Mutation, Selection, Gene Flow, Genetic Drift, and Nonrandom Mating Results in Evolution

15.2
Intro

In biology, “evolution” refers specifically to changes in the genetic makeup of populations over time.

**Population**—a group of individuals of a single species that live and interbreed in a particular geographic area at the same time.

Individuals do not evolve; populations do.
Mutation Generates Genetic Variation

The origin of genetic variation is mutation.

**Mutation**—any change in nucleotide sequences.

Mutations occur randomly with respect to an organism’s needs; natural selection acts on this random variation and results in adaptation.
Mutation Generates Genetic Variation

Mutations can be deleterious, beneficial, or have no effect (neutral).
Mutation both creates and helps maintain genetic variation in populations.
Mutation rates vary, but even low rates create considerable variation.
Mutation Generates Genetic Variation

Because of mutation, different forms of a gene, or alleles, may exist at a locus.

Gene pool—sum of all copies of all alleles at all loci in a population

Allele frequency—proportion of each allele in the gene pool

Genotype frequency—proportion of each genotype among individuals in the population
Each oval represents a single individual

Three Alleles – $X_1$, $X_2$, $X_3$ – exist at a locus X in this population. Each diploid individual carries two copies of the gene, which may be the same or different alleles. No diploid individual can have more than two alleles.
An experiment demonstrates how mutations accumulate in populations:

- Lines of *E. coli* were grown in the laboratory for 20,000 generations, and genomes were sequenced every 5,000 generations.
- The lines accumulated about 45 changes to their genomes, and these changes appeared at a fairly constant rate.
Mutations Accumulate Continuously

These are 95% confidence limits for the expected numbers of mutations, if the rate is constant over time.

This line represents a constant rate of mutation accumulation.
Selection on Genetic Variation Leads to New Phenotypes

The gene pools of nearly all populations contain variation for many traits.

Selection that favors different traits can lead to many different lineages that descend from the same ancestor.

Artificial selection on different traits in a single species of wild mustard produced many crop plants.
Selection on Genetic Variation Leads to New Phenotypes

Many of Darwin’s observations of variation and selection came from domesticated plants and animals.

Darwin bred pigeons and recognized similarities between selection by breeders and selection in nature.

In both cases, selection simply increases the frequency of the favored trait from one generation to the next.
Artificial Selection
Selection on Genetic Variation Leads to New Phenotypes

Laboratory experiments also demonstrate genetic variation in populations.

Selection for certain traits in the fruit fly *Drosophila melanogaster* resulted in new combinations of genes that were not present in the original population.

Low- and high-selected populations do not overlap the original population.
Artificial Selection Reveals Genetic Variation

![Histogram showing genetic variation in bristle number under artificial selection.](image-url)
Natural selection increases the frequency of beneficial mutations in a population

Natural selection:
- Far more individuals are born than survive to reproduce.
- Offspring tend to resemble their parents but are not identical to their parents or to one another.
- Differences among individuals affect their chances of survival and reproduction, which will increase the frequency of favorable traits in the next generation.

- 5 Fingers of Evolution
- Crash Course – Natural Selection
Natural selection increases the frequency of beneficial mutations in a population

**Adaptation**—a favored trait that evolves through natural selection

Adaptation also describes the process that produces the trait.

Individuals with deleterious mutations are less likely to survive, reproduce, and pass their alleles on to the next generation.
Gene Flow

Migration of individuals or movement of gametes (e.g., pollen) between populations results in **gene flow**, which can change allele frequencies.
Genetic Drift

**Genetic drift**—random changes in allele frequencies from one generation to the next

In small populations, it can change allele frequencies.
- Harmful alleles may increase in frequency, or rare advantageous alleles may be lost.

Even in large populations, genetic drift can influence frequencies of neutral alleles.
**Genetic Drift**

**Population bottleneck**—an environmental event results in survival of only a few individuals  
- This can result in genetic drift and changing allele frequencies.

Populations that go through bottlenecks loose much of their genetic variation. This is a problem for small populations of endangered species.
Genetic Drift

**Founder effect**—genetic drift changes allele frequencies when a few individuals colonize a new area

- It is equivalent to a large population reduced by a bottleneck.

- Bozeman – Genetic Drift

![Prevalence and Founder Effect](image_url)
Nonrandom mating can change genotype or allele frequencies

Nonrandom mating:

Self-fertilization is common in plants. When individuals prefer others of the same genotype, homozygous genotypes will increase in frequency, and heterozygous genotypes will decrease.

Tale of the Peacock

NOVA: Creature Courtship
Nonrandom mating can change genotype or allele frequencies

**Sexual selection** occurs when individuals of one sex mate preferentially with particular individuals of the opposite sex rather than at random.

Some seemingly nonadaptive traits may make an individual more attractive to the opposite sex.

There may be a trade-off between attracting mates (more likely to reproduce) and attracting predators (less likely to survive).
Nonrandom mating can change genotype or allele frequencies

Studies of African long-tailed widowbirds showed that females preferred males with longer tails.

Males with artificially elongated tails attracted four times more females than males with artificially shortened tails.

Thus males with long tails pass on their genes to more offspring, which leads to the evolution of this unusual trait.
Sexual Selection in Action (Part 1)

**INVESTIGATION**

**HYPOTHESIS**
Female widowbirds prefer to mate with the male that displays the longest tail; longer-tailed males thus are favored by sexual selection because they will father more offspring.

**METHOD**
1. Capture males and artificially lengthen or shorten tails by cutting or gluing on feathers. In a control group, cut and replace tails to their normal length (to control for the effects of tail-cutting).
2. Release the males to establish their territories and mate.
3. Count the nests with eggs or young on each male’s territory.

**RESULTS**
Male widowbirds with artificially shortened tails established and defended display sites successfully but fathered fewer offspring than did control or unmanipulated males. Males with artificially lengthened tails fathered the most offspring.

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**CONCLUSION**
Sexual selection in *Euplectes progne* has favored the evolution of long tails in the male.