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Species and Their Formation



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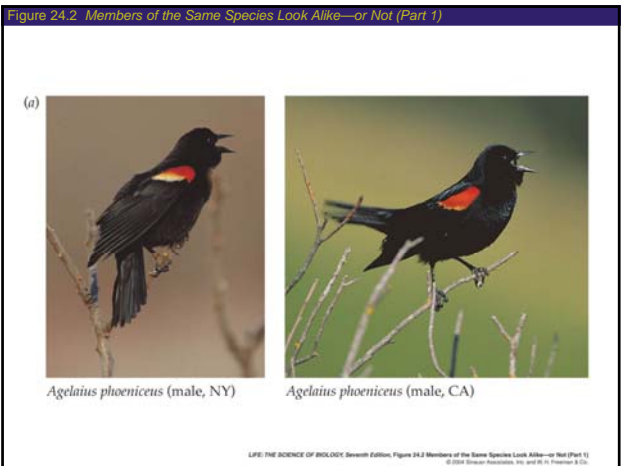
Species and Their Formation

- What Are Species?
- How Do New Species Arise?
- Completing Speciation: Reproductive Isolating Mechanisms
- Hybrid Zones: Incomplete Reproductive Isolation
- Variation in Speciation Rates
- Evolutionary Radiations

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What Are Species?

- The literal meaning of species is “kinds.”
- Not all members of a species look the same. For example, 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.
- If individuals within a population mate with one another but not with individuals of other populations, they are an independent evolutionary unit.

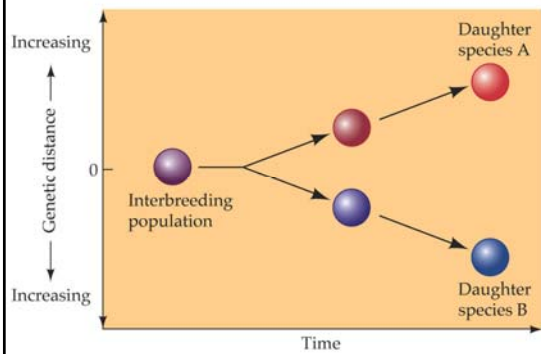


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What Are Species?

- Over 200 years ago, Carolus Linnaeus created the system of naming organisms that we use today, using a **morphological concept** of species.
- In 1940 Ernst Mayr proposed the **biological species concept**: “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.

Figure 24.3 Speciation May Be a Gradual Process



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How Do New Species Arise?

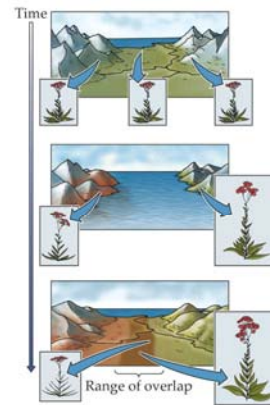
- **Speciation** is the process by which one species splits into two species.
- Not all evolutionary changes result in new species.
- The critical process in the formation of new species is the segregation of the gene pool of the ancestral species into two separate gene pools.
- Speciation is facilitated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

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How Do New Species Arise?

- Speciation that results when a population is divided by a geographic barrier is known as **allopatric speciation** or **geographic speciation**.
- Allopatric speciation is thought to be the dominant form of speciation among most groups of organisms.

Figure 24.4 Allopatric Speciation



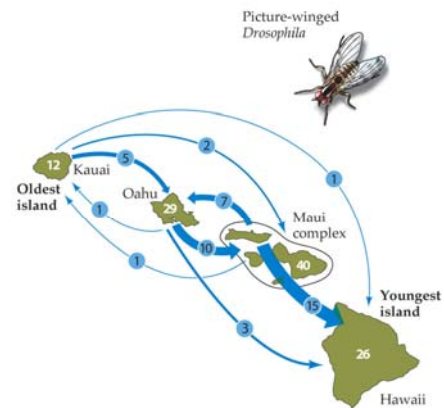
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How Do New Species Arise?

- 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 of the **founder effect**.
- A small group of founding individuals has an incomplete representation of the gene pool of the parent population.

Figure 24.5 Founder Events Lead to Allopatric Speciation



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How Do New Species Arise?

- The finches of the Galápagos archipelago demonstrate the importance of geographic isolation for speciation.
- The 14 species of finches arose by speciation from a single South American species.
- The islands are isolated from one another, and have different environmental conditions.
- Populations of finches have differentiated over millions of years, and can no longer interbreed.

Figure 24.6 Allopatric Speciation among Darwin's Finches (Part 1)

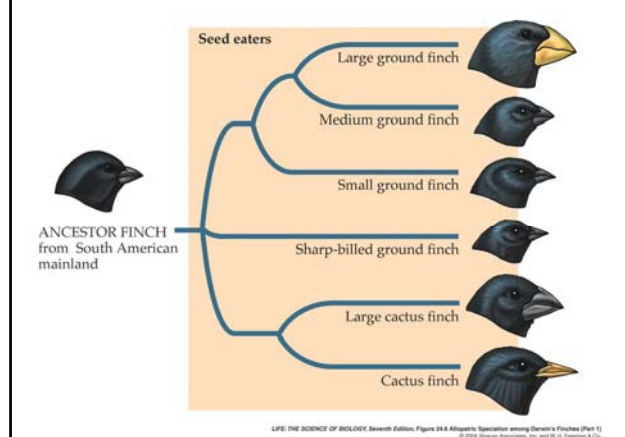
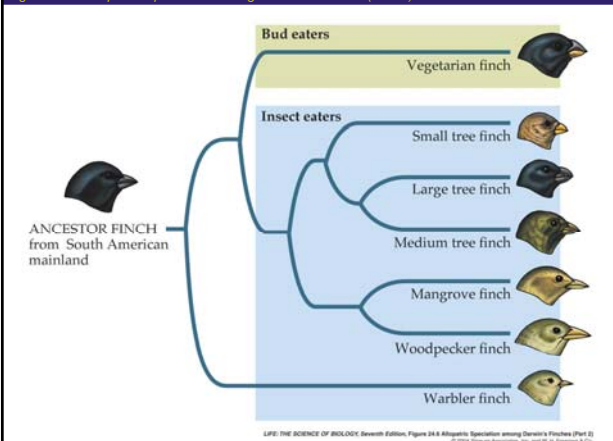


Figure 24.6 Allopatric Speciation among Darwin's Finches (Part 2)



How Do New Species Arise?

- 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 not be a barrier for a butterfly.

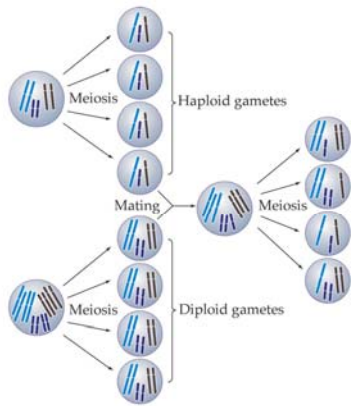
How Do New Species Arise?

- A partition of a gene pool that occurs without physical separation is called **sympatric speciation**.
- The most common means of sympatric speciation is **polyploidy**.
- Polyploidy arises in two ways:
 - **Autopolyploidy** is chromosome duplication in a single species.
 - **Allopolyploidy** is the combining of chromosomes from two different species.

How Do New Species Arise?

- Autopolyploidy can result from the accidental production of cells that have four sets (**tetraploid**) instead of the usual two sets (**diploid**) of chromosomes.
- If tetraploid and diploid individuals mate, the triploid offspring are usually sterile because the chromosomes do not synapse correctly.
- Tetraploid plants are thus reproductively isolated very quickly.

Figure 24.7 Tetraploids Are Soon Reproductively Isolated from Diploids



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How Do New Species Arise?

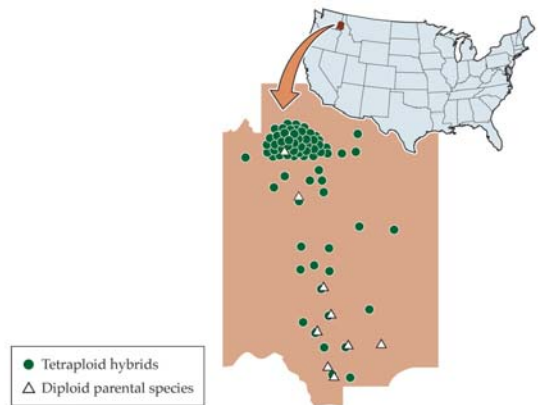
- Allopolyploidy can arise when individuals of closely related species interbreed or **hybridize**.
- Allopolyploids are usually fertile because each of the chromosomes has a nearly identical partner to pair with during meiosis.

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How Do New Species Arise?

- Polyploidy can create new species of plants more easily than animals because plants of many species can reproduce by self-fertilization.
- Speciation by polyploidy has been important in the evolution of flowering plants. About 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.

Figure 24.8 Polyploids May Outperform Their Parent Species



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Completing Speciation: Reproductive Isolating Mechanisms

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

Figure 24.9 Geographically Separated, Morphologically Similar



(a) *Platanus occidentalis*

(b) *Platanus hispanica*

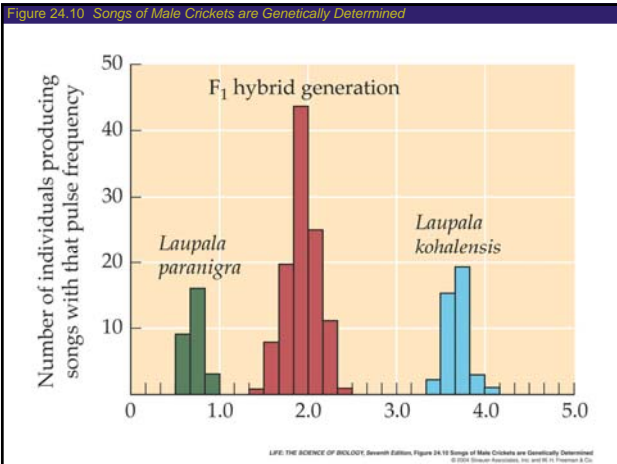
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24 Completing Speciation: Reproductive Isolating Mechanisms

- **Prezygotic reproductive barriers** operate before fertilization:
 - Spatial isolation
 - Temporal isolation
 - Mechanical isolation
 - Gametic isolation
 - Behavioral isolation

24 Completing Speciation: Reproductive Isolating Mechanisms

- Two closely related species of crickets from Hawaii provide an example of behavioral isolation.
- Males of these species produce genetically determined songs that differ in the number of pulses per second.
- 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.



24 Completing Speciation: Reproductive Isolating Mechanisms

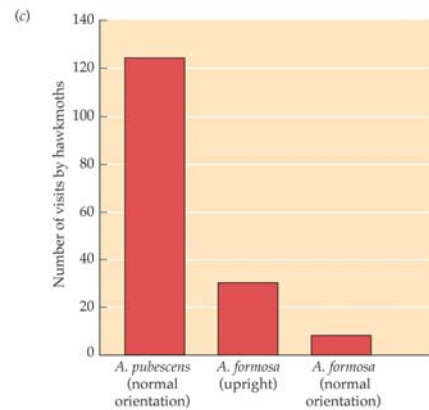
- The mate choice of one species can be mediated by the behavior of individuals of other species. For example, whether two plant species hybridize may depend on the preferences of their pollinators.
- The evolution of floral traits that generate reproductive isolation has been studied in the columbines of the genus *Aquilegia*.
- Genetically based differences in flower color result in each species attracting a different pollinator.

Figure 24.11 Hawkmoths Favor Flowers of One Columbine Species (Part 1)



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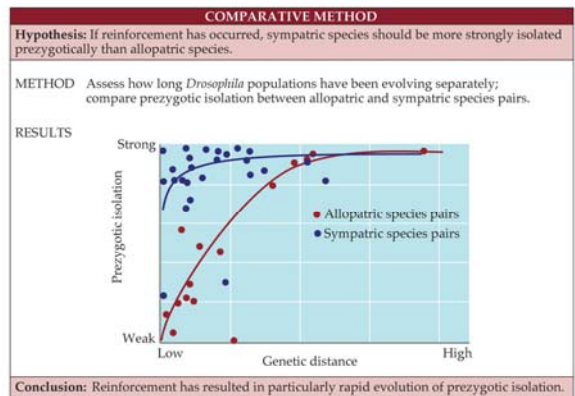
Figure 24.11 Hawkmoths Favor Flowers of One Columbine Species (Part 2)



24 Completing Speciation: Reproductive Isolating Mechanisms

- **Postzygotic reproductive barriers** operate after fertilization:
 - Hybrid zygote abnormality
 - Hybrid infertility
 - Low hybrid viability
- If hybrid offspring survive poorly, more effective prezygotic barriers may evolve, a process known as **reinforcement**.

Figure 24.12 Prezygotic Barriers Can Evolve Rapidly



24 Completing Speciation: Reproductive Isolating Mechanisms

- The picture-winged fruit fly, *Rhagoletis pomonella*, provides an example of speciation in progress.
- Before apple orchards were planted, these fruit flies deposited their eggs only on hawthorn fruits.
- Afterward, some *Rhagoletis* laid their eggs on apples instead of hawthorns.
- Larvae that survived on the apples recognized the odor of the apples and thus sought out apple trees for mating when they emerged as adults.
- The two types of *Rhagoletis* may now be on their way to becoming distinct species.

24 Hybrid Zones: Incomplete Reproductive Isolation

- Contact between formerly isolated populations before reproductive isolation is complete may result in interbreeding.
- There are three possible outcomes to such interbreeding:
 - If hybrid offspring are successful, hybrids may spread through both populations, combining the two gene pools so that no new species result.
 - 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 happen.

24 Hybrid Zones: Incomplete Reproductive Isolation

- 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.
- Although the hybrids are not as fit as purebred individuals, the narrow hybrid zone has persisted because there has been no opportunity for reinforcement to occur.

Figure 24.13 Hybrid Zones May Be Long and Narrow (Part 1)

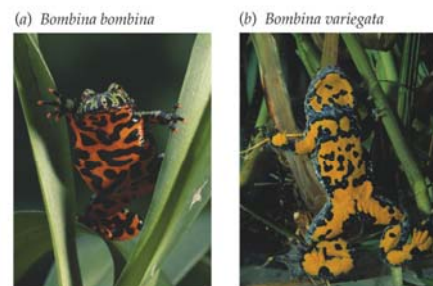
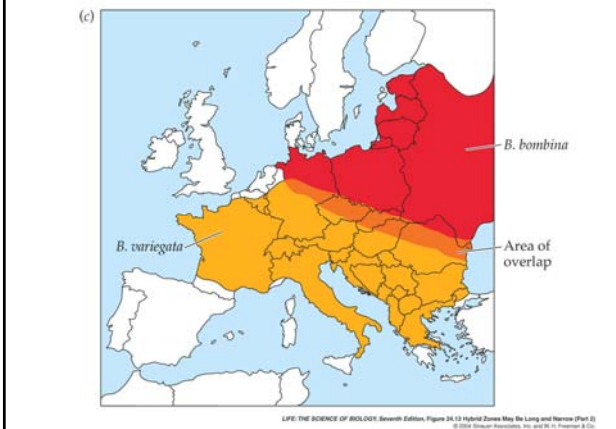


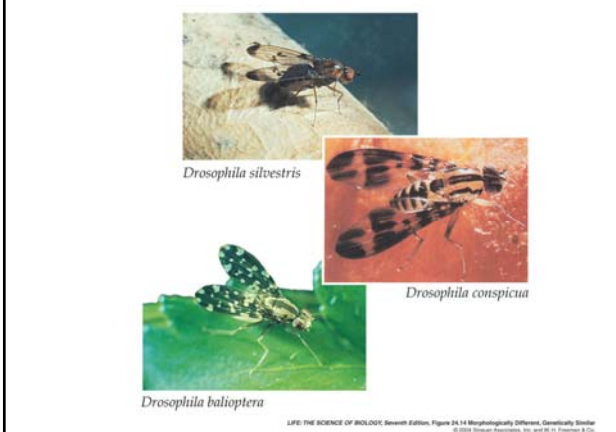
Figure 24.13 Hybrid Zones May Be Long and Narrow (Part 2)



24 Hybrid Zones: Incomplete Reproductive Isolation

- 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.
- Fewer than ten, and often fewer than five, genes are responsible for reproductive isolation.

Figure 24.14 Morphologically Different, Genetically Similar



24 Variation in Speciation Rates

- A number of factors influence speciation rates.
 - Species richness: The larger the number of species there are in a lineage, the larger the number of opportunities there are for new species to form.
 - Dispersal rates: Individuals of species with poor dispersal abilities are unlikely to establish new populations by dispersing across barriers.
 - Ecological specialization: species restricted to habitat types that are patchy in distribution are more likely to diverge than those in continuous habitats.

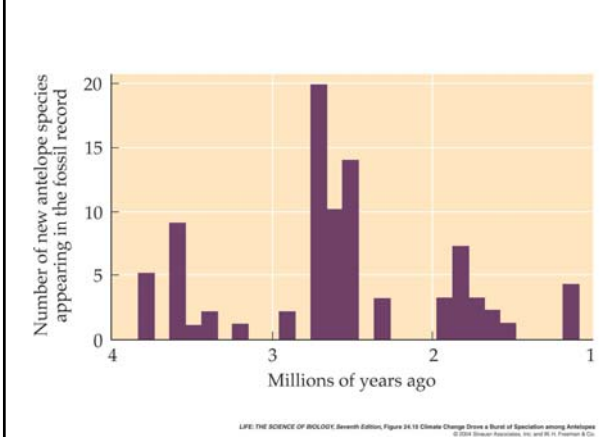
24 Variation in Speciation Rates

- Population bottlenecks: Changes to the gene pool that occur when a population passes through a bottleneck may result in new adaptations.
- Type of pollination: Animal-pollinated species tend to have increased speciation rates.
- Sexual selection: Animals with complex behavior discriminate among potential mating partners. This can influence which individuals are most successful in producing offspring, and may lead to rapid reinforcement of reproductive isolation between species.

24 Variation in Speciation Rates

- Environmental changes: Oscillations of climates may fragment populations of species that live in formerly continuous habitats.
 - Climate change was responsible for driving a burst of speciation among African antelopes between 2.5 and 2.9 mya.

Figure 24.15 Climate Change Drove a Burst of Speciation among Antelopes



24 Evolutionary Radiations

- The fossil record reveals certain periods of high speciation rates in Earth's history (**evolutionary radiations**).
- Evolutionary radiations are likely when an organism colonizes an environment that has relatively few species, such as an island.
- Islands lack many plant and animal groups found on the mainland, so ecological opportunities exist that may stimulate rapid evolutionary changes when a new species does reach them.
- Water barriers also restrict gene flow among islands.

24 Evolutionary Radiations

- The Hawaiian Islands are an example of the rapid evolution possible in an environment with few species.
- The Hawaiian Islands are the most isolated islands in the world.
- More than 90 percent of plant species are **endemic**, found nowhere else in the world.
- Some plant groups, such as the silverswords, are much more diverse than their mainland counterparts.
- The diversity of this group reflects the absence of tree and shrub species on the islands when the first colonizers arrived.

Figure 24.16 Rapid Evolution among Hawaiian Silverswords (Part 1)

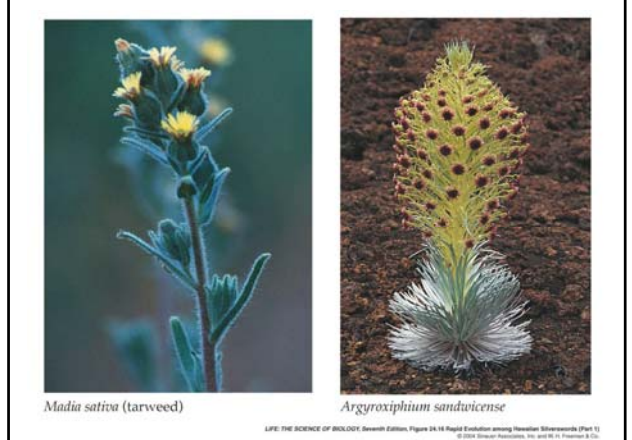


Figure 24.16 Rapid Evolution among Hawaiian Silverswords (Part 2)

