Formation of New Species

Inquire: Speciation

Overview

Speciation occurs along two main pathways: geographic separation (allopatric speciation) and through mechanisms that occur within a shared habitat (sympatric speciation). Both pathways isolate a population reproductively in some form. Mechanisms of reproductive isolation act as barriers between closely related species, enabling them to diverge and exist as genetically independent species. Prezygotic barriers block reproduction prior to formation of a zygote; whereas, postzygotic barriers block reproduction after fertilization occurs. For a new species to develop, something must cause a breach in the reproductive barriers.

Big Question: What genetic variables lead to speciation?

Watch: Speciation

Speciation occurs when two (or more) distinct species form from one species. There are two types of speciations: (1) geographic or allopatric speciation or (2) shared habitat or sympatric speciation.

Allopatric speciation involves geographic separation of populations from a parent species and subsequent evolution. Scientists have documented numerous cases of allopatric speciation taking place. For example, along the west coast of the United States, two separate spotted owl subspecies exist. The northern spotted owl has genetic and phenotypic differences from its close relative: the Mexican spotted owl, which lives in the south.

Can speciation occur if no physical barriers are in place to separate individuals who continue to live and reproduce in the same habitat? The answer is yes. We call the process of speciation within the same space sympatric. Scientists have proposed and studied many mechanisms.

For example, consider a fish species that lives in a lake. As the population grows, competition for food increases. Under pressure to find food, suppose that a group of these fish had the genetic flexibility to discover and feed off another resource that other fish did not use. What if this new food source was located at a different depth of the lake? Over time, those feeding on the second food source would interact more with each other than the other fish; therefore, they would breed together as well. Offspring of these fish would likely behave as their parents: feeding and living in the same area and keeping separate from the original population. If this group of fish continued to remain separate from the first population, eventually sympatric speciation might occur as more genetic differences accumulated between them.
This scenario does play out in nature, as do others that lead to reproductive isolation. One such place is Lake Victoria in Africa, famous for its sympatric speciation of cichlid fish. Researchers have found hundreds of sympatric speciation events in these fish, which have not only happened in great number, but also over a short period of time. Cichlid fish from Lake Apoyeque, Nicaragua, show evidence of sympatric speciation. Lake Apoyeque, a crater lake, is 1800 years old, but genetic evidence indicates that a single population of cichlid fish populated the lake only 100 years ago. Nevertheless, two populations with distinct morphologies and diets now exist in the lake, and scientists believe these populations may be in an early stage of speciation.

Read: Formation of New Species

Overview
Given the extraordinary diversity of life on the planet, there must be processes for speciation: the formation of two species from one original species. For speciation to occur, two new populations must be formed from one original population, and they must evolve in such a way that it becomes impossible for individuals from the two new populations to interbreed. Biologists have proposed that this can fall into two broad categories. Allopatric speciation, meaning speciation in “other homelands,” involves a species being separated geographically from the original species and then evolving to form a new species. Sympatric speciation, meaning speciation in the “same homeland,” involves speciation occurring within a parent species while remaining in one location.

Biologists think of speciation events as the splitting of one ancestral species into two descendant species. However, there is no reason why speciation can’t produce more than two distinct species.

Speciation through Geographic Separation
A geographically continuous population has a gene pool that is relatively homogeneous, or of the same kind. Gene flow, the movement of alleles across the range of the species, is relatively free because individuals can move and then mate with individuals in their new location. Thus, the frequency of an allele at one end of a distribution will be similar to the frequency of the allele at the other end. When populations become geographically separated, the free flow of alleles is prevented. When that separation lasts for a period of time, the two populations are able to evolve along different paths. Their allele frequencies at numerous genetic locations gradually become more and more different as new alleles independently arise by mutation in each population. Typically, environmental conditions, such as climate, resources, predators, and competitors, for the two populations will differ causing natural selection to favor divergent adaptations in each group. Different histories of genetic drift, enhanced because the populations are smaller than the parent population, will also lead to divergence.

Isolation of populations leading to allopatric speciation can occur in a variety of ways: from a river forming a new branch, erosion forming a new valley, or a group of organisms traveling to a new location without the ability to return, such as seeds floating over the ocean to an island. The nature of the geographic separation necessary to isolate populations depends entirely on the biology of the organism and its potential for dispersal. If two flying insect populations took up residence in separate nearby valleys, chances are that individuals from each population would fly back and forth, continuing gene flow. However, if two rodent populations became divided by the formation of a new lake, continued gene flow would be unlikely; therefore, speciation would be more likely. Biologists group allopatric processes into two categories. If a few members of a species move to a new geographical area, this is called dispersal. If a natural situation arises to divide organisms physically, this is called vicariance.
Scientists have found that the further the distance between two groups that once were the same species, the more likely for speciation to take place. This seems logical because as the distance increases, the various environmental factors would likely have less in common than locations in close proximity.

Consider the two owls; in the north, the climate is cooler than in the south; the other types of organisms in each ecosystem differ, as do their behaviors and habits; also, the hunting habits and prey choices of the owls in the south vary from the northern ones. These variances can lead to evolved differences in the owls, and over time, speciation will likely occur unless gene flow between the populations is restored.

In some cases, a population of one species disperses throughout an area, and each finds a distinct niche or isolated habitat. Over time, the varied demands of their new lifestyles lead to multiple speciation events originating from a single species, which is called adaptive radiation. From one point of origin, many adaptations evolve causing the species to radiate into several new ones. Island archipelagos like the Hawaiian Islands provide an ideal context for adaptive radiation events because water surrounds each island, which leads to geographical isolation for many organisms. The Hawaiian honeycreeper illustrates one example of adaptive radiation. From a single species, called the founder species, numerous species have evolved.

Change in the genetic variation for beaks in response to natural selection based on specific food sources in each new habitat led to evolution of a different beak suited to the specific food source. The fruit and seed-eating birds have thicker, stronger beaks which are suited to break hard nuts. The nectar-eating birds have long beaks to dip into flowers to reach their nectar. The insect-eating birds have beaks like swords, appropriate for stabbing and impaling insects. Darwin’s finches are another well-studied example of adaptive radiation in an archipelago.

Speciation without Geographic Separation

Can divergence occur if no physical barriers are in place to separate individuals who continue to live and reproduce in the same habitat? A number of mechanisms for sympatric speciation have been proposed and studied.

One form of sympatric speciation can begin with a chromosomal error during meiosis or the formation of a hybrid individual with too many chromosomes. Polyploidy is a condition in which a cell, or organism, has an extra set, or sets, of chromosomes. Scientists have identified two main types of polyploidy that can lead to reproductive isolation of an individual in the polyploid state. In some cases a polyploid individual will have two or more complete sets of chromosomes from its own species resulting in an autopolyploid. The prefix “auto” means self, so the term means multiple chromosomes from one’s own species. Polyploidy results from an error in meiosis in which all of the chromosomes move into one cell instead of separating.

The cultivated forms of wheat, cotton, and tobacco plants are all allopolyploids. Although polyploidy occurs occasionally in animals, most chromosomal abnormalities in animals are lethal; it takes place most commonly in plants. Scientists have discovered more than half of all plant species studied relate back to a species evolved through polyploidy.
Reflect: Experiencing Speciation

Poll
Think of the last time you were outdoors. What surrounded you? Trees? Animals? Water? What type of speciation did you observe?
- Allopatric Speciation
- Sympatric Speciation

Expand: Reproductive Isolation

Discover
Given enough time, the genetic and phenotypic divergence between populations will affect characters that influence reproduction. If individuals of the two populations were brought together, mating would be less likely; but if mating occurred, offspring would be non viable or infertile. Many types of diverging characters may affect the reproductive isolation, the ability to interbreed, of the two populations.

Reproductive isolation can take place in a variety of ways. Scientists organize them into two groups: prezygotic barriers and postzygotic barriers. Recall that a zygote is a fertilized egg: the first cell of an organism's development that reproduces sexually. Therefore, a prezygotic barrier is a mechanism that blocks reproduction from taking place. This includes barriers that prevent fertilization when organisms attempt reproduction. A postzygotic barrier occurs after zygote formation. This includes organisms that don’t survive the embryonic stage and those that are born sterile.

Some types of prezygotic barriers prevent reproduction entirely. Many organisms only reproduce at certain times of the year, often just annually. Differences in breeding schedules, which we call temporal isolation, can act as a form of reproductive isolation. For example, two frog species inhabit the same area, but one reproduces from January to March; whereas, the other reproduces from March to May.

In some cases, populations of a species move or are moved to a new habitat and take up residence in a place that no longer overlaps with the same species' other populations. We call this situation habitat isolation. Reproduction with the parent species ceases, and a new group exists that is now reproductively and genetically independent. For example, a cricket population that was divided after a flood could no longer interact with each other. Over time, natural selection forces, mutation, and genetic drift will likely result in the two groups diverging.

Behavioral isolation occurs when the presence or absence of a specific behavior prevents reproduction. For example, male fireflies use specific light patterns to attract females. Various firefly species display their lights differently. If a male of one species tried to attract the female of another, she would not recognize the light pattern and would not mate with the male.

Other prezygotic barriers work when differences in their gamete cells (eggs and sperm) prevent fertilization from taking place. We call this a gametic barrier. Similarly, in some cases, closely related organisms try to mate, but their reproductive structures simply do not fit together. For example, damselfly males of different species have differently shaped reproductive organs. If one species tries to mate with the female of another, their body parts simply do not fit together.
In plants, certain structures aimed to attract one type of pollinator simultaneously prevent a different pollinator from accessing the pollen. The tunnel through which an animal must access nectar can vary widely in length and diameter, which prevents the plant from cross-pollinating with a different species.

When fertilization takes place and a zygote forms, postzygotic barriers can prevent reproduction. Hybrid individuals in many cases cannot form normally in the womb and simply do not survive past the embryonic stages. We call this hybrid inviability because the hybrid organisms simply are not viable. In another postzygotic situation, reproduction leads to hybrid birth and growth that is sterile. Therefore, the organisms are unable to reproduce offspring of their own. We call this hybrid sterility.

**Lesson Toolbox**

**Additional Resources and Readings**

Speciation: Of Ligers & Men - Crash Course Biology #15
- A Crash Course Biology video covering speciation
- https://www.youtube.com/watch?v=2oKlKmrbLoU

PBS
- An interactive activity allowing you to see how island birds evolved in evolutionary increments from five million years ago to today

BioInteractive
- An animation featuring the anole lizards as an example of how a single species can split and multiply into many different species with distinct traits
- https://www.hhmi.org/biointeractive/anole-lizards-example-speciation

**Lesson Glossary**

- **adaptive radiation**: speciation when one species radiates to form several other species
- **allopatric speciation**: speciation that occurs via geographic separation
- **allopolyploids**: polyploidy formed between two related, but separate species
- **autopolyploid**: polyploidy formed within a single species
- **behavioral isolation**: type of reproductive isolation that occurs when a specific behavior or lack of one prevents reproduction from taking place
- **dispersal**: an allopatric speciation that occurs when a few members of a species move to a new geographical area
- **gametic barrier**: prezygotic barrier occurring when closely related individuals of different species mate, but differences in their gamete cells (eggs and sperm) prevent fertilization from taking place
- **habitat isolation**: reproductive isolation resulting when species’ populations move or are moved to a new habitat, taking up residence in a place that no longer overlaps with the same species’ other populations
- **postzygotic barrier**: reproductive isolation mechanism that occurs after zygote formation
- **prezygotic barrier**: reproductive isolation mechanism that occurs before zygote formation
- **reproductive isolation**: situation that occurs when a species is reproductively independent from other species; behavior, location, or reproductive barriers may cause this to happen
- **speciation**: formation of a new species
- **species**: group of populations that interbreed and produce fertile offspring
- **sympatric speciation**: speciation that occurs in the same geographic space
**temporal isolation**: differences in breeding schedules that can act as a form of prezygotic barrier leading to reproductive isolation

**vicariance**: allopatric speciation that occurs when something in the environment separates organisms of the same species into separate groups

**Check Your Knowledge**

1. What is the main difference between autopolyploid and allopolyploid?
   A. the number of chromosomes
   B. the functionality of the chromosomes
   C. the source of the extra chromosomes
   D. the number of mutations in the extra chromosomes

2. __________ occurs when a species is reproductively independent from other species; behavior, location, or reproductive barriers may cause this to happen.
   A. Behavioral isolation
   B. Reproductive isolation
   C. Habitat isolation
   D. Temporal isolation

3. A ________ is the offspring of two closely related individuals.
   A. hybrid
   B. species
   C. vicariance
   D. speciation

**Answer Key**

1. C  2. B  3. A

**Citations**

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