, and insects to fly is an example of...

- A Adaptive radiation
- B Divergent evolution
- C Coevolution
- D Convergent evolution

38 Darwin's finches and tortoises are examples of...

- Adaptative radiation
- Divergent evolution
- Coevolution
- Convergent evolution

Why Study Evolution?

Evolution is a well-supported and useful theory that provides a basis for understanding a wide range of observations.

Evolution matters because it is a continuous process that drives change in our world.