Mechanisms of Evolutionary Change

- Evolution is defined as a change in allele frequencies over time.
- Natural selection acts on individuals, but evolutionary change occurs in populations.

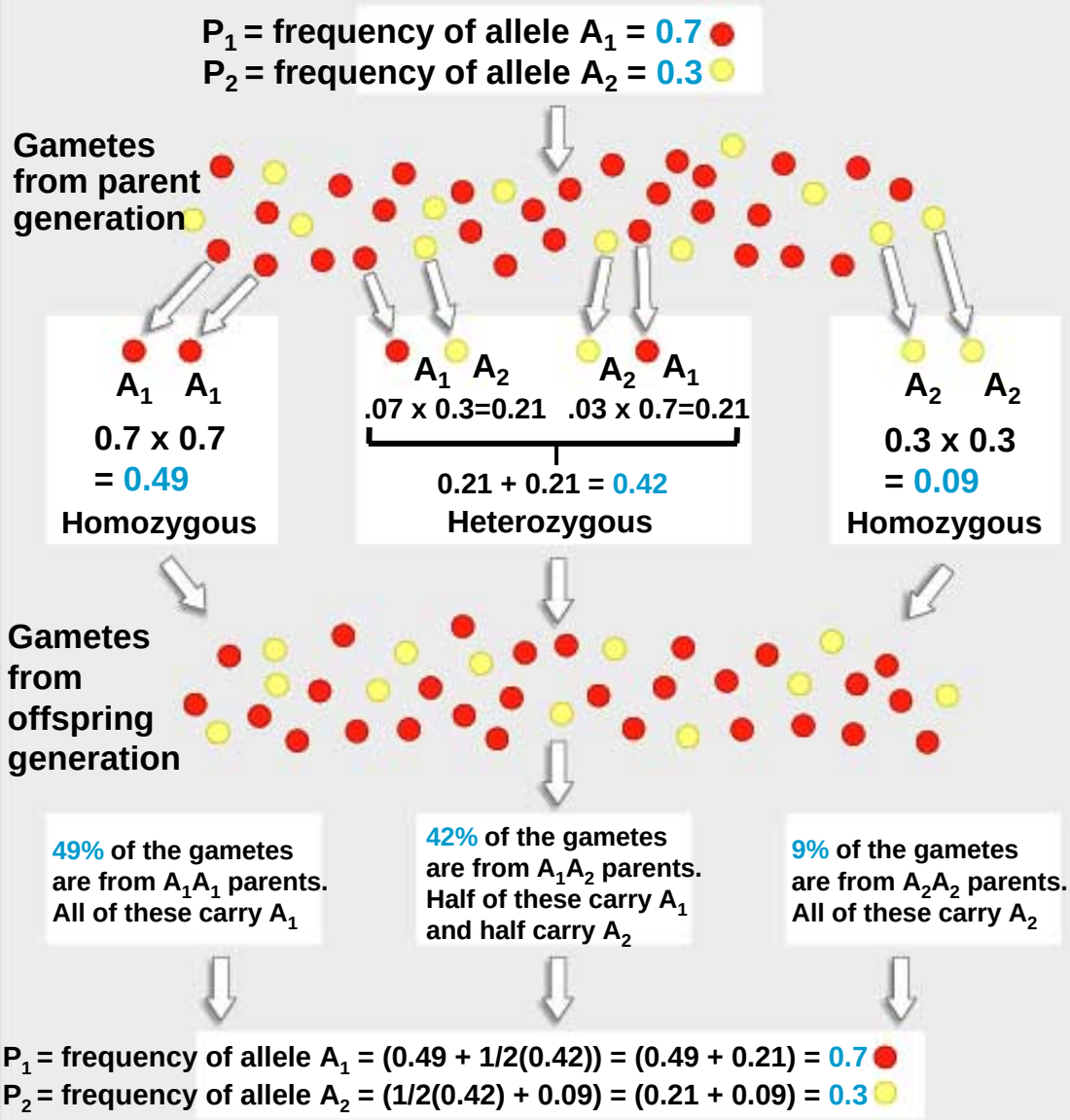
Mechanisms of Evolutionary Change

- Mechanisms that change allele frequencies in populations:
  - Natural selection
  - Mutation
  - Gene flow
  - Genetic drift
- Natural selection is the only mechanism that results in adaptation and leads to increased ***fitness***.

Analyzing Allele Frequency Change: The Hardy-Weinberg Model

- Analyzes what happens to the frequencies of two alleles at a single locus when the four evolutionary forces are not acting on a population.
- If allele frequencies are the same between a parental and offspring generation, then no evolution is occurring.
- Assumes that there is no mutation, migration, genetic drift, selection, or nonrandom mating in the population.
- This model has been tested and verified many times in the lab and field.

DERIVING THE HARDY-WEINBERG PRINCIPLE-A NUMERICAL EXAMPLE



1. Suppose that the allele frequencies in the parental generation were 0.7 and 0.3.

2. 70% of the gametes in the gene pool carry allele A_1 and 30% carry allele A_2.

3. Pick two gametes at random from the gene pool to form offspring. Three genotypes are possible.

4. Calculate the frequencies of these three combinations of alleles.

5. When the offspring breed, imagine that their gametes go into a gene pool.

6. Calculate the frequencies of the two alleles in this gene pool.

BEHOLD! *The allele frequencies of A_1 and A_2 have not changed from parent generation to offspring generation. Evolution has not occurred.*

Genotype frequencies will be given by: $p_1^2 : 2p_1p_2 : p_2^2$ as long as all Hardy-Weinberg assumptions are met

Mutation

- Mutation is the ultimate source of genetic variability. Mutations occur constantly in DNA and protein synthesis.

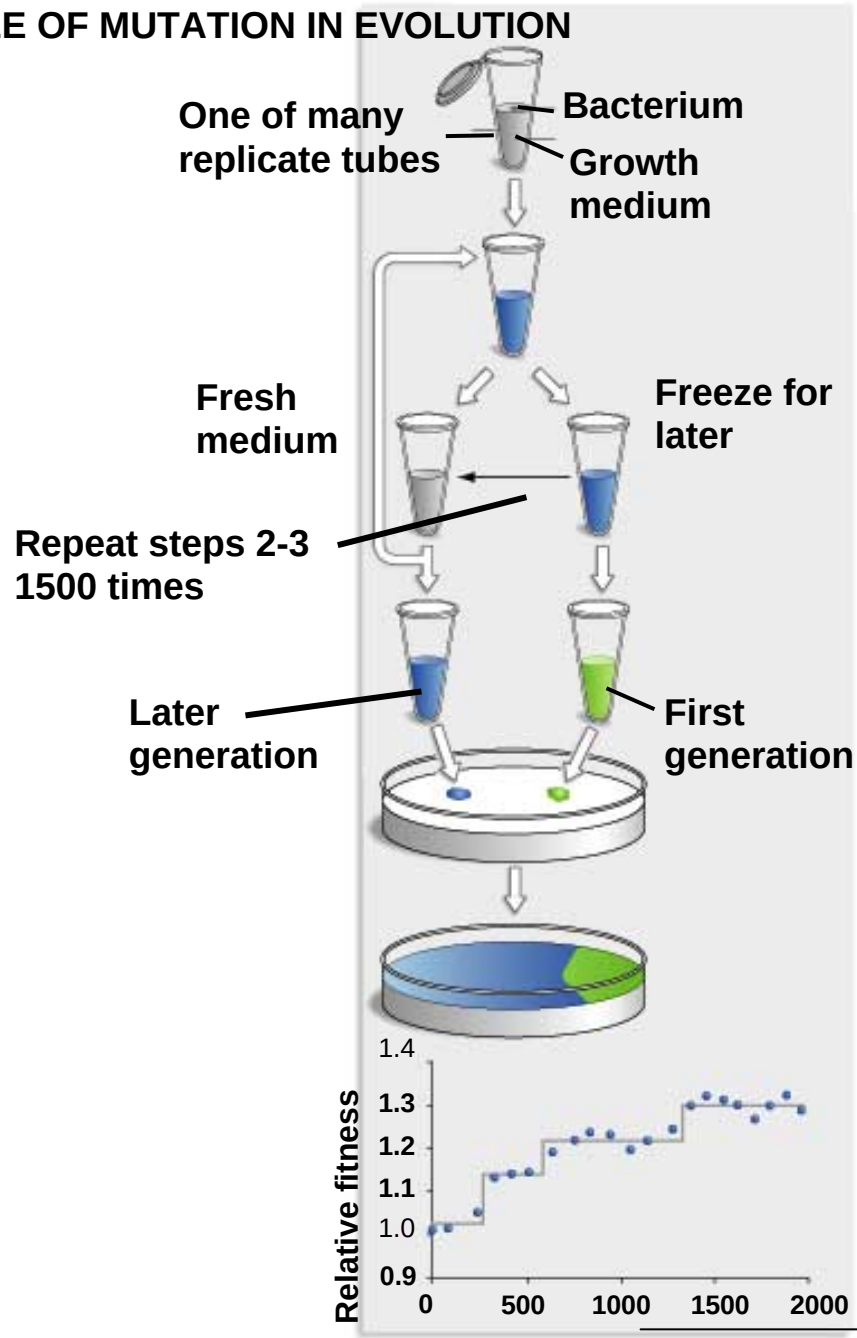
Mutation

- By itself, mutation is not an important cause of evolutionary change because it does not occur often enough.

Mutation

- When considered across genomes, and combined with natural selection, mutation becomes an evolutionary force.

TESTING THE ROLE OF MUTATION IN EVOLUTION



1. Start long-term experiment by placing 10 mL of identical growth medium and a genetically identical *E.* coli cell to many replicate tubes.

2. Incubate overnight. Average population in each tube is now 5×10^8 cells.

3. Remove 0.1 mL from each tube and move to 10 mL of fresh medium. Freeze remaining cells for later analysis.

4. Take cells from generation 1 and add a genetic marker so that they can be identified.

5. Put an equal number of cells from generation 1 and a later generation in fresh growth medium.

6. Incubate overnight and count the cells. Which are more numerous?

Migration

- Migration refers to the movement of alleles between populations. This is known as gene flow.

Migration

- It tends to eliminate genetic differences in populations by equalizing allele frequencies.

Migration

- Can be used as a conservation tool because it increases genetic diversity in small, isolated populations.

Genetic Drift

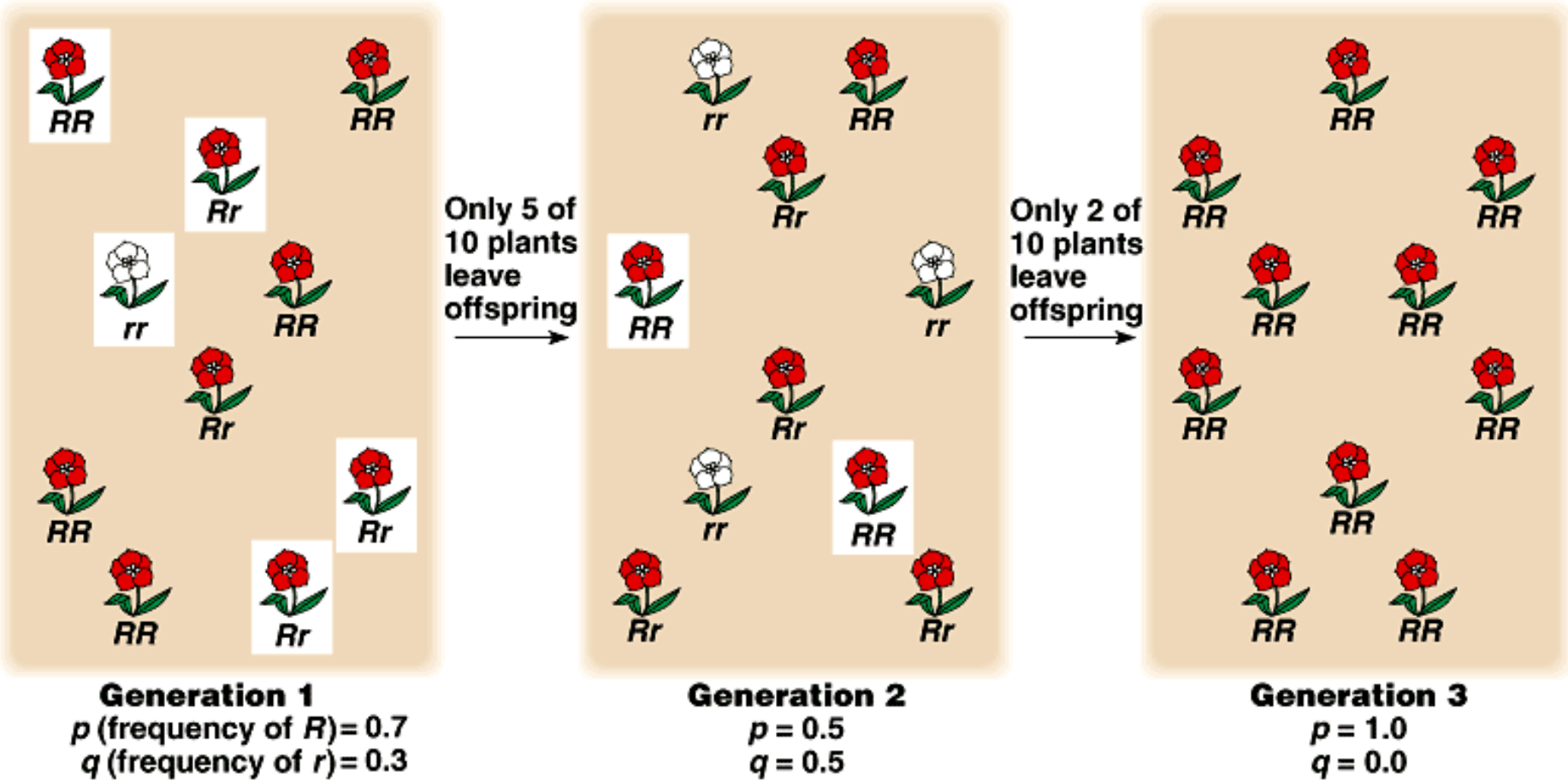
- This is any change in the allele frequencies in a population that is due to random chance.

Genetic Drift

- Genetic drift is much more pronounced in small populations.

Genetic Drift

- Drift can lead to the loss, or “fixation”, of alleles and can be intensified by a genetic bottleneck.



Natural Selection

- Selection is the only evolutionary mechanism that leads to nonrandom changes in allele frequencies.

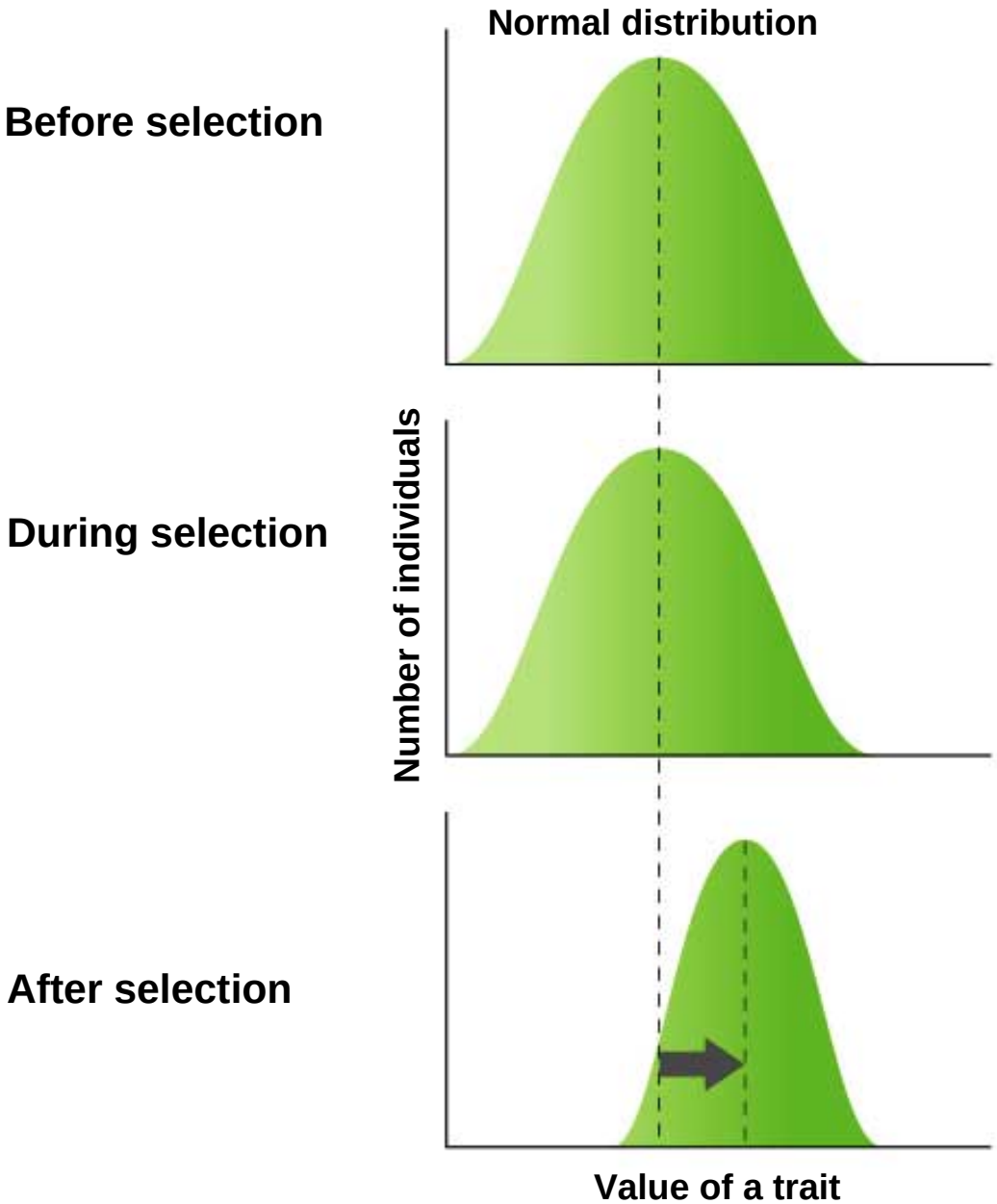
Natural Selection

- Natural selection can increase or decrease the amount of genetic diversity in a population.

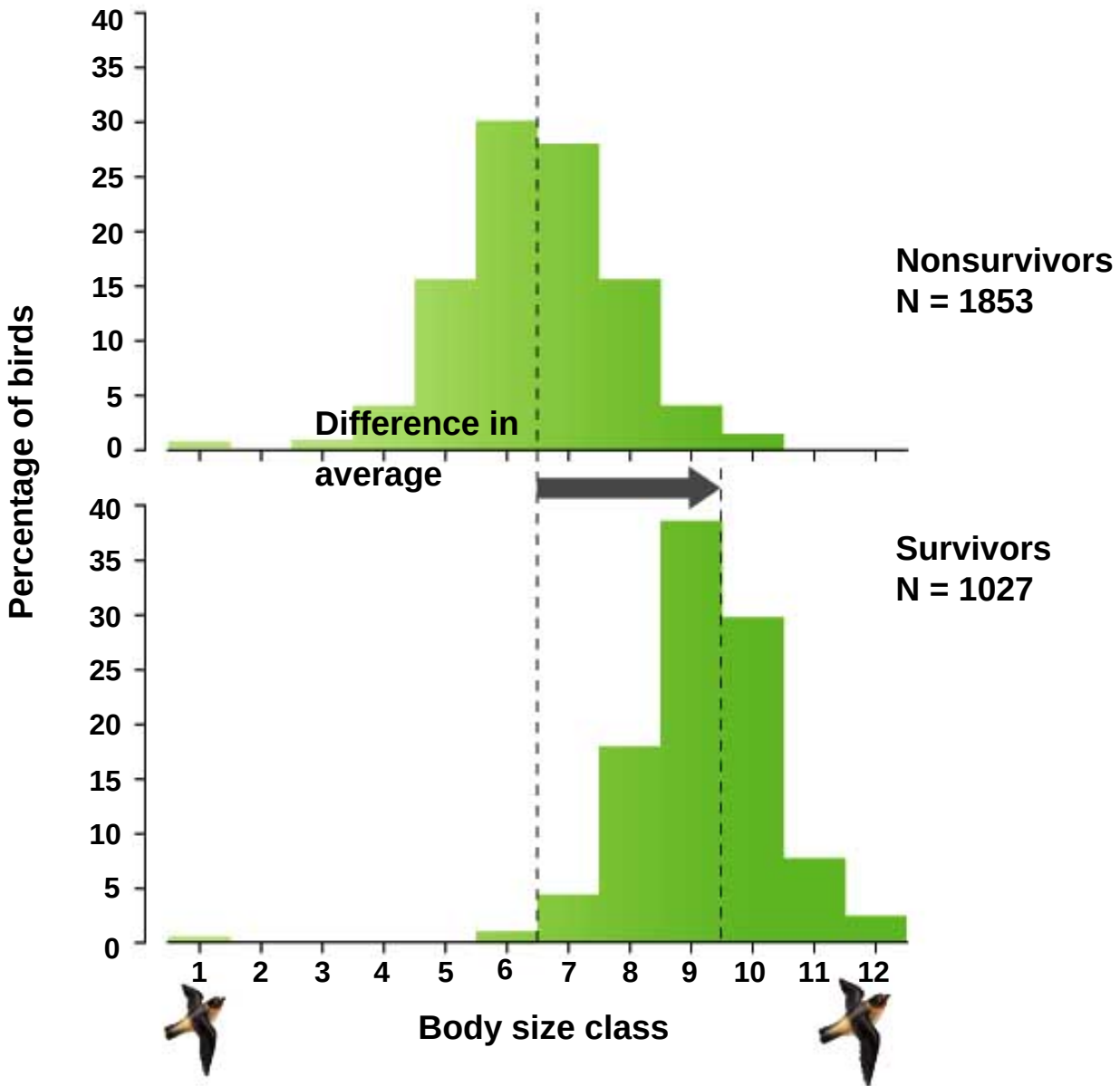
Natural Selection

- Types of natural selection:
  - Directional selection decreases diversity by favoring one extreme phenotype in the population.
  - Stabilizing selection decreases diversity by favoring the average phenotype over both extremes.
  - Disruptive selection increases diversity by favoring both extremes, and selecting against the average.

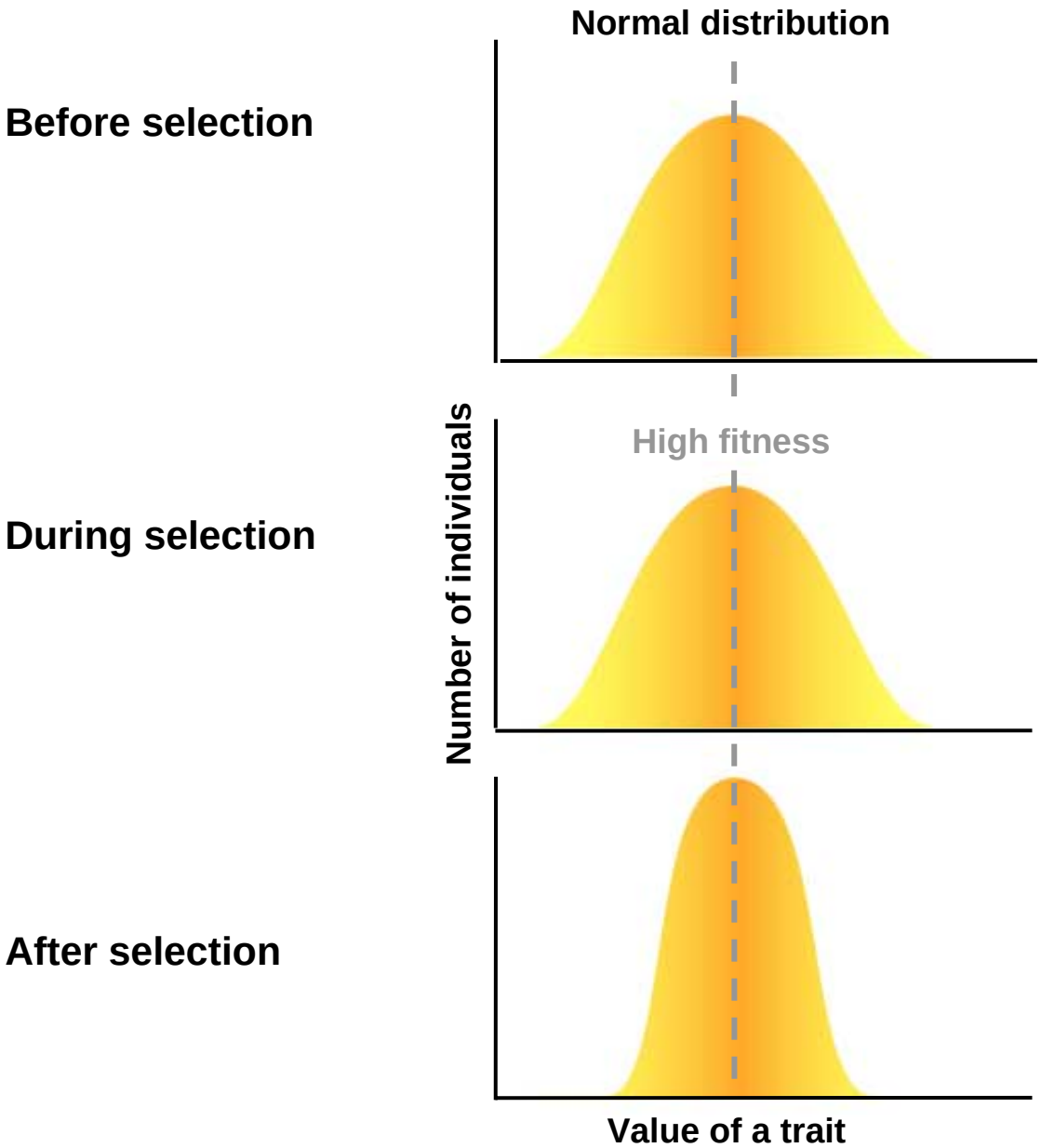
Directional selection changes the average value of a trait.



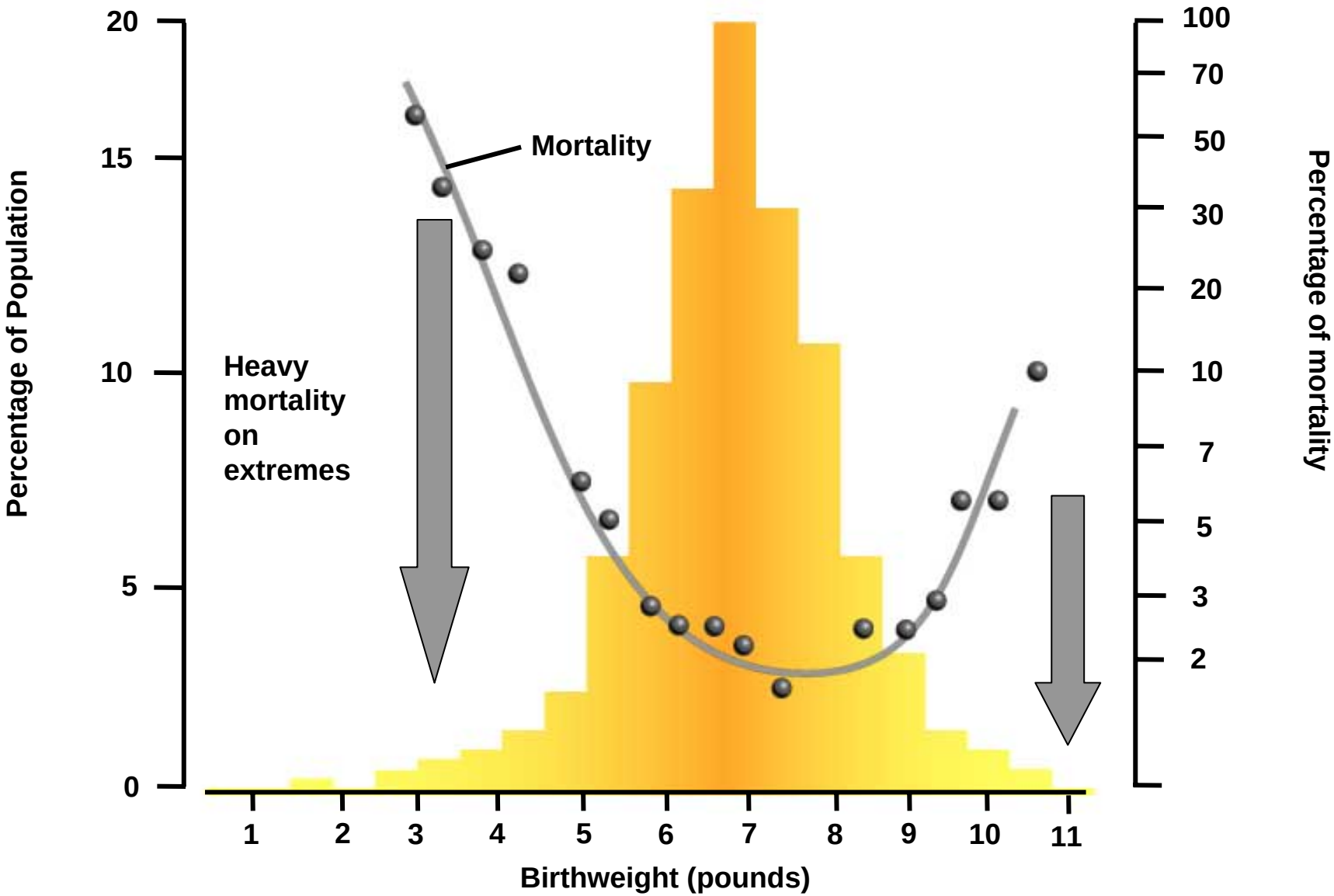
For example, directional selection caused overall body size to increase in a cliff swallow population



Stabilizing selection reduces the amount of variation in a trait.



For example, very small and very large babies are most likely to die, leaving a narrower distribution of birthweights.

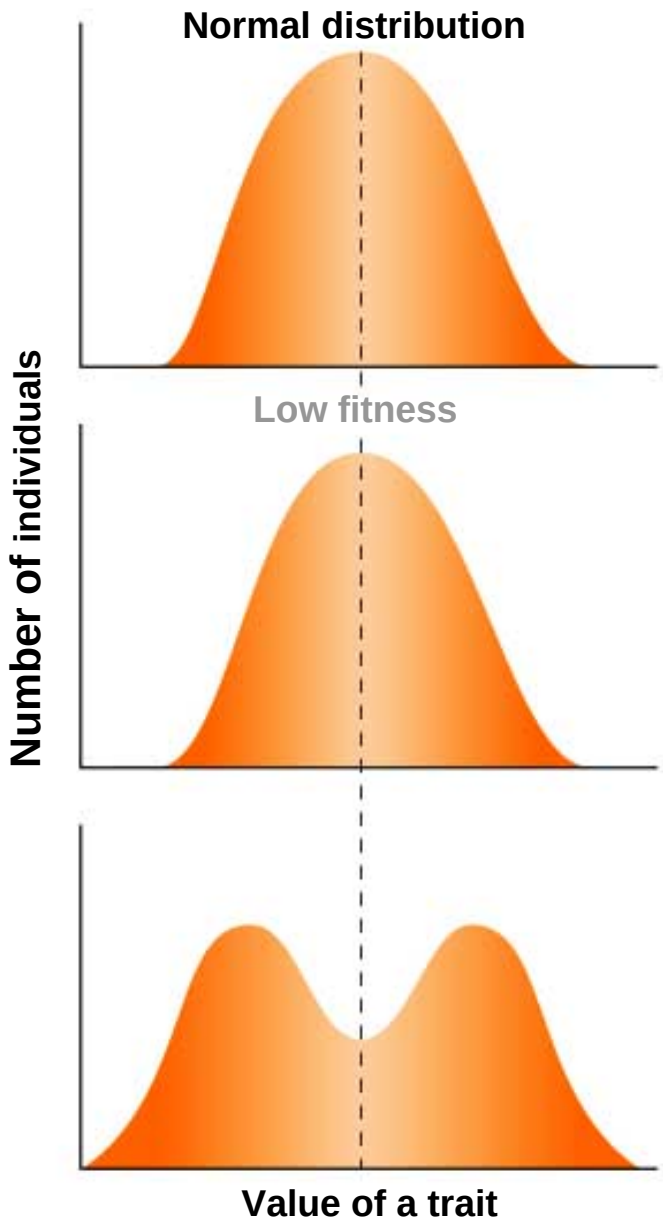


Disruptive selection increases the amount of variation in a trait.

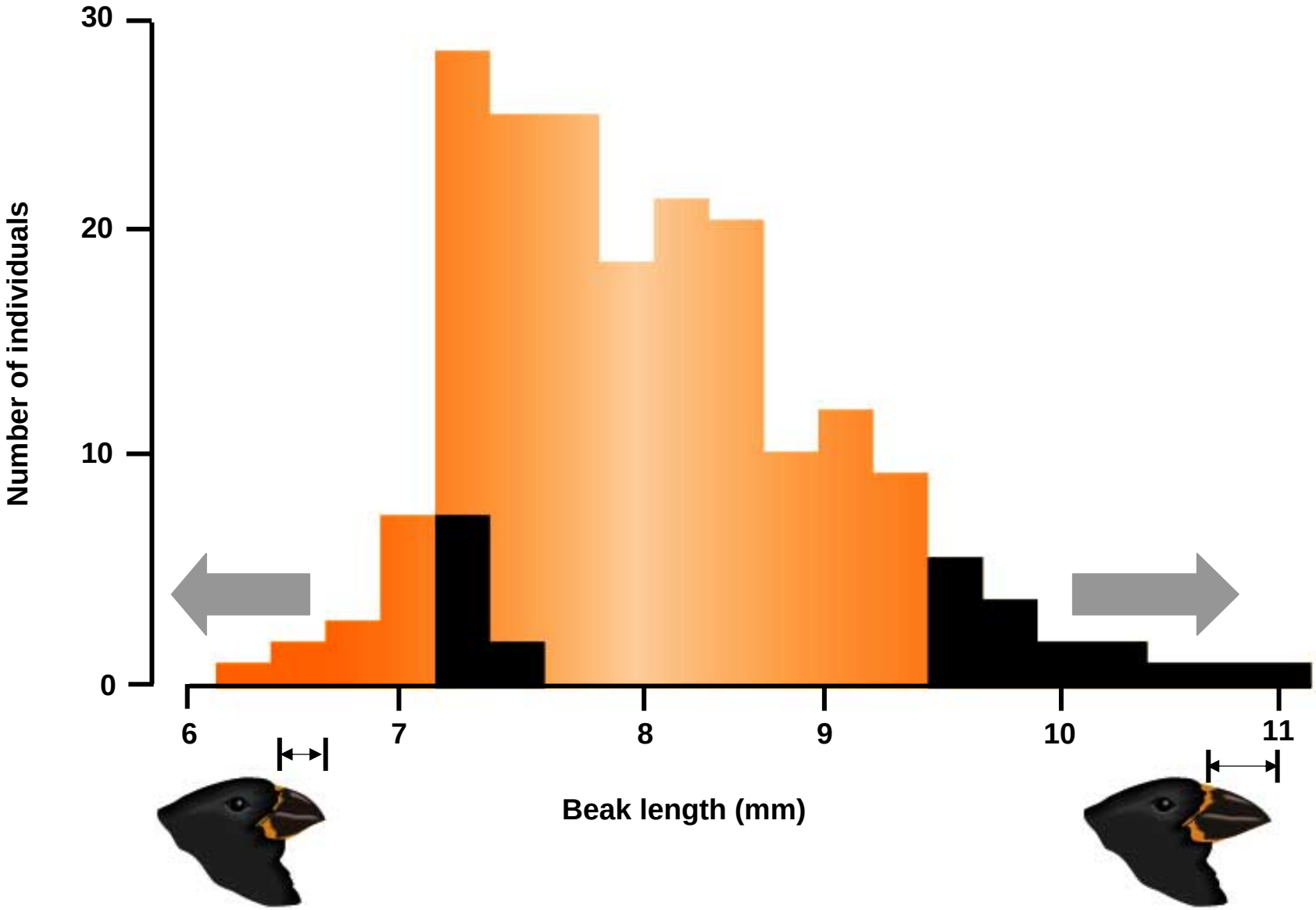
Before selection

During selection

After selection



For example, only juvenile blackbellied seedcrackers with very long or very short beaks survived long enough to breed.



Inbreeding

- A form of non-random mating.
- In nature, matings between individuals are seldom, if ever, random.
- In small populations, matings between relatives are common. This is known as inbreeding.

Inbreeding

- Inbreeding increases the proportion of homozygotes and reduces the proportion of heterozygotes in any population in which it occurs.
- Inbreeding depression is the loss of fitness that takes place when homozygosity is increased.

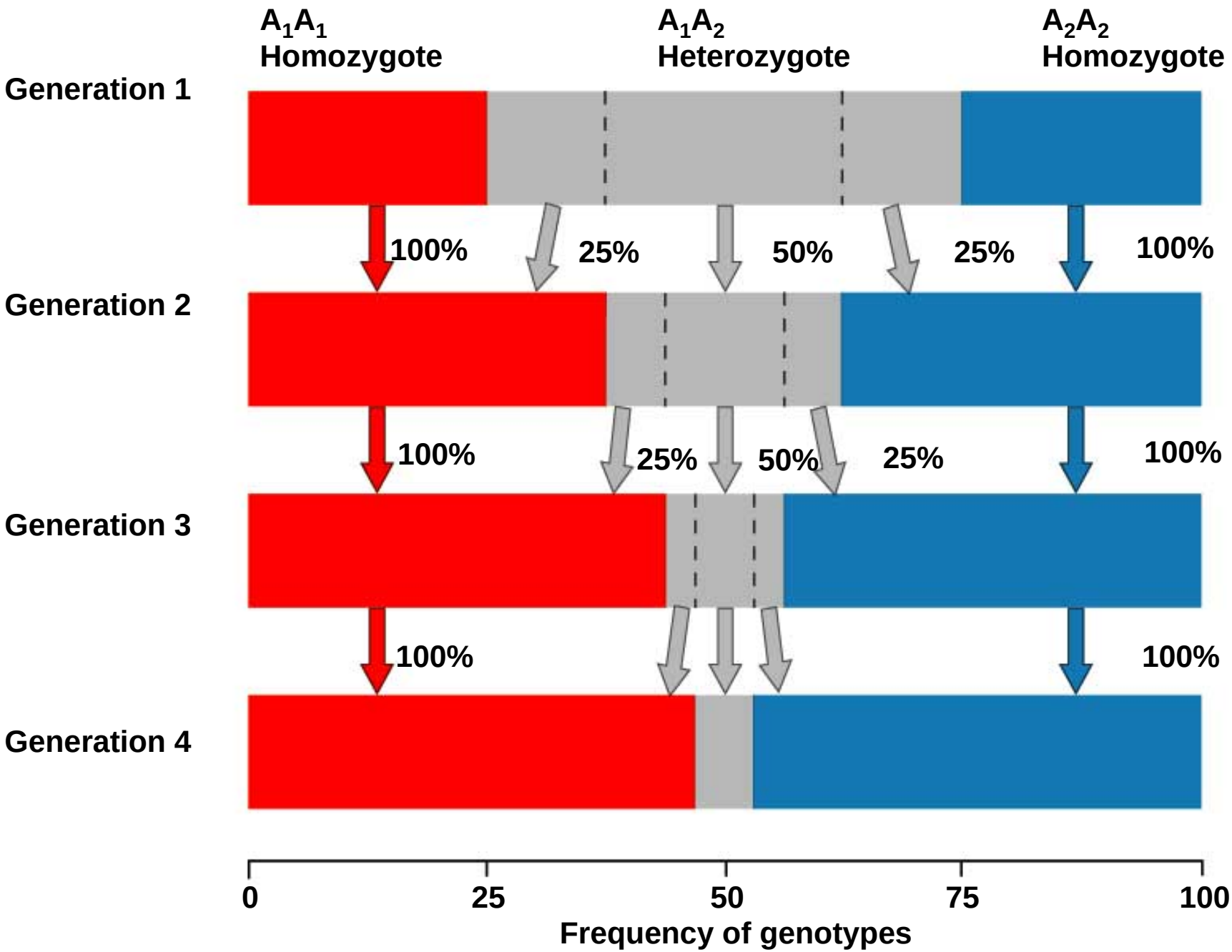


TABLE 22.3 Inbreeding Reduces Fitness in Humans

The percentages reported here give the mortality rate of children produced by first-cousin marriages versus marriages between nonrelatives. In every study, children of first-cousin marriages have a higher mortality rate.

Deaths	Period	Children of First Cousins (%)	Children of Nonrelatives (%)
Children under 20 (U.S.)	18th–19th century	17.0	12.0
Children under 10 (U.S.)	1920–1956	8.1	2.4
At/before birth (France)	1919–1950	9.3	3.9
Children (France)	1919–1950	14.0	10.0
Children under 1 (Japan)	1948–1954	5.8	3.5
Children 1-8 (Japan)	1948–1954	4.6	1.5

Source: C. Stern, Principles of Human Genetics (San Francisco: Freeman, 1973).

Inbreeding

- Inbreeding is an indirect cause of evolution because it increases the rate at which natural selection eliminates deleterious recessive alleles.
- Many species have mechanisms that help avoid or prevent inbreeding.

Sexual Selection

- Occurs when individuals in a population differ in their ability to attract mates. It is a form of nonrandom mating.
- Unlike inbreeding, it targets loci that code for mate choice traits and produces changes in allele frequencies.

Sexual Selection

- Sexual selection often results in sexual dimorphism.
  - Sexual selection usually acts on males much more strongly than females.
  - Females usually invest much more in their offspring than do males

(a) Beetle

(b) Sage grouse

(c) Cichlid

Females

Males

During the breeding season, males of the beetle *Dynastes granti* use their elongated mandibles to fight over females.

Each male sage grouse has a display territory. Males vie among themselves for the best territory. Females choose the male giving the best display as the father of their offspring.

In this species and many other cichlids from the Rift Lakes of Africa, males are brightly colored and perform courtship displays.