

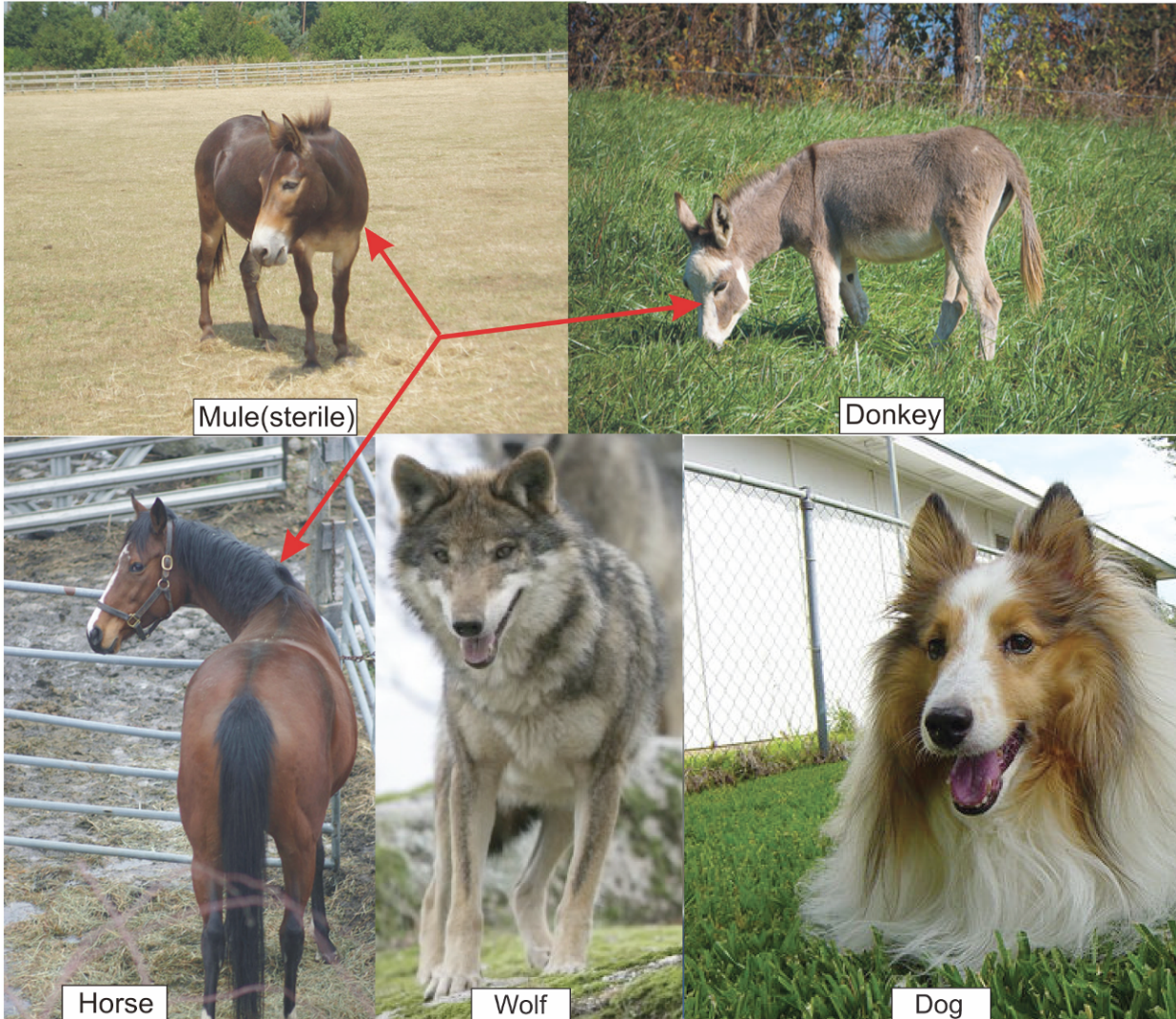
# Population Genetics and Patterns of Evolution

Chapter 17 and a bit of 19.2 and  
19.3 Notes

Are these organisms the same species?



# Are these organisms the same species?



# How do we study evolution?

- A **species** is defined as a group of similar organisms that are capable of producing fertile offspring.
- A **population** is a localized group of a species in a defined area. We study evolution as **genetic change** in a population.

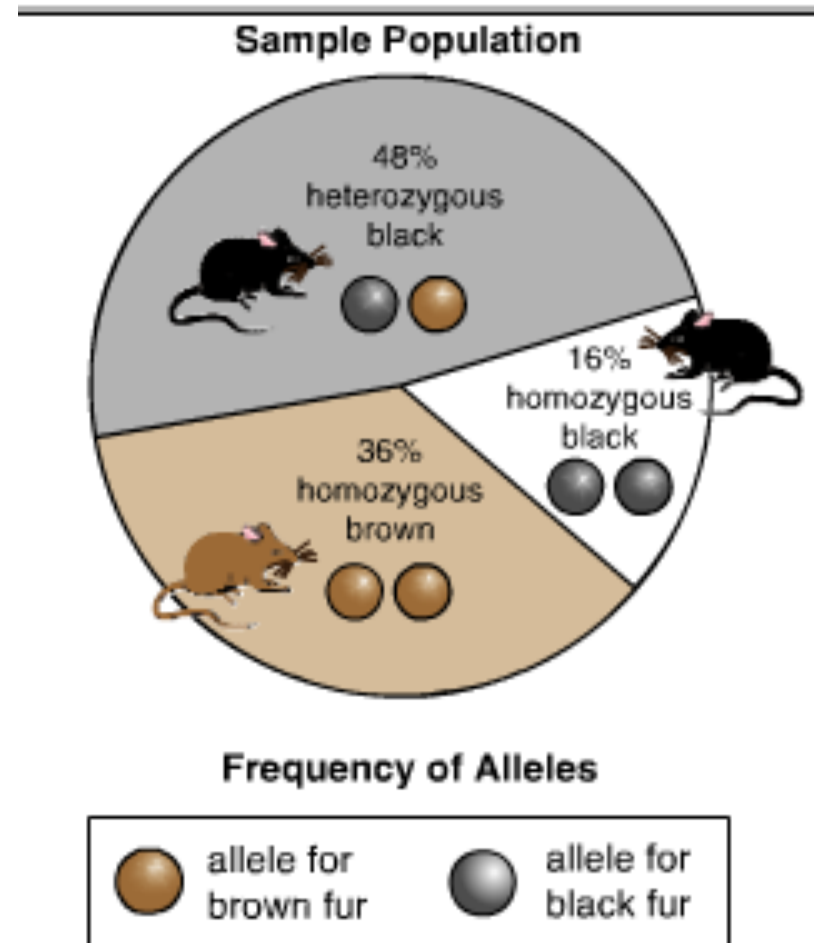
# How do we study evolution?

- Evolution is change over time, which means it occurs within a group whose individuals are ***actually*** breeding with each other;
- and therefore, we study evolution by examining genetic change within a population.
- INDIVIDUALS do NOT EVOLVE, a population evolves.

# Genes and Variation

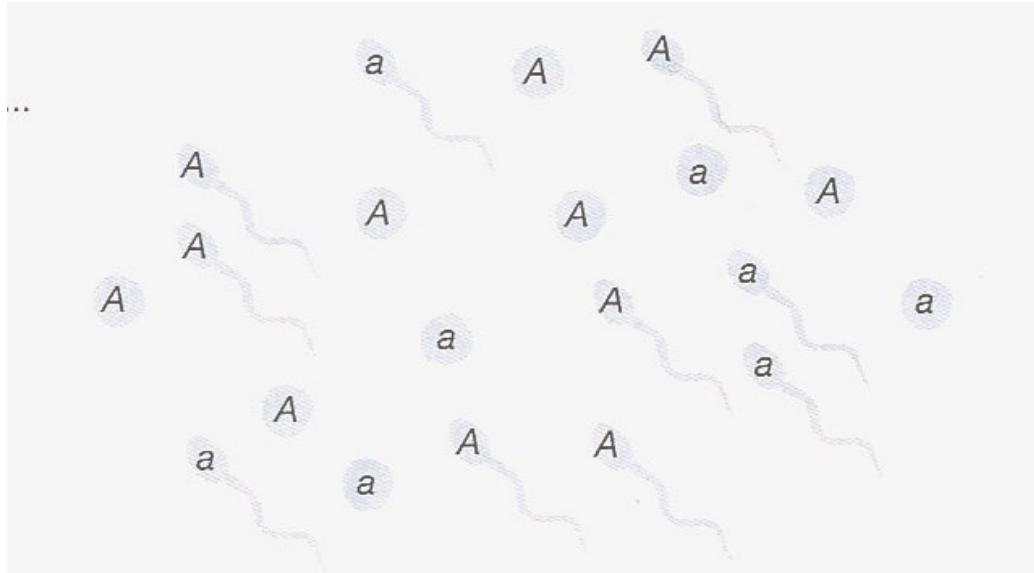
1. Inheritable traits are coded for by **genes**, and the different forms of a gene are called **alleles**. There exists **variation within a population** for many of these alleles.

1. We can figure out what the **frequency** of a particular allele is by calculating the number of times that allele appears in that population compared to others in the entire **gene pool**.

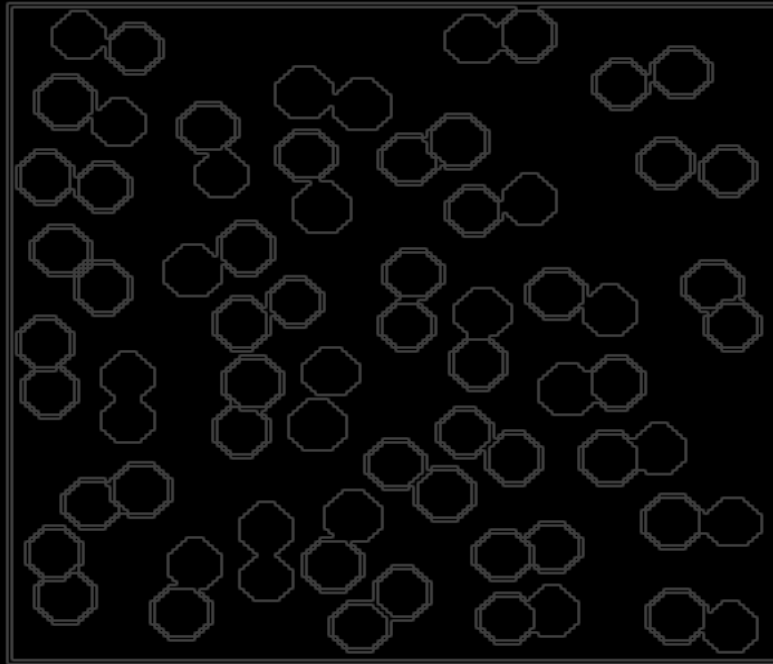




1. The **gene pool** consists of all the genes present in a population. The **relative frequency** of an allele in a population is often expressed in a percentage.







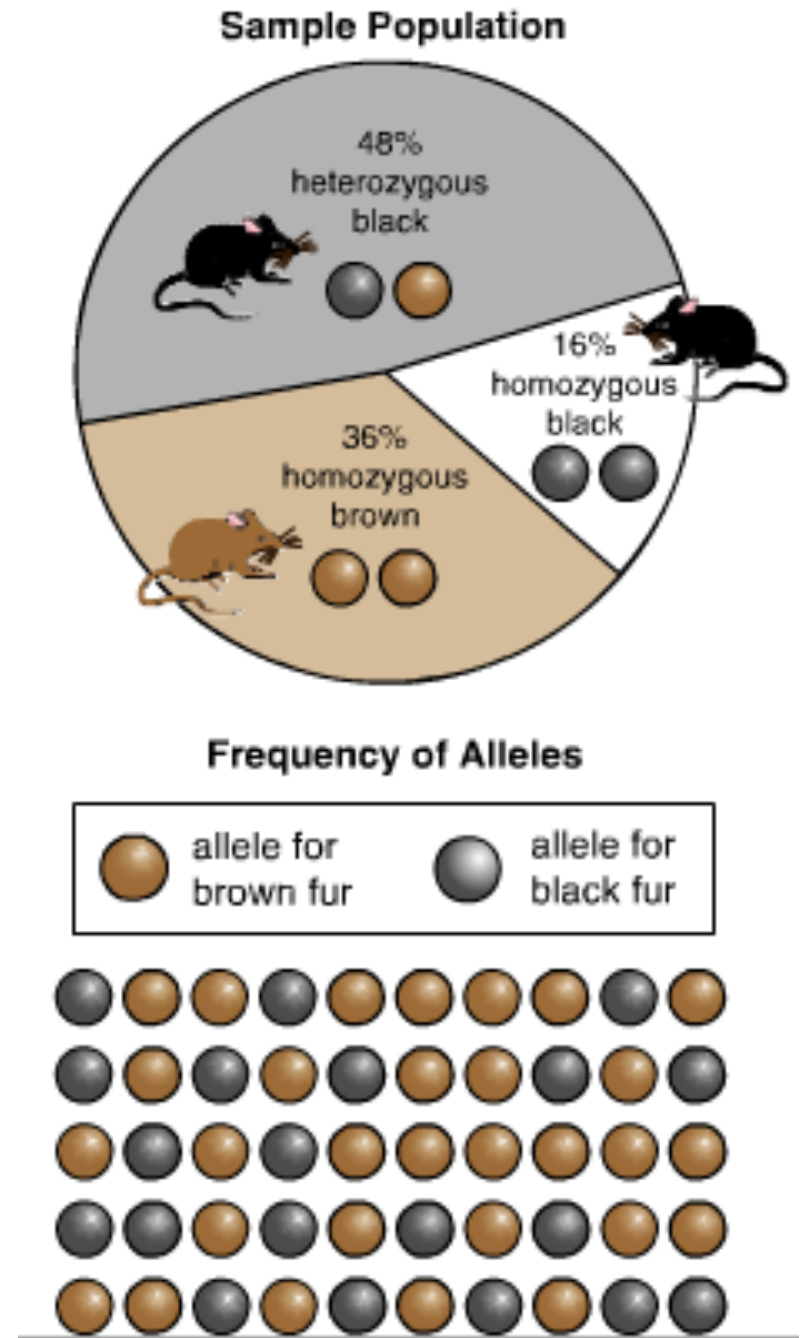
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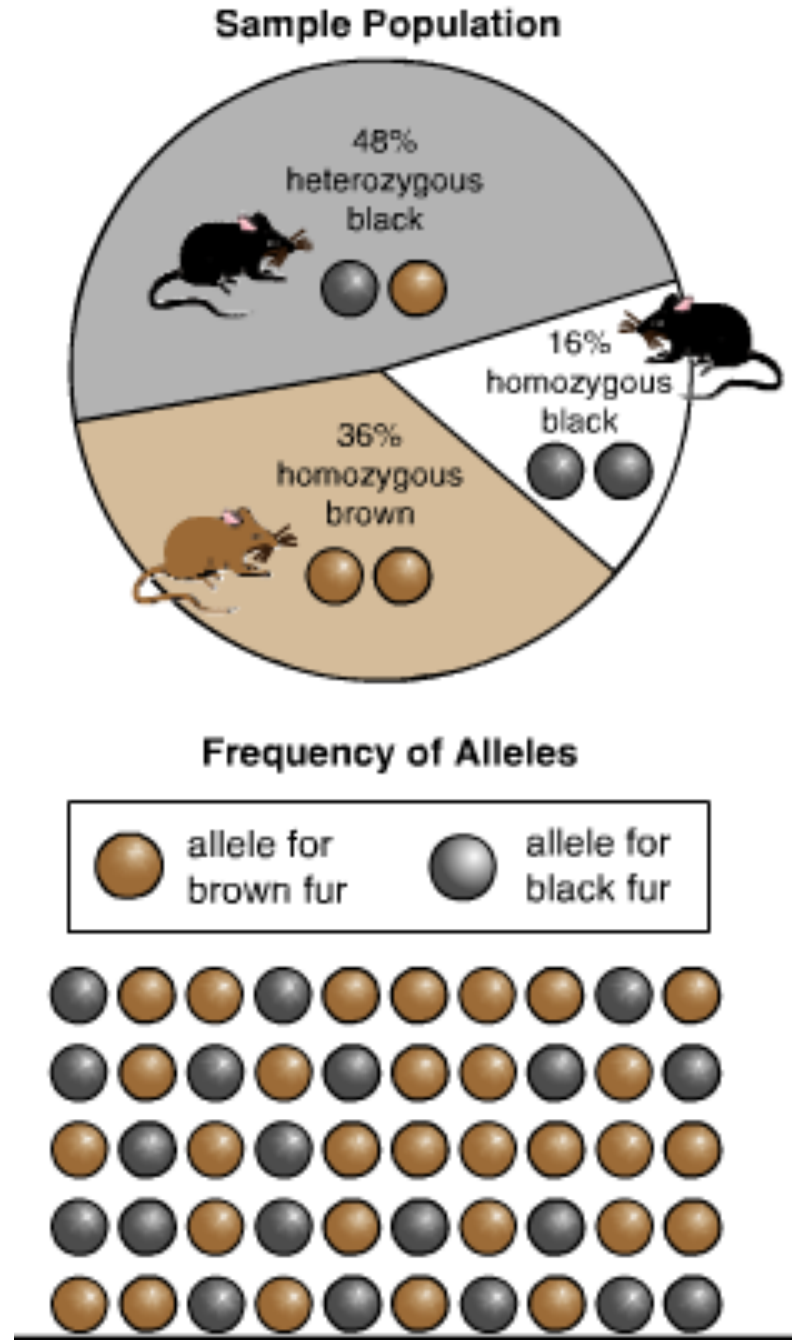
**"See Larry, there is nothing wrong with you. You're such a nice guy...but it's just that...I guess it's time for me to move on to someone from a better gene pool, that's all."**

1. How many genes are in our gene pool?
2. What is the frequency of the black allele?
  - 20 out of 50
  - 0.4
3. What is the frequency of the brown allele?
  - 30 out of 50
  - 0.6



In this sample population, is the most common allele the dominant one?

The most common allele does not have to be dominant!!



b. When a change in the relative frequency of an allele occurs in a population, “change over time” has occurred, and this is evolution on a small scale.

This is called **MICROEVOLUTION**



- i. Example:* Consider alleles for polydactyly in the gene pool, the allele coding for extra digits, the polydactyly allele ( $P$ ), is only 1% of the population, the frequency is 0.01.
- The allele for 5 fingers and toes ( $p$ ) is 99% of the population, or a frequency of 0.99.
  - If over time, extra fingers was an advantage, and natural selection selected FOR individuals with extra digits, a shift in that allele frequency might happen, and evolution on a small scale would have occurred!

# Sources of Genetic Variation

- **Mutations-** a new alleles can arise only if a mutation occurs and a new sequence of DNA makes a new form of gene.
- **Gene shuffling-** independent assortment of chromosomes and crossing over during gamete formation produce millions of possibly arrangements of your genes! There is not change in a frequency when genes are shuffled, but that is why there is so much variation



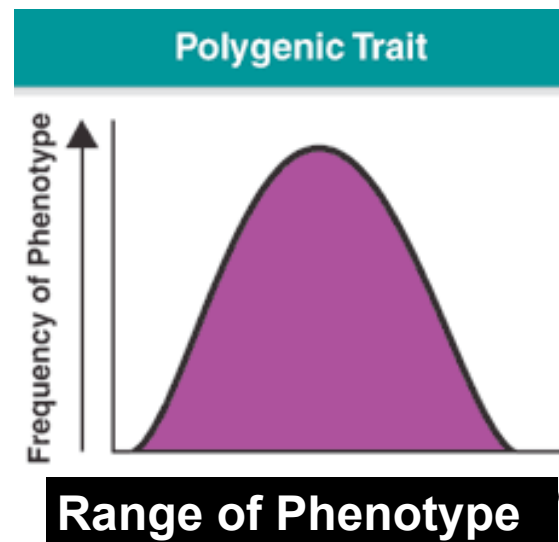
# Selection on a Single-Gene trait

- A **single-gene trait** with two alleles will show two phenotypes. A change in frequency is easy to see in a population. Example: see pg. 409; 485

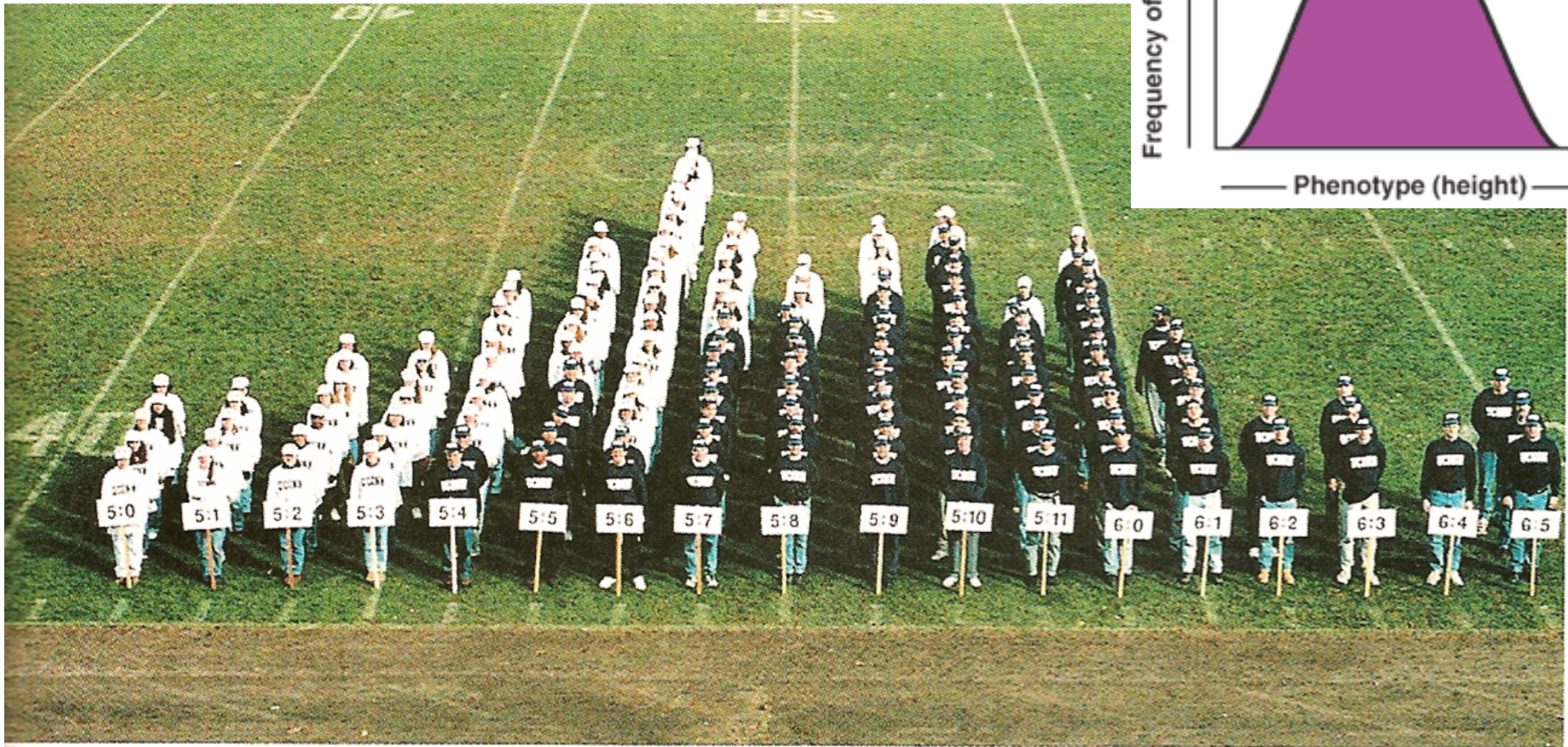
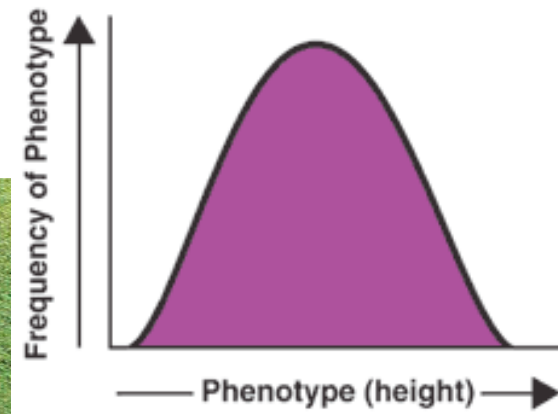


# Selection on a Polygenic Trait

- A **polygenic trait** is one that is controlled by more than one gene.
- Things such as height in humans are polygenic traits.
- If you were to graph out the frequencies of the phenotypes, you would get a **bell shaped curve**.



## Polygenic Trait



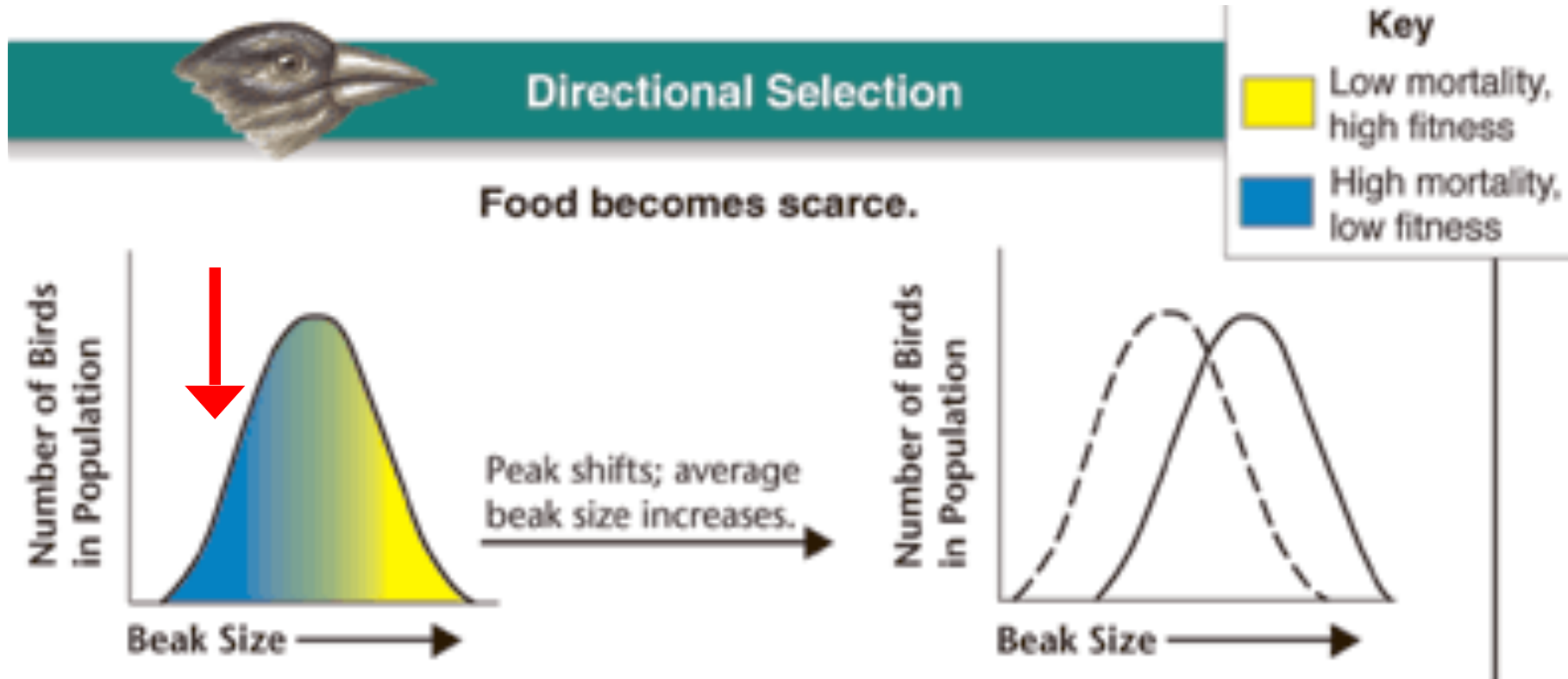
ing histogram. These students and faculty at the University of Connecticut have sorted themselves into columns by height.  
(Morenus, University of Connecticut)

# Selection on a Polygenic Trait

1. Directional Selection- occurs when individuals at one end of the curve (with phenotypes at one end of the spectrum) are advantaged, and selection against the other end occurs. The individuals with the higher fitness, or ability to survive and reproduce, will succeed. Over time the population will shift in its phenotypes to one direction.
  - *Example:* Food becomes scarce and one type of beak is most efficient

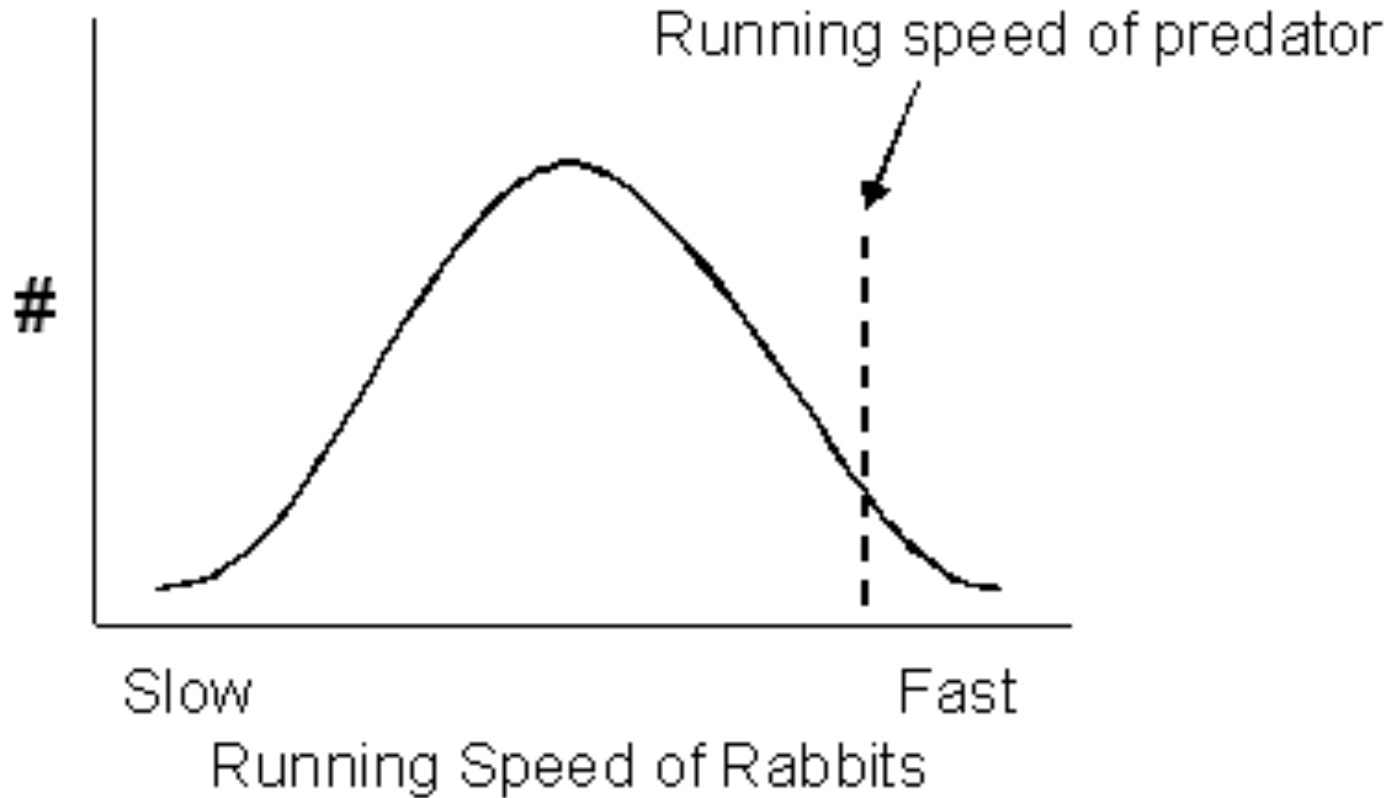


# Selection on a Polygenic Trait



Draw the line!

# Number vs. Running speed of Rabbits

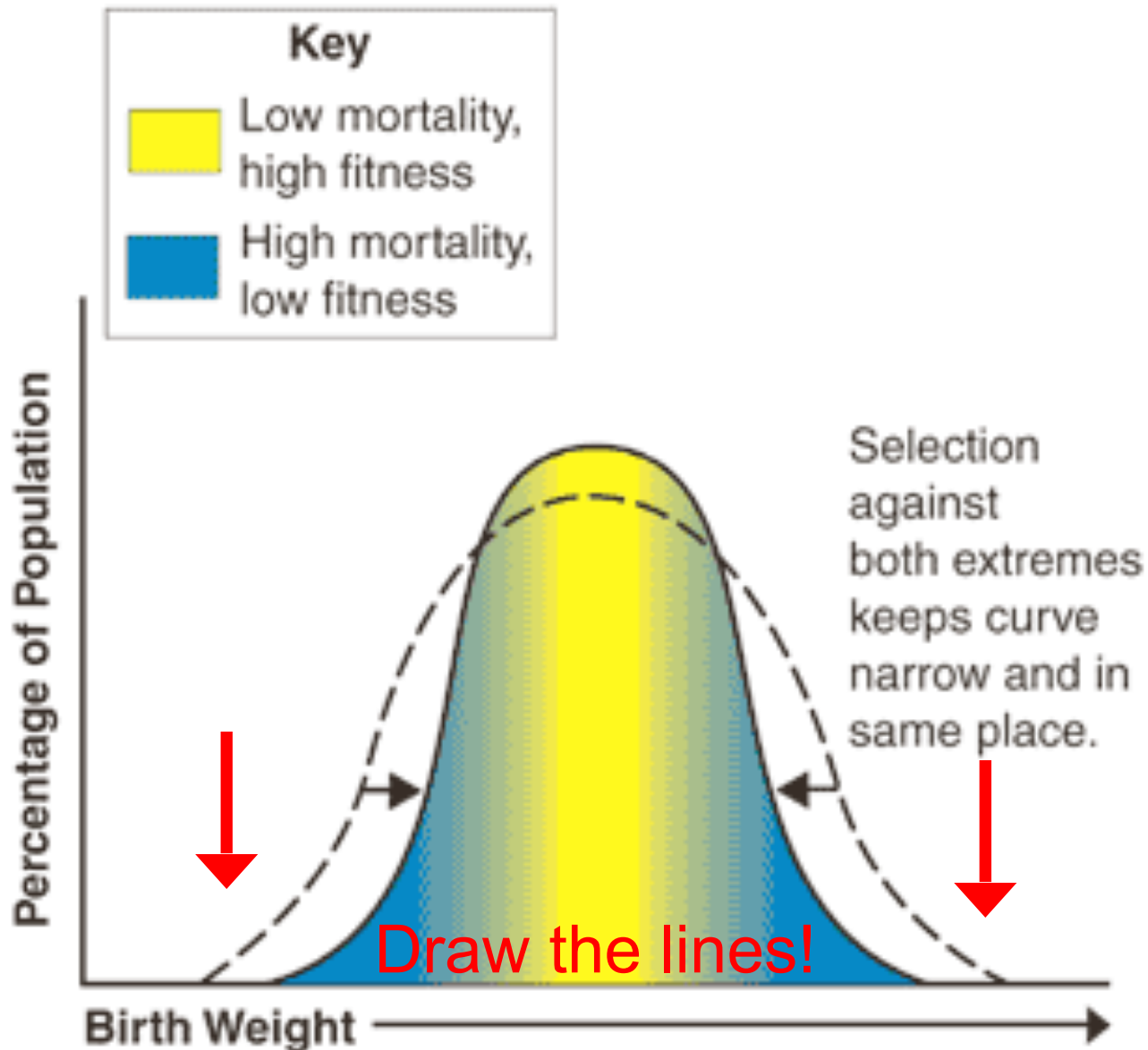


# Selection on a Polygenic Trait

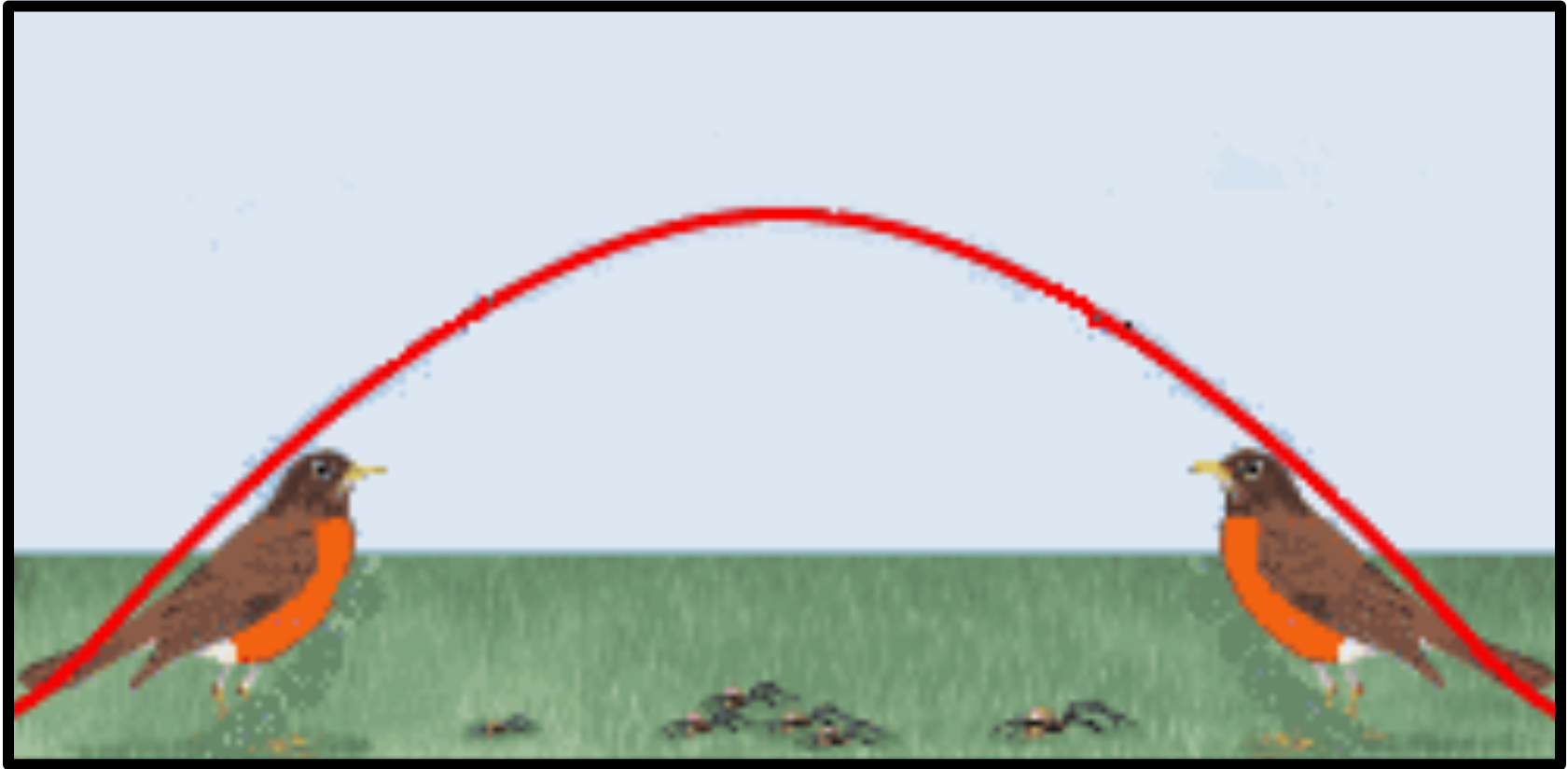
2. Stabilizing selection- occurs when individuals in the middle of the curve are more advantaged, or have a higher fitness, than individuals at the ends. This causes the frequency of the mid-phenotypes to increase, and the ends to decrease
  - *Example:* Birth weight in humans



# Stabilizing Selection



# Number of spiders vs. body size



Increasing body size  $\longrightarrow$

# Selection on a Polygenic Trait

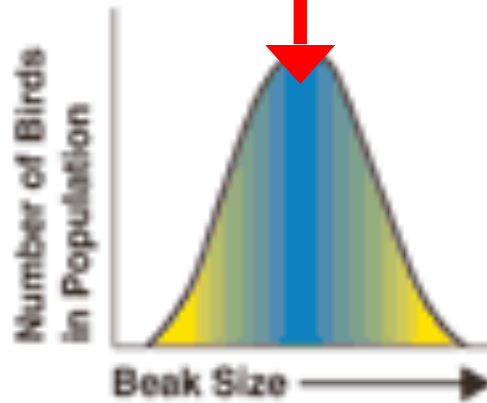
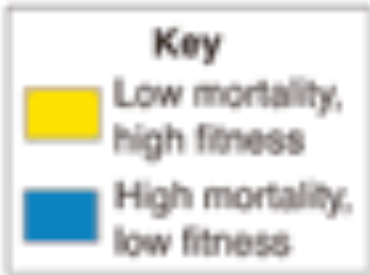
3. Disruptive Selection- occurs when individuals at the ends of the curve are more advantaged, or have a higher fitness, than the individuals at the middle of the curve. This is less common. A single curve will appear to split in two.
  - *Example*: Larger and smaller seeds become more common

# Selection on a Polygenic Trait

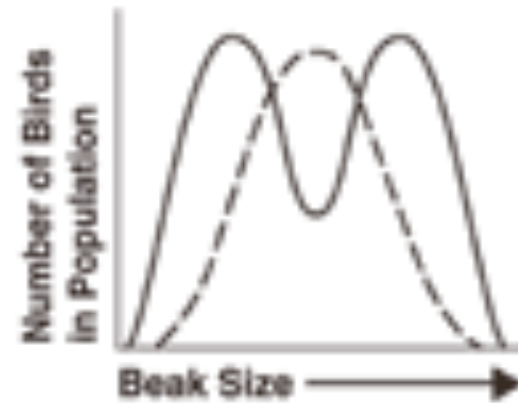


## Disruptive Selection

Largest and smallest seeds become more common.



Population splits into two subgroups specializing in different seeds.



Draw the line!

# Hardy Weinberg Equilibrium

- We study evolution as genetic change by comparing to a population that is not evolving. There are 5 criteria for a NON-evolving population (Hardy-Weinberg principle) which means the population is in **Genetic Equilibrium**. Hardy-Weinberg predicts that these (5) conditions, if they change, can disturb genetic equilibrium and cause evolution to occur.

# Hardy Weinberg Equilibrium

- Random mating- all members of the population have an equal shot at mating, and selecting mates based on traits does not occur
- No genetic drift- genetic drift is a random change of frequency of an allele because the population is small. Natural selection affects small populations much more than large ones.
- No immigration or emigration- no new individuals can add to the gene pool

# Hardy Weinberg Equilibrium

- No mutations- mutations are the ultimate source of genetic change, so a non-evolving population would have no mutations
- No natural selection- all individuals have the same ability to survive and reproduce



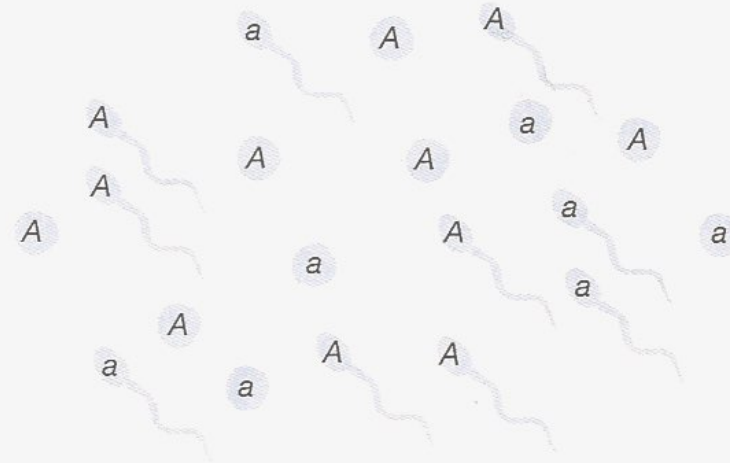
# Hardy Weinberg Equilibrium

- Does this happen in nature? \_\_\_\_\_
- We can calculate genetic change using the Hardy-Weinberg equation comparing allelic frequencies. We will solve some tomorrow.

# Hardy Weinberg Derivation

**Figure 5.2** Random mating in the gene pool of our model mouse population produces zygotes with predictable genotype frequencies

A gene pool with allele frequencies of 0.6 and 0.4...



...yields zygotes with genotype frequencies of 0.36, 0.48, and 0.16

| Egg | & | Sperm | → | Zygote | Probability             |
|-----|---|-------|---|--------|-------------------------|
| A   |   | A     | → | AA     | $0.6 \times 0.6 = 0.36$ |
| A   |   | a     | → | Aa     | $0.6 \times 0.4 = 0.24$ |
| a   |   | A     | → | aA     | $0.4 \times 0.6 = 0.24$ |
| a   |   | a     | → | aa     | $0.4 \times 0.4 = 0.16$ |

} = 0.48

# Speciation

- First of all what is a species?
  - As defined by Ernst Mayr- the Biological Species Concept states: “**Species are groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups.**”
  - When natural selection acts on a population, certain characteristics are **avored** and others are **not**.

# Speciation

- What causes **new species** to arise?
  - They must be separated and no longer be able to produce **fertile offspring**, or become **reproductively isolated**, in order to become officially a different **species**.
  - This is called **speciation**.

# Types of Reproductive Isolating Mechanisms (RIMs):

- **Prezygotic** (prevent mating or fertilization)
  - Geographical isolation- different habitats or rarely encounter each other



# Types of Reproductive Isolating Mechanisms (RIMs):

- **Prezygotic** (prevent mating or fertilization)
  - Temporal isolation- breed/flower at different times of the year or day

# Types of Reproductive Isolating Mechanisms (RIMs):

- **Prezygotic** (prevent mating or fertilization)
  - Behavioral isolation- differences in mating/ courting; usually a result of sexual selection

*Ex.* The eastern meadowlark (left) and western meadowlark (right) have overlapping ranges. They do not interbreed because they have different mating songs.





# Types of Reproductive Isolating Mechanisms (RIMs):

- **Prezygotic** (prevent mating or fertilization)
  - Mechanical isolation- anatomically incompatible sex organs on plants or animals

# Types of Reproductive Isolating Mechanisms (RIMs):

- **Postzygotic** (reduce viability of hybrids)
  - Hybrid inviability- hybrids do not develop or are less likely to survive
  - Hybrid sterility- F1 hybrids develop, but cannot reproduce
  - Hybrid breakdown- F1 hybrids are viable, but F2s are not

# **How did speciation occur in the Galapagos? (17.3)**

1. Because the Galapagos are a group of islands, there are separate ecosystems on each.
2. Founder populations arrived on an island from the mainland of South America.

# **How did speciation occur in the Galapagos? (17.3)**

3. Reproductive isolation occurred (geographic).
4. Frequencies of different traits changed in that population over time because of natural selection, based on food source, soil types, predators, etc.
5. Eventually, over a long period of time, the original population and the founder population on the second island are very different and are considered different species.

### 1 Founders Arrive

Galápagos Islands

SOUTH AMERICA

A

A few finches travel from South America to one of the islands. There, they survive and reproduce.

### 2 Separation of Populations

A

A

Some birds from species A cross to a second island. The two populations no longer share a gene pool.

### 3 Changes in the Gene Pool

A

B

Seed sizes on the second island favor birds with larger beaks. The population on the second island evolves into a population, B, with larger beaks.

### 4 Reproductive Isolation

A

B

B

If a few population-B birds cross back to the first island, they will not mate with the birds of population A. The gene pools are now separate. Populations A and B are separate species.

### 5 Ecological Competition

A

B

C

As species A and B compete for seeds on the first island, they continue to evolve. A new species, C, may evolve. Some members of the original species B may travel to a new island.

### 6 Continued Evolution

A

B

C

D

E

The process continues, leading to the formation of all 13 finch species on the Galápagos.

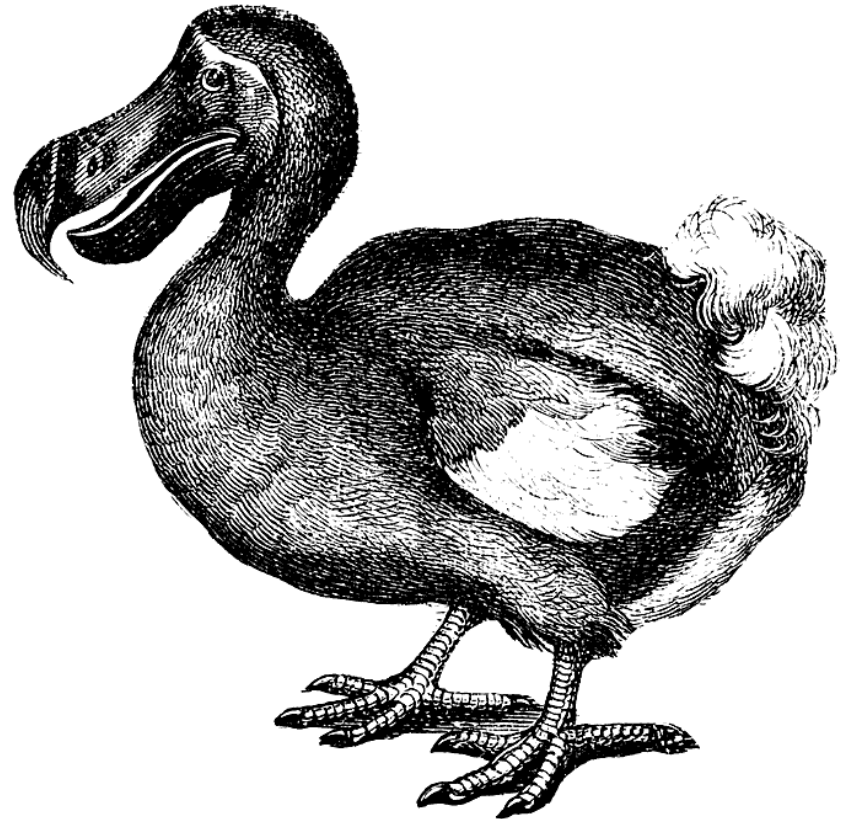
# What type of beak would each bird have?

- Notice the beaks' structure fits their functions

| Galápagos Islands Finches    |                       |                                |                    |                     |                           |                     |
|------------------------------|-----------------------|--------------------------------|--------------------|---------------------|---------------------------|---------------------|
| Shape of Head and Beak       |                       |                                |                    |                     |                           |                     |
| Common Name of Finch Species | Vegetarian tree finch | Large insectivorous tree finch | Woodpecker finch   | Cactus ground finch | Sharp-beaked ground finch | Large ground finch  |
| Main Food                    | Fruits                | Insects                        | Insects            | Cacti               | Seeds                     | Seeds               |
| Feeding Adaptation           | Parrotlike beak       | Grasping beak                  | Uses cactus spines | Large crushing beak | Pointed crushing beak     | Large crushing beak |
| Habitat                      | Trees                 | Trees                          | Trees              | Ground              | Ground                    | Ground              |

# Patterns of Evolution (19-2)

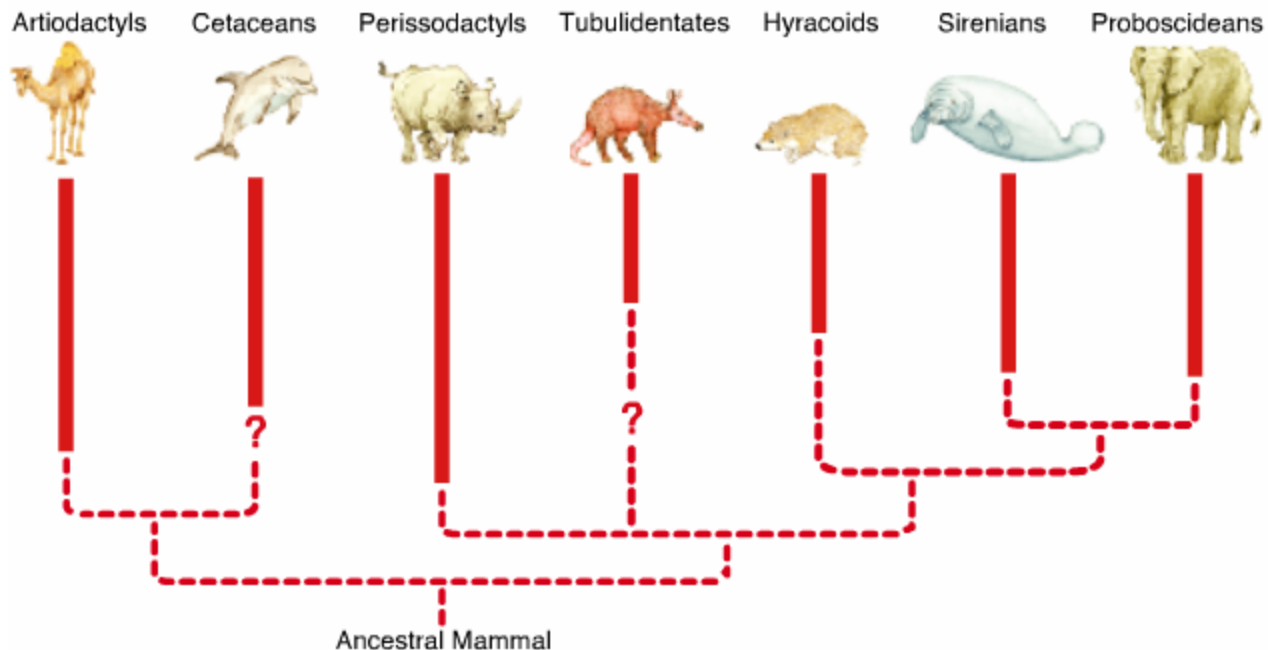
1. Extinction- 99% of all species that have ever lived are now extinct. In the struggle for existence, species compete for resources, and some lose, and die.
  - Sudden changes in the environment or natural disasters can cause mass extinctions.
  - A mass extinction allows for a new radiation of species to fill all the empty niches.



- The dodo bird has been extinct for several hundred years after humans introduced predators to their habitat

# Patterns of Evolution (19-2)

2. Adaptive Radiation- several vastly different species arise from a single species to fill available niches.





# Patterns of Evolution (19-2)

3. Convergent Evolution- unrelated organisms come to resemble each other because their adaptations resemble each other.
- Penguins are birds, dolphins are mammals, and they have modified structures that are like that of a fish for swimming!
  - They are structures with the same functions, but are not on related animals are called **analogous structures**.



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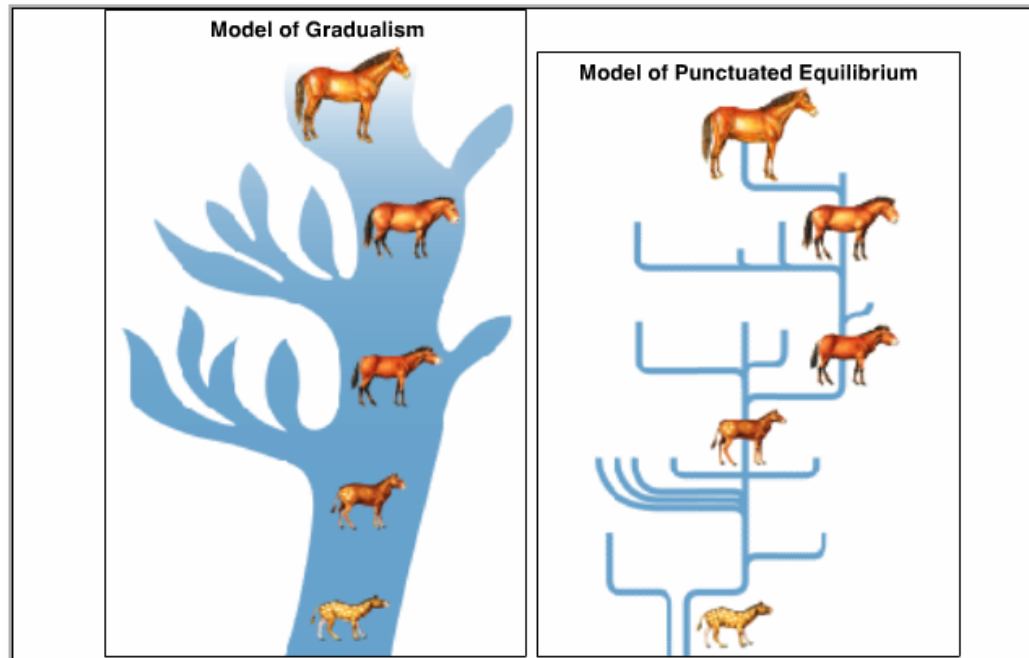
# Patterns of Evolution (19-2)

4. Coevolution- two species evolve along with each other based on a close relationship with each other. Plants and their pollinators, parasites with their hosts, etc.



# Patterns of Evolution (19-2)

5. Punctuated equilibrium- long periods of time with stable species broken with rapid period of change.



**Rates of Evolution** Biologists have considered two different explanations for the rate of evolution, as illustrated in these diagrams. Gradualism involves a slow, steady change in a particular line of descent. Punctuated equilibrium involves stable periods interrupted by rapid changes involving many different lines of descent. **Interpreting Graphics** How do the diagrams illustrate these explanations?