Inquire: Understanding Evolution

Overview

Evolution is the process of adaptation through mutation, which allows more desirable characteristics to pass to the next generation. Over time, organisms evolve more characteristics that are beneficial to their survival. For living organisms to adapt and change to environmental pressures, genetic variation must be present. With genetic variation, individuals have differences in form and function that allow some to survive certain conditions better than others.

These organisms pass their favorable traits to their offspring. Eventually, environments change, and what was once a desirable, advantageous trait may become an undesirable trait and organisms may further evolve. Evolution may be convergent with similar traits evolving in multiple species or divergent with diverse traits evolving in multiple species that came from a common ancestor. We can observe evidence of evolution by means of DNA code and the fossil record, and also by the existence of homologous structures and vestigial structures.

Big Question: How is population genetics used to study the evolution of populations?

Watch: Genetic Diversity

Genetic diversity in a population comes from two main sources: mutation and sexual reproduction. Mutation, a change in DNA, is the ultimate source of new alleles, or new genetic variation in any population.

We call a heritable trait that helps an organism's survival and reproduction in its present environment an adaptation. Scientists describe organisms adapting to their environment when a genetic variation occurs over time that increases or maintains the population's “fit” to its environment. For instance, a platypus' webbed feet are an adaptation for swimming. A snow leopard's thick fur is an adaptation for living in the cold. A cheetah's fast speed is an adaptation for catching prey. These adaptation traits are now passed on to all platypus, snow leopards, and cheetahs. Charles Darwin, a scientist you will learn about more in the lesson, called this phenomenon natural selection.

Whether or not a trait is favorable depends on the current environmental conditions. The same traits are not always selected because environmental conditions can change. For example, consider a plant species that once grew in a moist climate and did not need to conserve water. Large leaves were selected because they allowed the plant to obtain more energy from the sun. Large leaves require more water to maintain than small leaves, and the moist environment provided favorable conditions to support large leaves. After thousands of years, the climate changed and the area no longer had excess water.
The direction of natural selection shifted so that plants with small leaves were selected because those populations were able to conserve water to survive the new environmental conditions.

Read: Understanding Evolution

Overview

All species of living organisms — from the bacteria on our skin, to the trees in our yards, to the birds outside — evolved at some point from a different species. Although it may seem that living things today stay much the same from generation to generation, that is not the case: evolution is ongoing. Evolution is the process through which the characteristics of species change and through which new species arise.

The theory of evolution is the unifying theory of biology, meaning it is the framework within which biologists ask questions about the living world. Its power is that it provides direction for predictions about living things in experiment after experiment. This lesson will explain some of the mechanisms for evolutionary change and the kinds of questions that biologists can, and have, answered using evolutionary theory.

Charles Darwin

In the mid-19th century, two naturalists, Charles Darwin and Alfred Russel Wallace, independently developed and described the actual mechanism for evolution. Importantly, each naturalist spent time exploring the natural world on expeditions to the tropics. From 1831 to 1836, Charles Darwin traveled around the world on H.M.S. Beagle, including stops in South America, Australia, and the southern tip of Africa. Wallace traveled to Brazil to collect insects in the Amazon rainforest from 1848 to 1852 and to the Malay Archipelago from 1854 to 1862.

Darwin’s journey, like Wallace’s later journeys to the Malay Archipelago, included stops at several island chains, the last being the Galápagos Islands west of Ecuador. On these islands, Darwin observed species of organisms on different islands that were clearly similar, yet had distinct differences. For example, the ground finches inhabiting the Galápagos Islands comprised several species with a unique beak shape. The species on the islands had assorted series of beak sizes and shapes, with very small differences between the most similar. He observed that these finches closely resembled another finch species on the South American mainland. Darwin imagined that the island species might be modified from one of the original mainland species. Upon further study, he realized that each finch’s varied beaks helped the birds acquire a specific type of food. For example, seed-eating finches had stronger, thicker beaks for cracking seeds, and insect-eating finches had spear-like beaks for stabbing their prey.

Natural Selection

Wallace and Darwin both observed similar patterns in other organisms, and they independently developed the same explanation for how and why such changes take place. Darwin called this natural selection. Natural selection, or “survival of the fittest,” is the reproduction of individuals with traits that allow them to survive environmental change or hardships. This leads to evolutionary change.

For example, Darwin observed a population of giant tortoises in the Galápagos Archipelago to have longer necks than those that lived on other islands with dry lowlands. These tortoises were “selected” because they could reach more leaves and access more food than those with short necks. In times of drought when fewer leaves would be available, those that could reach more leaves had a better chance to eat and survive than those that couldn’t reach the food source. Consequently, long-necked tortoises
would be more likely to pass the long-necked trait to their offspring. Over time, only long-necked tortoises would be present in the population.

Darwin argued that natural selection was an inevitable outcome of three principles that operated in nature. First, most characteristics of organisms are passed from parent to offspring. Although no one, including Darwin and Wallace, knew how this happened at the time, it was a common understanding.

Second, more offspring are produced than are able to survive, so resources for survival and reproduction are limited. The ability for reproduction in all organisms moves faster than the availability of resources to support their numbers. There is competition for those resources in each generation. Both Darwin and Wallace’s understanding of this principle came from reading an essay by economist Thomas Malthus that explained this principle in relation to human populations.

Third, offspring vary among each other in regard to their characteristics, and those variations are inherited. Darwin and Wallace reasoned that offspring with inherited characteristics, which allow them to best compete for limited resources, will survive and have more offspring than those individuals with variations that are less able to compete. Because characteristics are inherited, these traits will be better represented in the next generation. This will lead to change in populations over generations in a process that Darwin called descent with modification. Ultimately, natural selection leads to greater adaptation of the population to its local environment. It is the only mechanism known for adaptive evolution.

In 1858, Darwin and Wallace presented papers at the Linnean Society in London that discussed the idea of natural selection. The following year Darwin’s book, *On the Origin of Species*, was published. His book outlined in considerable detail his arguments for evolution by natural selection.

**Reflect: Plant Seeds**

Poll

If a person scatters a handful of plant seeds from one species in an area, do you think natural selection would work in this situation?

- Yes
- No

**Expand: Reconnection and Speciation Rates**

Processes and Patterns of Evolution

Natural selection can only take place if there is variation, or differences, among individuals in a population. Importantly, these differences must have some genetic basis; otherwise, the selection will not lead to change in the next generation. This is critical because non-genetic reasons can cause variation among individuals, such as an individual’s height, because of better nutrition rather than different genes.

The evolution of species has resulted in enormous variation in form and function. Sometimes, evolution gives rise to groups of organisms that become tremendously different from each other. We call two species that evolve in diverse directions from a common point divergent evolution. We can see such divergent evolution in the forms of the reproductive organs of flowering plants which share the same basic anatomies; however, they can look very different as a result of selection in different physical environments and adaptation to different kinds of pollinators.
In other cases, similar phenotypes evolve independently in distantly related species. For example, flight has evolved in both bats and insects; they both have structures we refer to as wings, which are adaptations to flight. However, bat and insect wings have evolved from very different original structures. We call this phenomenon **convergent evolution**, where similar traits evolve independently in species that do not share a common ancestry. The two species came to the same function — flying — but did so separately from each other.

These physical changes occur over enormous time spans and help explain how evolution occurs. Natural selection acts on individual organisms, which can then shape an entire species. Although natural selection may work on an individual in a single generation, it can take thousands, or even millions, of years for an entire species’ genotype to evolve. It is over these large time spans that life on earth has changed and continues to change.

**Lesson Toolbox**

**Additional Resources and Readings**

**Understanding Evolution**
- An interactive site to guess which bone structures are homologous and which are analogous, and see examples of evolutionary adaptations to illustrate these concepts
- https://evolution.berkeley.edu/evolibrary/article/similarity_hs_01

**The Making of a Theory: Darwin, Wallace, and Natural Selection — HHMI BioInteractive Video**
- A video providing an overview history of the theory of evolution
- https://www.youtube.com/watch?v=OolUZ3ycZwU

**Learn.Genetics**
- A natural selection interactive game
- http://learn.genetics.utah.edu/content/selection/comparative/

**Lesson Glossary**

**adaptation**: heritable trait or behavior in an organism that aids in its survival and reproduction in its present environment

**convergent evolution**: process by which groups of organisms independently evolve to similar forms

**divergent evolution**: process by which groups of organisms evolve in diverse directions from a common point

**evolution**: the process through which the characteristics of species change and through which new species arise

**homologous structures**: parallel structures in diverse organisms that have a common ancestor

**natural selection**: reproduction of individuals with favorable genetic traits that survive environmental change because of those traits, leading to evolutionary change

**variation**: genetic differences among individuals in a population

**vestigial structures**: physical structure present in an organism that has no apparent function and appears to be from a functional structure in a distant ancestor
Check Your Knowledge

1. Which scientific concept did Charles Darwin and Alfred Wallace independently discover?
   A. mutation
   B. natural selection
   C. overbreeding
   D. sexual reproduction

2. What are homologous structures?
   A. physical structures that have no apparent function
   B. parallel structures in diverse organisms
   C. physical structures that are used only occasionally
   D. similar structures in diverse organisms

3. Which is the best definition of adaptation?
   A. A trait or behavior that aids an organism’s survival and reproduction.
   B. A heritable trait or behavior that aids an organism’s survival and reproduction.
   C. A trait or behavior that aids a population’s survival and reproduction.
   D. A heritable trait or behavior that aids a population's survival and reproduction.

Answer Key:

Citations

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