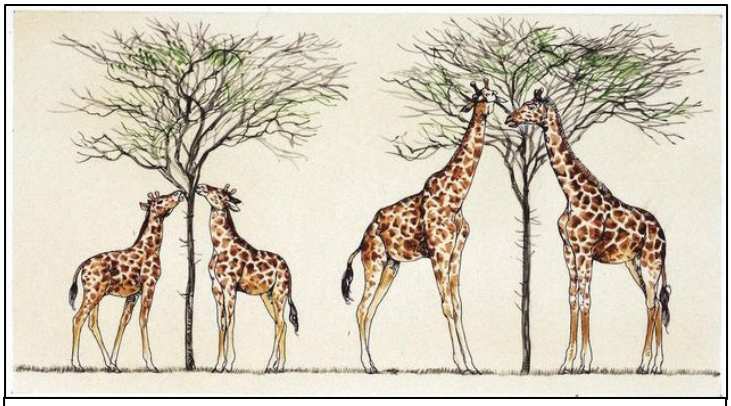
An Introduction to Evolutionary Theory

A Brief History of Evolutionary Thought

- Plato (400 BCE): Proposed the philosophy of *essentialism* in which the "essence" of a species is unchanging through time. This idea was held through the 1700s.
- Georges-Louis Leclerc, Comte du Buffon (1707-1788): Proposed the idea that species emerged in the form they were created in. He thought life was divided into a number of distinct types and that each species was made from an "internal mould." However, through migration, these moulds could be altered as a species moved into a new environment.
- Jean-Baptiste Lamarck (1774-1834): Proposed the idea that individuals acquire trait differences throughout their lives that are heritable, a principle referred to as *inheritance of acquired traits*.



Example of Lamarck's Proposed Idea: Originally, giraffes had short necks, but stretched their necks to reach foliage higher in trees. This caused their necks to lengthen, which was inherited by their offspring, resulting in giraffe's necks getting longer and longer over the course of many generations.

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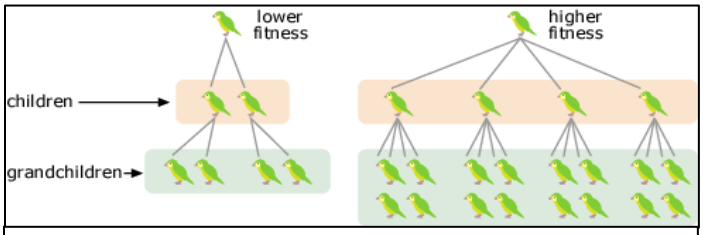
- Alfred Russel Wallace (1823-1913): Communicated with Darwin and proposed natural selection as a mechanism of evolutionary change in 1858. He came to this idea through studying the wildlife of South America and Asia.
- Charles Darwin (1809-1888): Proposed evolution by **natural selection** in 1858 and published *On the Origin of Species by Means of Natural Selection* in 1859. A key component of Darwin's theory was **descent with modification**. Unlike Lamarck's idea, the modifications Darwin proposed did not occur within an organism's lifetime. Rather, individuals within a population had variations of a trait that would give them a reproductive advantage. These traits were heritable and would be passed along through generations. Accumulations of these traits could result in one species diverging from another, leading to the various forms of life we see today.
- Gregor Mendel (1822-1884): Often referred to as the "Father of Genetics." Mendel developed laws of inheritance and published his findings in 1865, but they were not widely noticed until 1900. These laws of inheritance helped support Darwin's theory, as he did not have an explanation for inheritance of traits.
- Hugo de Vries (1848-1935): Rediscovered Mendel's work in the 1890s and coined the term **mutation**. He proposed the idea that evolution occurred in jumps due to big mutations.
- R.A. Fisher (1890-1962), J.B.S. Haldane (1892-1964), and Sewell Wright (1889-1988) were instrumental in the **modern evolutionary synthesis**. They used mathematical models to show that mutations and natural selection together cause adaptive evolution. Mutations are the basis of natural selection.

Mechanisms of Evolution

The term **evolution** is widely used throughout the sciences. Broadly, it refers to how an entity, whether it is a social system, gas, or even a planet, changes through time. Darwin perhaps captured the essence of biological evolution best with his phrasing of descent with modification. Through time, species accumulate differences that results in their descendants differing from their ancestors. Thus, new species arise from existing ones.

Natural selection is often thought to be synonymous with evolution, but that is not actually the case. Evolution can occur by processes other than natural selection. These mechanisms of evolution include:



Reproductive success is quantified by evolutionary biologists as **fitness**, the number of offspring surviving in the next generation. The fittest phenotype is the one that produces, on average, the greatest number of offspring. Selection favors the fittest phenotypes, which is a combination of survival, mating success, and number of offspring per mating. Thus, predicting fitness from a single component can be tricky because traits favored for one component of fitness may be a disadvantage to others.

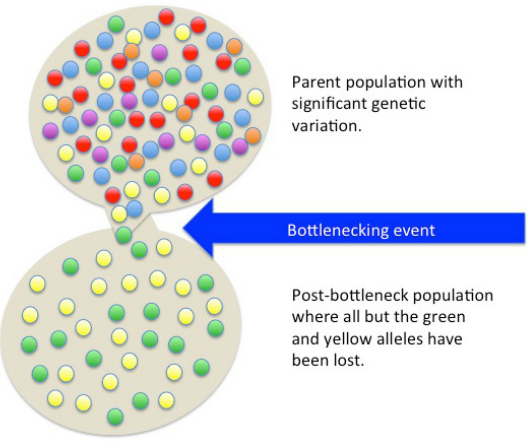
Image credit: University of California Museum of Paleontology's Understanding Evolution (http://evolution.berkeley.edu).

- **Mutation**: Mutations can result from errors made during the duplication of DNA. Our DNA has repair systems in place, should these errors occur. Unless that error is corrected, the errors of replication are inherited in the next generation. Most mutations are harmful and decrease the **fitness** (reproductive success) of the organism in which they occur. The mutations that aren't harmful, and thus weeded out, increase the genetic variation within a population and are the ultimate source of genetic variation upon which evolution can result.
- **Non-random Mating:** Individuals with certain **genotypes** occasionally mate with one another more often than would be expected on a random basis. This phenomenon is known as *nonrandom mating*. **Assortative mating** is a type of nonrandom mating in which organisms with a similar **phenotype** mate. This does not change the frequency of individual **alleles** but does increase the proportion of **homozygous** individuals in a population. Phenotypically similar individuals are likely to be genetically similar and are more likely to produce offspring who have two copies of the same allele (i.e. homozygous individuals).

- **Genotype:** the genetic makeup of the individual organism
- **Phenotype**: the observable characteristics of an organism resulting from its genotype (e.g. eye color)
- **Allele:** alternative forms of a **gene**
- **Homozygous:** Having two copies of an allele

- **Gene flow:** The movement of alleles from one population to another. Gene flow can be a powerful agent of change. Gene flow can be obvious, such as when an animal physically moves from one population/area to another. If the newly arrived individual has differing characteristics from the animals already there and is adapted well enough to survive and mate successfully, they can alter the genetic composition of the receiving population. Gene flow can also result from subtler movements of **gametes** (e.g. sperm and/or egg) or immature stages of plants or marine animals into another area. In addition, gene flow may occur from individuals from adjacent populations mating.

- **Genetic Drift**: Frequencies of certain alleles may change drastically by chance alone in small populations. These changes in allele frequencies may occur randomly, as if the frequencies were drifting from their original values. This phenomenon is known as genetic drift. Genetic drift can occur in any population size, though it is particularly likely to occur in populations founded by just a few individuals or populations that were reduced to a very small number at some time in the past. When genetic drift occurs, alleles that initially are uncommon are particularly vulnerable to being eradicated from a population.



Example of Genetic Drift: The **bottleneck effect**. Populations of organisms may be drastically reduced in size due to natural disasters or changes in the environment. Surviving individuals may constitute a random genetic sample of the original population. This can result in the loss of genetic variability. When a population is drastically reduced in numbers, such as in an endangered species, the bottleneck effect becomes a potential problem. The lack of genetic variation may mean the species is vulnerable to extinction, even if the population rebounds.

Image Source: Tsaneda. Wikimedia Commons.

- **Natural Selection:** Natural selection was proposed by Charles Darwin as a mechanism of evolution. Evolutionary change due to natural selection occurs when some individuals possess certain inherited characteristics and produce more surviving offspring exhibiting those characteristics than individuals lacking said characteristic. This results in the population gradually coming to include more and more individuals with the advantageous characterisitcs. Populations then evolve to become better **adapted** to its local circumstances.
    - An **adaptation** is any characteristic that enhances the survival or reproduction of organisms that bear it, relative to alternative characteristics. The only known mechanism to cause the evolution of adaptations is natural selection. Many biologists therefore define an adaptation as a characteristic that has evolved due to natural selection.

Conditions for Natural Selection to Occur:

1. **Variations must exist among individuals of a population.** Natural selection cannot operate if no variation exists as it works by favoring individuals with some traits over individuals with an alternative trait.
2. **Variation among individuals must result in differences in fitness.** This is the essence of natural selection. Some individuals are more successful than others in producing offspring than others due to their phenotype or behavior.
3. **Variation must be genetically inherited**. The selected differences must have a genetic basis for natural selection to result in evolutionary change.