

Introduction

- All species of organisms, living and extinct, are believed to be descended from a single ancestral species that lived more than 3 billion years ago.

What Are Species?

- The literal meaning of species is “kinds.”
- Animals often use appearance to distinguish one species from another or recognize members of the same species in different geographic locations. (See Figure 24.2.)
- Not all members of a species look the same.
 - Young animals or male and female animals of the same species may appear unrelated.
- The concept of genetic integration has been used to differentiate between species.
 - Genetic integration works on the premise that if individuals within a population mate with one another but not with individuals of other populations, they are an independent evolutionary unit (usually called a species).
- Over 200 years ago, Carolus Linnaeus created the system of naming organisms that we use today.
 - Linnaeus classified organisms based on their appearance, using a morphological concept of species.
 - Many species that were classified this way were actually independent evolutionary units.
- Genetic information is used today to help determine if morphologically similar organisms are actually different species.
- In 1940 Ernst Mayr proposed the “biological” definition of species: “Species are groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups.”
- Determining if two populations are actually different species can be difficult because speciation is often gradual. (See Figure 24.3.)

How Do New Species Arise?

- Speciation is the process by which one species splits into two species.
- Not all evolutionary changes result in new species.
- The critical process in the formation of new species is the segregation of the gene pool of the ancestral species into two separate gene pools.
- Speciation is facilitated by interruption of gene flow among populations.
- Gene flow among populations may be interrupted in several ways.

Allopatric speciation requires total genetic isolation

- Speciation that results when a population is divided by a geographic barrier is known as allopatric speciation or geographic speciation. (See Figure 24.4 and Animated Tutorial 24.2.)
- Allopatric speciation is thought to be the dominant form of speciation among most groups of organisms.
- Allopatric speciation also may result when some members of a population cross a barrier and form a new, isolated population.
 - Populations established in this way differ genetically from the parent populations because the groups of founding individuals have an incomplete representation of the gene pool of the parent population. This is called the founder effect.
 - New populations of fruit flies founded by individuals dispersing among the Hawaiian islands exemplify the founder effect. (See Figure 24.5.)
- The finches of the Galápagos archipelago demonstrate the importance of geographic isolation for speciation. (See Figure 24.6.)
- A barrier’s effectiveness at preventing gene flow depends on the size and mobility of the species in question.
 - For example, an impenetrable barrier for a terrestrial snail may be not be a barrier for a butterfly.

Sympatric speciation occurs without physical barriers

- A partition of a gene pool that occurs without physical separation is called sympatric speciation.
- The most common means of sympatric speciation is polyploidy, an increase in the number of chromosomes.
- Polyploidy arises in two ways.
 - One way is the accidental production of cells that have four sets (tetraploid) instead of the usual two sets (diploid) of chromosomes. (See Figure 24.7.)
 - Autopolyploid individuals have more than two sets of chromosomes.
 - A tetraploid individual cannot mate with diploid individuals and produce viable offspring.

- Polyploid species can also be produced when individuals from two different, but closely related, species interbreed, or hybridize.
 - Allopolyploids are usually fertile because each of the chromosomes has a nearly identical partner to pair with during meiosis.
- Polyploidy can create new species of plants more easily than it can create new species of animals because plants of many species can reproduce by self-fertilization.
 - Botanists estimate that 70 percent of flowering plants and 95 percent of ferns are polyploids.
- The speed with which allopolyploidy can produce new species is illustrated by the salsifies (*Tragopogon*), which have developed new species in about 50 years. (See Figure 24.8.)
 - Three diploid species of salsify were introduced into North America early in the twentieth century.
 - Two tetraploid hybrids between species of the original three were reported in 1950.
 - Both tetraploid species are now more widespread than the diploid parent species.
- (See Animated Tutorial 24.1.)

Completing Speciation: Reproductive Isolating Mechanisms

- Once a barrier to gene flow is established, the resulting daughter populations may diverge genetically because of the action of evolutionary agents.
- Geographic isolation does not necessarily lead to reproductive incompatibility, however, as evidenced by European and American sycamores. (See Figure 24.9.)
- Reproductive isolating mechanisms (formation of traits that prevent interbreeding between populations) result from a number of conditions.

Prezygotic barriers operate before fertilization

- Several prezygotic reproductive barriers have been described:
 - Spatial isolation of individuals of different species within their environment may mean that they never come into contact during their respective mating periods.
 - Temporal isolation is reproductive isolation by time if the mating seasons of two species do not overlap.
 - Mechanical isolation refers to differences in size and shape of the reproductive organs in different species, preventing the union of gametes.
 - Gametic isolation is the separation of species because of the inability of sperm from one species to fertilize the egg of another species.
 - Behavioral isolation occurs when individuals of a species may reject, or fail to recognize, individuals of other species as mating partners.
 - *Laupala paranga* and *Laupala kohalensis* are two closely related species of crickets from Hawaii that provide an example of behavioral isolation.
 - Males of these species produce genetically determined songs that differ in the number of pulses per second. (See Figure 24.10.)
 - Females are much more strongly attracted to the songs of their own species.
 - The genetic basis for this preference was demonstrated when it was shown that hybrid females are most strongly attracted to the songs of hybrid males.
- The mate choice of one species can be mediated by the behavior of individuals of other species. For example, whether two plant species hybridize may depend on the preferences of their pollinators.
 - The evolution of floral traits that generate reproductive isolation has been studied in the columbines of the genus *Aquilegia*.
 - *Aquilegia formosa* and *Aquilegia pubescens* are two columbine species that can produce fertile hybrids, but rarely do so in nature.
 - Genetically based differences in flower color result in each species attracting a different pollinator. (See Figure 24.11.)

Postzygotic barriers operate after fertilization

- If individuals of two different species overcome prezygotic reproductive barriers and interbreed, postzygotic reproductive barriers may prevent gene exchange.
- Several postzygotic reproductive barriers have been described:
 - Hybrid zygote abnormality is the failure of a hybrid zygote to develop to a reproductively viable stage of life.
 - Hybrid infertility is the inability of a hybrid to reproduce. Mules are an example.
 - Hybrid offspring may have low hybrid viability; they may be less viable than offspring resulting from mating within each species.

- If hybrid offspring survive poorly, more effective prezygotic barriers may evolve, known as reinforcement.
 - Reinforcement is difficult to detect experimentally, but has been detected using the comparative method in a study involving related sympatric and allopatric species of *Drosophila*. (See Figure 24.12.)

We can observe speciation in progress

- Many examples of populations at different stages on the way to complete reproductive isolation can be found.
- The picture-winged fruit fly, *Rhagoletis pomonella*, provides an example of speciation in progress.
 - Until the mid-1800s, these fruit flies courted, mated, and deposited their eggs only on hawthorn fruits.
 - About 150 years ago, commercial apple orchards were planted in the Hudson River Valley, near the natural habitat of *Rhagoletis*.
 - Apple trees are closely related to hawthorns, and some of the female *Rhagoletis* laid their eggs on apples instead of hawthorns, perhaps mistakenly.
 - Although fewer larvae survived on apples than on hawthorns, those that did recognized the odor of the apples and thus sought out apple trees for mating when they emerged as adults.
 - The two types of *Rhagoletis* that now exist in the Hudson River valley—one that feeds on apples and one that feeds on hawthorns—may be on their way to becoming distinct species.
- Reproductive isolation may develop rapidly or slowly depending on the species.

Hybrid Zones: Incomplete Reproductive Isolation

- If contact is reestablished between formerly isolated populations before reproductive isolation is complete, members of the two populations may interbreed.
- There are three possible outcomes of such interbreeding.
 - If hybrid offspring are as successful as those resulting from matings within each population, hybrids may spread through both populations and reproduce, combining the two gene pools so that no new species result from the period of isolation.
 - If hybrid offspring are less successful, complete reproductive isolation may evolve as reinforcement strengthens prezygotic barriers.
 - A narrow hybrid zone may persist if reinforcement does not occur.
- Hybrid zones provide natural laboratories for the study of speciation, containing recombinant individuals resulting from many generations of hybridization.
- European toads of the genus *Bombina* have been the subject of such studies.
 - The fire-bellied toad lives in eastern Europe, whereas the closely related yellow-bellied toad lives in western and southern Europe.
 - The ranges of the two species meet in a narrow zone that stretches 4,800 km, from eastern Germany to the Black Sea.
 - Although hybrids of the two species have been determined to be half as fit as purebred individuals, this narrow hybrid zone has persisted for hundreds of years because there has been no opportunity for reinforcement to occur. (See Figure 24.13.)
- Molecular biology techniques allow scientists to measure genetic differences among species.
- Studies of Hawaiian fruit flies are demonstrating that many sympatric species may be genetically very similar. (See Figure 24.14.)