



Activity #2

Adaptive Radiation in Rain Forest Birds

● ● ● In Advance *Student Reading*

- Assign the Student Page “Adaptive Radiation in Hawaiian Honeycreepers” (pp. 22-26) as homework.

● ● ● Class Period One *Adaptive Radiation Discussion*

Materials & Setup

For each student

- Student Page “Adaptive Radiation in Hawaiian Honeycreepers” (pp. 22-26)
- Student Page “Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading” (pp. 27-28)

Instructions

- 1) Have students complete the Student Page “Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading” in class.
- 2) Spend the remainder of the class discussing adaptive radiation and the homework reading, beginning with student responses to the questions.

Journal Ideas

- Many native birds are not found in low-elevation areas on Maui. Do you think that native birds once occupied these lowland areas? How would you go about finding out?
- Do you think anything should be done to protect the remaining Hawaiian honeycreepers? Why or why not?
- Keeping in mind the different human-caused pressures that have led to declines and extinctions among Hawaiian honeycreepers, what do you think can be done to protect the species that remain?
- Imagine being a traditional Hawaiian bird catcher, collecting thousands of feathers over your lifetime. What do you think it would have been like to work mostly alone in the forests of the gods?

Assessment Tools

- Student Page “Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading” (teacher version, pp. 20-21)
- Participation in class discussion
- Journal entries



Teacher Version

Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading

- 1) Define adaptive radiation, and explain its relationship to endemic species. Give one example of adaptive radiation in Hawaiian species other than honeycreepers.

Adaptive radiation is the evolution of many species from a single ancestor.

Well-reasoned responses about the relationship between adaptive radiation and endemism are acceptable. Possible relationships include:

- Adaptive radiation results in many endemic species (species that evolved here and are found nowhere else in the world) that are closely related to each other because of their common ancestor, and
- Because species are evolving in response to local conditions, adaptive radiation may result in species that are “narrowly endemic,” or restricted to a small range or a single island.

Examples include Hawaiian *Drosophila* flies and Hawaiian lobeliads. There are many others that students may have learned about outside this unit, including the silversword alliance which includes the ‘āhinahina or Haleakalā silversword.

- 2) Why are fossil records valuable sources of information to scientists studying the evolution of native bird species?

Well-reasoned responses are acceptable. Fossil records enable scientists to identify previously unknown species and establish their relationships with existing species. Among Hawaiian honeycreepers, for example, 18 species are known only from fossil records. That’s 35 percent of all known honeycreeper species. Our understanding of the scope of adaptive radiation among honeycreepers would be much narrower if not for the fossil record.



- 3) Is the shift in the size of *'i'iwi* bills over the last 100 years an example of adaptive radiation in action? Explain your answer.

Well-reasoned responses are acceptable. Two possibilities:

- The shift in *'i'iwi* bill size is probably not adaptive radiation in action because it is likely to be taking place across the entire species, so the changes that are taking place are probably not going to result in the creation of a new species. The extinction of the *'ō'ō* probably affected the *'i'iwi* across much of its range, as did the decline of the preferred food source, Hawaiian lobeliads.
- If there are islands or large stretches of habitat in which Hawaiian lobeliad populations are protected or restored and other places where they are not, then we may be seeing adaptive radiation in action, as the habitat for some populations of *'i'iwi* would favor their existing bill size, and the habitat for others would favor a shorter bill, possibly leading to species differentiation over a long period of time.

- 4) Using what you have learned about evolution and adaptation, explain why extinctions of rain forest bird species have happened—and continue to occur—so rapidly in the face of human-caused changes to native Hawaiian rain forests.

Well-reasoned responses are acceptable. Two possibilities:

- Human-caused changes such as habitat destruction, pressures by introduced species, and introduced diseases are altering conditions for native birds so quickly that evolution cannot keep up. The honeycreepers took millions of years to evolve, but humans have caused dramatic changes in their environment within hundreds of years.
- Human activity has contributed to many different pressures on native birds including habitat destruction, predation and competition by introduced species, and disease. A species that might be able to adapt and survive in the face of a single human-caused pressure may not fare so well when there are multiple pressures working against its survival.



Adaptive Radiation in Hawaiian Honeycreepers

The Hawaiian Islands are the most isolated archipelago on the planet. Here, we are more than 2,000 miles away from the nearest continent and some 1,000 miles away from the closest Pacific atolls. Because of this isolation, over millions of years, relatively few plant and animal species arrived on the islands. The “three Ws” (wind, waves, and wings) are used to describe the means by which species arrived here. From a small collection of “founding species” descended all of the animals and plants that are native to Hawai‘i. The Hawaiian rain forest is a hotbed of “endemism.” Of its native inhabitants, a large proportion are unique to these islands.

In contrast to “indigenous” species, Hawaiian endemic species evolved into a new species after arriving here from somewhere else. Indigenous species have remained relatively unchanged since their arrival and are not unique to Hawai‘i. Among the endemic forest birds, most species belong to a group known as the Hawaiian honeycreepers. All of the honeycreeper species are thought to have evolved from a single finch species that arrived on the islands more than 15 million years ago. This process of “adaptive radiation” has, over time, resulted in honeycreepers that are very different from each other and adapted to many different environments.

The oldest of today’s main islands, Kaua‘i, is only about five million years old. So much of the early evolution of the honeycreepers probably happened on other, older islands in the chain. Through a process called “interisland dispersal,” the ancestors of the honeycreeper species we know today colonized the new islands, even as their old homelands were being slowly eroded

away. These new islands may have offered different habitat for the birds, which over time could have further radiated into new species.

In the 1970s, paleontologists began in earnest to collect partially fossilized bird remains from sand dunes, lava tubes, caves, and sinkholes in the Hawaiian Islands. This fossil record revealed many species of honeycreepers that were already

Hawaiian Honeycreepers at a Glance

- Thought to have evolved from a single species of finch.
- Fifty-two species are thought to be part of the Hawaiian honeycreeper subfamily.

Eighteen species, known only from fossil record, were probably extinct by 1778.	35 percent
Twelve species have gone extinct since 1778.	23 percent
Fourteen surviving species are classified as endangered, some may already be extinct.	27 percent
Eight surviving species are not classified as endangered.	15 percent

extinct by the time Western scientists had started identifying and describing Hawaiian birds. Most of these extinctions were most likely a result of the impacts of the Hawaiian people: competition or predation by Polynesian introductions, conversion of lowland habitats into agricultural areas, and killing of birds for food and other human uses.



In addition to uncovering evidence of bird extinctions, fossil research has helped to shed new light on the true extent of adaptive radiation in Hawaiian honeycreepers. From the single ancestral finch species, at least 52 honeycreeper species are known to have evolved. What caused this remarkable formation of new species?

Adaptive Radiation

Adaptive radiation is often thought of as being driven by the need or opportunity for plants or animals to live in habitats other than the ones to which they are best adapted. It is easy to see how such needs and opportunities could arise for birds arriving on the Hawaiian Islands from other parts of the world. The Hawaiian honeycreepers evolved into species with different primary food sources: nectar, hard seeds, soft fruit, and insects and larvae. Some honeycreeper species have diets made up of combinations of these food sources.



Variations in bill morphology of selected Hawaiian honeycreepers
(Illustration: H. Douglas Pratt, Jr.)

Their beak structure and even their leg and facial muscles reflect their diet and how they forage for food.

Some nectar-eating honeycreepers have beaks that are shaped to fit specific flowers. This is evidence of coevolution, in which honeycreepers and flowering plants evolved together, the birds feeding on the nectar and in turn spreading pollen from flower to flower. Birds and flowers evolved specialized relationships, of which the *'i'iwi* and Hawaiian lobeliad plants are an excellent example. The long, curved bill of the *'i'iwi* is perfectly suited to gathering nectar from the long, tubular, curved flowers of many lobeliad species.

Many factors are thought to have influenced adaptive radiation in Hawaiian honeycreepers, including the following:

Isolation and Dispersability

Populations of a bird species that remain isolated from each other can, over time, evolve into separate species. In general, birds can easily disperse from one place—or island—to another by flying. But the pattern of species and island-specific subspecies of honeycreepers suggests that some species were more likely to do so than were others.

Some scientists believe that insect-eating honeycreepers have a more reliable source of food than do species that feed on fruit or nectar. They hypothesize that “frugivorous” (fruit-eating) and “nectivorous” (nectar-feeding) birds are more likely to fly between islands looking for food in lean years. Because the “insectivores” (insect-feeders) had less reason to move around, they remained more isolated and developed into more species and subspecies.

Other scientists believe that there is not such a clear link between eating habits and interisland dispersal. Instead, they distinguish between common “generalists” such as the *‘apapane* and *‘amakihi* that are widespread across the islands on the one hand, and specialized seed eaters and nectivores on the other hand. Generalists are able to feed on a variety of food types. The more specialized eaters, some scientists maintain,



would have been more likely to stay where their food source was and further evolve in that place. The generalists would have been more likely to fly from island to island.

Adaptation to Food Resources

Birds can rapidly adapt to new types of food or changes in the abundance of food sources. Over time, these adaptations (physical or behavioral changes) can result in the emergence of new species. In 1984 and 1985, studies of endangered Laysan finches that had been introduced in 1967 to Pearl and Hermes Reef, showed significant differences had already developed between the Pearl and Hermes finches and their ancestors on Laysan. The differences appeared to be a response to differences in food availability. If those differences turn out to be genetically linked, then evolutionary change had occurred among these birds in fewer than 20 generations.

Intraspecies Food Competition

Competition for food among members of the same species can lead to “adaptive shifts” or changes. Less competitive members of the species may shift to feeding on a different size or type of food, and over time this division of food can lead to bills that are specialized to this available food source.



'I'iwi (Photo: Eric Nishibayashi)

Other Rain Forest Examples of Adaptive Radiation

- The Hawaiian *Drosophila* flies: Over 500 species of flies in the Drosophilidae family have been identified in Hawai‘i, all of which evolved from a single common ancestor species. Nearly one-quarter of the known species in this family are found in Hawai‘i, including many that are “narrowly endemic.” That means that they occur in only a very small area.
- Hawaiian lobeliads: Six of seven genera of this group of plants are endemic to Hawai‘i. The 98 species in the genera *Cyanea*, *Clermontia*, *Delissea*, and *Rollandia* are considered by many scientists to be the largest group of Hawaiian plants to have evolved from a single immigrant species.

Evolution is Not Over

Evolutionary changes in Hawaiian honeycreepers did not end at some time in the past. In fact, there is evidence that rapid evolutionary changes have occurred within the past 100 years, in response to human-induced extinctions and habitat changes. Given the fact that the honeycreepers evolved over *millions* of years, to measure significant changes in *one hundred* years indicates rapid natural selection.

Here is an example of such a rapid shift:

In the early 1990s, a group of biologists compared body measurements of live 'i'iwi with museum specimens collected prior to 1900 (Smith, et al., 1995). Early studies of the 'i'iwi—prior to 1900—reported that the long, curved flowers of Hawaiian lobeliads were this bird's preferred food. Now, however, 'i'iwi feed mainly on the open flowers of 'ōhi'a, which do not have tubular, curved flowers.



What might have caused this change in diet? Researchers point to two factors. The first is that the lobeliads, once a prominent part of the understory of Hawaiian rain forests, are now rare. During the 20th century, habitat degradation and grazing by feral ungulates induced the extinction of 25 percent of Hawaiian lobeliad species. Most of the species that remain are rare or endangered. So the preferred food of the ‘i‘iwi is greatly reduced.

Researchers suggest the second factor influencing this dietary shift was the extinction of the ‘ō‘ō. The ‘ō‘ō was a Hawaiian honeyeater, another native Hawaiian bird not related to the honeycreepers. This bird was behaviorally dominant over the ‘i‘iwi, keeping the ‘i‘iwi from feeding heavily in the favored trees of the ‘ō‘ō: the ‘ōhi‘a. By 1900, the ‘ō‘ō was extinct, and as the lobeliads declined over the course of the 1900s, the ‘i‘iwi shifted its foraging emphasis to ‘ōhi‘a flowers.

Birds that feed most efficiently on ‘ōhi‘a flowers, such as the ‘apapane and the ‘ākohekohe, have short bills to exploit this food source. Researchers hypothesized that a shift in diet away from the long, tubular, curved lobeliad flowers to the open ‘ōhi‘a flowers would have resulted in selective pressures which favored shorter bills over longer bills.

The biologists tested this hypothesis by comparing bill measurements and other body measurements of live ‘i‘iwi with museum specimens collected prior to the extinction of the ‘ō‘ō. Evaluating the data they collected, they found that the upper mandible (beak portion) became shorter, while overall body size stayed the same. The results of their analysis suggest “the longer billed birds, presumably due to lower feeding efficiencies on ‘ōhi‘a, were lost over time as selection favored shorter and possibly straighter bills.”

As human-induced extinctions and declines of native species continue, the structure of Hawaiian natural communities is changing rapidly. These

changes open the possibility for rapid evolutionary shifts, such as the one that appears to be happening with the ‘i‘iwi.

Ongoing Threats

Of the 22 known surviving species of Hawaiian honeycreepers, 14 are considered endangered, and some of these may already be extinct. What is contributing to this loss of species today?

- **Habitat destruction:** The Maui parrotbill is an illustrative example of the impact of habitat destruction. By the 1890s, it was already rare in the remaining *koa*-dominated rain forests. These *koa* forests were destroyed, largely by wildfires, browsing by introduced animals, and logging. Today, the parrotbill survives only in higher-elevation ‘ōhi‘a forests, where it is an extremely rare bird.
- **Avian malaria and other diseases:** Like many Hawaiian honeycreepers, the rare ‘ākohekohe is thought to be highly susceptible to avian malaria, a disease introduced early this century with nonnative birds. The disease is transmitted by a nonnative mosquito and is believed to prevent honeycreeper populations from surviving in lower-elevation forests. Mosquitos rarely occur above 1200 meters (3936 feet) elevation. Many native birds escape infection only while they remain in upper-elevation forests.
- **Predation by cats, mongooses, and rats:** These animals eat native bird eggs and chicks, and sometimes even adult birds, especially those tending their young.

These pressures are happening at a rapid rate, much more quickly than many bird species can adapt. The honeycreepers that are faring the best tend to be those that can adapt to a broad range of habitats. The most common honeycreepers on Maui and in Hawai‘i are the ‘apapane and the ‘amakihi. Both of these birds range from the rain



forests into upper-elevation shrublands and even into planted forests. As the 'i'iwi shows, however, rapid evolutionary shifts are possible, and that possibility—along with efforts at habitat protection, feral animal control, and research into avian diseases—may spell survival for some of the remaining Hawaiian honeycreeper species.

Sources

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