16-3 The Process of Speciation

Standards: Bio 8a, 8b, 8d

Vocabulary
speciation, reproductive isolation, behavioral isolation, geographic isolation, temporal isolation

Factors such as natural selection and chance events canchange the relative frequencies of alleles in a population. But how do these changes lead to the formation of new species, or speciation?

Recall that biologists define a species as a group of organisms that breed with one another and produce fertile offspring. This means that individuals in the same species share a common gene pool. Because a population of individuals has a shared gene pool, a genetic change that occurs in one individual can spread through the population as that individual and its offspring reproduce. If a genetic change increases fitness, that allele will eventually be found in many individuals of that population.

Isolating Mechanisms

Given this genetic definition of species, what must happen for a species to evolve into two new species? The gene pools of two populations must become separated for them to become new species. **As new species evolve, populations become reproductively isolated from each other**. When the members of two populations cannot interbreed and produce fertile offspring, **reproductive isolation** has occurred. At that point, the populations have separate gene pools. They respond to natural selection or genetic drift as separate units. Reproductive isolation can develop in a variety of ways, including behavioral isolation, geographic isolation, and temporal isolation. Behavioral Isolation One type of isolating mechanism, behavioral isolation, occurs when two populations are capable of interbreeding but have differences in courtship rituals or other reproductive strategies that involve behavior. For example, the **eastern and western meadowlarks** shown, are very similar birds whose habitats overlap in the center of the United States. Members of the two species will not mate with each other, however, partly because they use different songs to attract mates. Eastern meadowlarks will not respond to western meadowlark songs, and vice versa.

Geographic Isolation With **geographic isolation**, two populations are separated by geographic barriers such as rivers, mountains, or bodies of water. The **Abert squirrel in Figure 16-**12, for example, lives in the Southwest. About 10,000 years ago, the Colorado River split the species into two separate populations.
Two separate gene pools formed. Genetic changes that appeared in one group were not passed to the other. Natural selection worked separately on each group and led to the formation of a distinct subspecies, the Kaibab squirrel. The Abert and Kaibab squirrels have very similar anatomical and physiological characteristics, indicating that they are closely related. However, the Kaibab squirrel differs from the Abert squirrel in significant ways, such as fur coloring.

Geographic barriers do not guarantee the formation of new species, however. Separate lakes may be linked for a time during a flood, or a land bridge may temporarily form between islands, enabling separated populations to mix. If two formerly separated populations can still interbreed, they remain a single species. Also, any potential geographic barrier may separate certain types of organisms but not others. A large river will keep squirrels and other small rodents apart, but it does not necessarily isolate bird populations.

Temporal Isolation A third isolating mechanism is temporal isolation, in which two or more species reproduce at different times. For example, three similar species of orchid all live in the same rain forest. Each species releases pollen only on a single day. Because the three species release pollen on different days, they cannot pollinate one another.

√*Checkpoint: How can temporal isolation lead to speciation?*

Testing Natural Selection in Nature

Now that you know the basic mechanisms of evolutionary change, you might wonder if these processes can be observed in nature. The answer is yes. In fact, some of the most important studies showing natural selection in action involve descendants of the finches that Darwin observed in the Galapagos Islands.

Those finch species looked so different from one another that when Darwin first saw them, he did not realize they were all finches. He thought they were blackbirds, warblers, and other kinds of birds. The species he examined differed greatly in the sizes and shapes of their beaks and in their feeding habits, as shown in **Figure 16-13**. Some species fed on small seeds, while others ate large seeds with thick shells. One species used cactus spines to pry insects from dead wood. One species, not shown here, even pecked at the tails of large sea birds and drank their blood!

Once Darwin discovered that these birds were all finches, he hypothesized that they had descended from a common ancestor. Over time, he proposed, natural selection shaped the beaks of different bird populations as they adapted to eat different foods.

That was a reasonable hypothesis. But was there any way to test it? No one thought so, until the work of Peter and Rosemary Grant from Princeton University proved otherwise. For more than twenty years, the Grants, shown in **Figure** 16-14, have been collaborating to band and measure finches on the Galapagos Islands. They realized that Darwin's hypothesis relied on two testable assumptions. First, in order for beak size and shape to evolve, there must be enough heritable variation in those traits to provide raw material for natural selection. Second, differences in beak size and shape must produce differences in fitness that cause natural selection to occur.

The Grants tested these hypotheses on the medium ground finch on Daphne Major, one of the Galapagos Islands. This island is large enough to support good-sized finch populations, yet small enough to enable the Grants to catch and identify nearly every bird belonging to the species under study.

Variation The Grants first identified and measured as many individual birds as possible on the island. They recorded which birds were still living and which had died, which had succeeded in breeding and which had not. For each individual, they also recorded anatomical characteristics such as wing length, leg length, beak length, beak depth, beak color, feather colors, and total mass. Many of these characteristics appeared in bell-shaped distributions typical of polygenic traits. These data indicate that there is great variation of heritable traits among the Galapagos finches.

Natural Selection Other researchers who had visited the Galapagos did not see the different finches competing or eating different foods. During the rainy season, when these researchers visited, there is plenty of food. Under these conditions, finches often eat the most available type of food. During dry-season drought, however, some foods become scarce, and others disappear altogether. At that time, differences in beak size can mean the difference between life and death. To survive, birds become feeding specialists. Each species selects the type of food its beak handles best. Birds with big, heavy beaks, for example, select big, thick seeds that no other species can crack open.

The Grants' most interesting discovery was that individual birds with different-sized beaks had different chances of survival during a drought. When food for the finches was scarce, individuals with the largest beaks were more likely to survive, as shown in **Figure 16-15**. Beak size also plays a role in mating behavior, because big-beaked birds tend to mate with other big-beaked birds. The Grants observed that average beak size in that finch population increased dramatically over time. This change in beak size is an example of directional selection operating on an anatomical trait.

By documenting natural selection in the wild, the Grants provided evidence of the process of evolution: The next generation of finches had larger beaks than did the generation before selection had occurred. An important result of this work was their finding that natural selection takes place frequently—and sometimes very rapidly. Changes in the food supply on the Galapagos caused measurable fluctuations in the finch populations over a period of only decades. This is markedly different from the slow, gradual evolution that Darwin envisioned.

√Checkpoint: What type of natural selection did the Grants observe in the Galapagos?

Speciation in Darwin's Finches

The Grants' work demonstrates that finch beak size can be changed by natural selection. If we combine this information with other evolutionary concepts you have learned in this chapter, we can show how natural selection can lead to speciation. We can devise a hypothetical scenario for the evolution of all Galapagos finches from a single group of founding birds. **Speciation in the Galapagos finches occurred by founding of a new population, geographic isolation, changes in the new population's gene pool, reproductive isolation, and ecological competition.**

Founders Arrive Many years ago, a few finches from the South American mainland—species A—flew or were blown to one of the Galapagos Islands, as shown in **Figure** 16-16. Finches are small birds that do not usually fly far over open water. These birds may have gotten lost, or they may have been blown off course by a storm. Once they arrived on one of the islands, they managed to survive and reproduce.

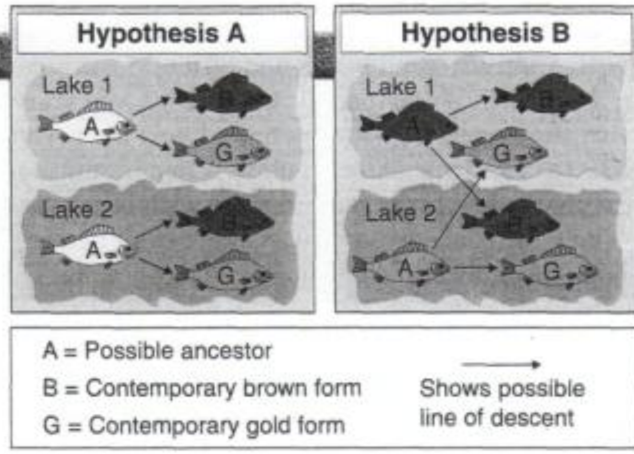
Geographic Isolation Later on, some birds from species A crossed to another island in the Galapagos group. Because these birds do not usually fly over open water, they rarely move from island to island. Thus, finch populations on the two islands were essentially isolated from each other and no longer shared a common gene pool.

√Checkpoint: How did finches arrive in the Galapagos Islands?

Analyzing Data

How Are These Fish Related?

A research team studied two lakes in an area that sometimes experiences flooding. Each lake contained two types of similar fish: a dull brown form and an iridescent gold form. The team wondered how all the fish were related, and they considered the two hypotheses diagrammed on the right.



1. **Interpreting Graphics** Study the two diagrams. What does hypothesis A indicate about the ancestry of the fish in Lake 1 and Lake 2? What does hypothesis B indicate?
2. **Comparing and Contrasting** According to the two hypotheses, what is the key difference in the way the brown and gold fish populations might have formed?
3. **Drawing Conclusions** A DNA analysis showed that the brown and gold fish from Lake 1 are the most closely related. Which hypothesis does this evidence support?
4. **Asking Questions** To help determine whether the brown and gold fish are members of separate species, what question might scientists ask?

Changes in the Gene Pool Over time, populations on each island became adapted to their local environments. The plants growing on the first island may have produced small thin-shelled seeds, whereas the plants on the second island may have produced larger thick-shelled seeds. On the second island, directional selection would favor individuals with larger, heavier beaks. These birds could crack open and eat the large seeds more easily. Thus, birds with large beaks would be better able to survive on the second island. Over time, natural selection would have caused that population to evolve larger beaks, forming a separate population, B.

Reproductive Isolation Now, imagine that a few birds from the second island cross back to the first island. Will the population-A birds breed with the population-B birds? Probably not. These finches choose their mates carefully. As part of their courtship behavior, they inspect a potential partner's beak very closely. Finches prefer to mate with birds that have the same-sized beak as they do. In other words, big-beaked birds prefer to mate with other big-beaked birds, and smaller-beaked birds prefer to mate with other smaller-beaked birds. Because the birds on the two islands have different-sized beaks, it is likely that they would not choose to mate with each other. Thus, differences in beak size, combined with mating behavior, could lead to reproductive isolation. The gene pools of the two bird populations remain isolated from each other—even when individuals live together in the same place. The two populations have now become separate species.

Ecological Competition As these two new species live together in the same environment (the first island), they compete with each other for available seeds. During the dry season, individuals that are most different from each other have the highest fitness. The more specialized birds have less competition for certain kinds of seeds and other foods, and the competition among individual finches is also reduced. Over time, species evolve in a way that increases the differences between them. The species-B birds on the first island may evolve into a new species, C.

Continued Evolution This process of isolation on different islands, genetic change, and reproductive isolation probably repeated itself time and time again across the entire Galapagos island chain. Over many generations, it produced the 13 different finch species found there today. Use the steps in this illustration to explain how other Darwin finches, such as the vegetarian tree finch that feeds on fruit, might have evolved.

Studying Evolution Since Darwin

It is useful to review and critique the strengths and weaknesses of evolutionary theory. Darwin made bold assumptions about heritable variation, the age of Earth, and relationships among organisms. New data from genetics, physics, and biochemistry could have proved him wrong on many counts. They didn't. Scientific evidence supports the theory that living species descended with modification from common ancestors that lived in the ancient past.

Limitations of Research The Grants' research clearly shows the effects of directional selection in nature. The Grants' data also show how competition and climate change affect natural selection. The work does have limitations. For example, while the Grants observed changes in the size of the finches' beaks, they did not observe the formation of a new species. Scientists predict that as new fossils are found, they will continue to expand our understanding of how species evolved.

Unanswered Questions The studies of the Grants fit into an enormous body of scientific work supporting the theory of evolution. Millions of fossils show that life has existed on Earth for more than 3 billion years and that organisms have changed dramatically over this time. These fossils form just a part of the evidence supporting the conclusion that life has evolved. Remember that a scientific theory is defined as a well-tested explanation that accounts for a broad range of observations. Evolutionary theory fits this definition. To be sure, many new discoveries have led to new hypotheses that refine and expand Darwin's original ideas. No scientist suggests that all evolutionary processes are fully understood. Many unanswered questions remain.

Why is understanding evolution important? Because evolution continues today, driving changes in the living world such as drug resistance in bacteria and viruses, and pesticide resistance in insects. Evolutionary theory helps us understand and respond to these changes in ways that improve human life.

16-3 Section Assessment

1. How is reproductive isolation related to the formation of new species?
2. What type of isolating mechanism was important in the formation of Galapagos finch species?
3. Explain how behavior can play a role in the evolution of species.
4. What recent research findings support Darwin's theory of evolution?
5. Suppose that a drought on an island eliminates all but plants that produce large, tough seeds. All the finches on the island have very small beaks. How might this environmental change impact the survival of this finch population?