The Galapagos— A Laboratory for Evolution

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NOVEMBER 24, 1979, marked the 120-year anniversary of Charles Darwin's book, *Origin of Species by Means of Natural Selection*. That fact was missed by many of the biology classes in the United States. At the high school level, and more particularly at the elementary level, teachers still find it difficult to discuss and teach evolution, especially when the name Darwin or the word evolution is used. Living in the area of the country referred to as the "Bible Belt" makes us particularly aware that many parents are aroused and become quite vocal if their children come home talking about evolution or nonliteral interpretations of the book of Genesis. The South, however, is not the only area with this problem. It exists in communities across the United States where religious fundamentalism is strong. Witness attempts in Texas and California and a dozen other states to require the teaching of the creation theory alongside the evolution theory. The Southern Baptist Convention has recently passed a motion to encourage states to pass such laws.

Many teachers completely omit the chapter on evolution rather than confront the problem. This procedure eliminates telephone calls from parents, negative suggestions from administrators, or a reduced rapport with their students. Others disguise their efforts to teach evolution by using alternate terms, such as adaptation, change, development, alteration, variation, modification, deviation, divergence, shift, transformation, or modulation. It seems to us that a law mandating the teaching of both evolution and creationism might provide more latitude for teaching evolution than presently exists in many schools.

A trip to the Galapagos Islands during the summer of 1979 has suggested to us an approach to teaching evolution that combines geography, history, theory, and mechanics.

A perusal of a number of freshman high school biology texts reveals that the Galapagos experience by Darwin is seldom elaborated. A text that does a good job of displaying material from the *Voyage of the Beagle*, Darwin's *Journal of Researches* and other more modern fact and theory from and about the Galapagos, but does not approach the problem from an ecological point of view, is the *BSCS Green Version*.

We feel that studying the islands from an ecological point of view will help a student to see the logic behind the concept of adaptive radiation as Darwin saw it, and thus effectively teach the basics of evolution. Of course, ecology can be most easily taught by a trip to the island; but short of that, we think an accurate idea of Darwin's thinking can be obtained from knowledge of Galapagos geology, topography, climate, weather, ecology, the history of Darwin's visit, the organisms he collected, his reaction to them, and the eventual formulation of the theory of evolution through natural selection. Vicariously following Darwin around the islands for his month's stay in October 1835 will provide a starting point to help students understand evolution.

The Galapagos

Let us look at the islands as Darwin saw them. They arose through volcanic activity from an undersea platform beginning about 3 million years ago with the southeastern group of San Cristobal and Espanola. The northwestern group of Isabela and Fernandina were present by about 1 million years ago, but eruptions were still occur-

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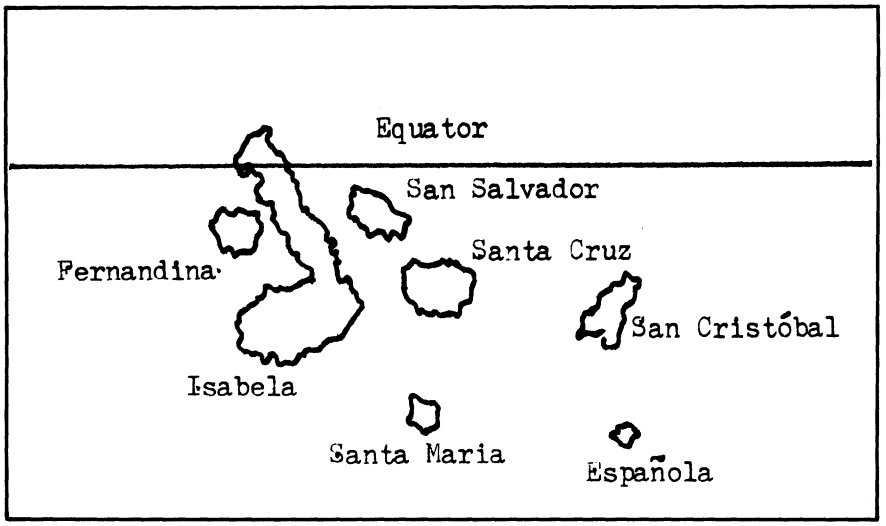

FIGURE 1. Enlarged Map of Galapagos Islands

ing as recently as February, 1979. A profile view of the islands shows this difference in age. Those in the Southeast are low and eroded; those in the Northwest are high with peaks containing large calderas at 3,000-4,000 feet. All the coastal areas are dry and desert-like. The influence of cold water and wind from the south retards precipitation, but produces a fog layer at 3,000 feet and higher. Darwin described the view of the islands at sea level as uninhabitable and fit only for the devil. In many places black lava rock almost devoid of vegetation stretches as far as the eye can see.

Seeds and spores of plants, evidently carried by air or on floating mats arrived from the South American coastal area. The 500-600 miles that they had to travel made the trip precarious and, for most voyagers, unsuccessful. Only about 500 species of plants are presently found on the islands, of which approximately 200 are endemic and found nowhere else.

Animals had the same problem. Travel at the will of the wind and the current severely limited the number that arrived, let alone those that became established. Is it any wonder that the ecosystem on the Galapagos is very sparse? There are only 25 species of land birds, 16 of reptiles, no amphibians, land mammals, or freshwater fish. Even of the few insect groups present 50% are endemic.

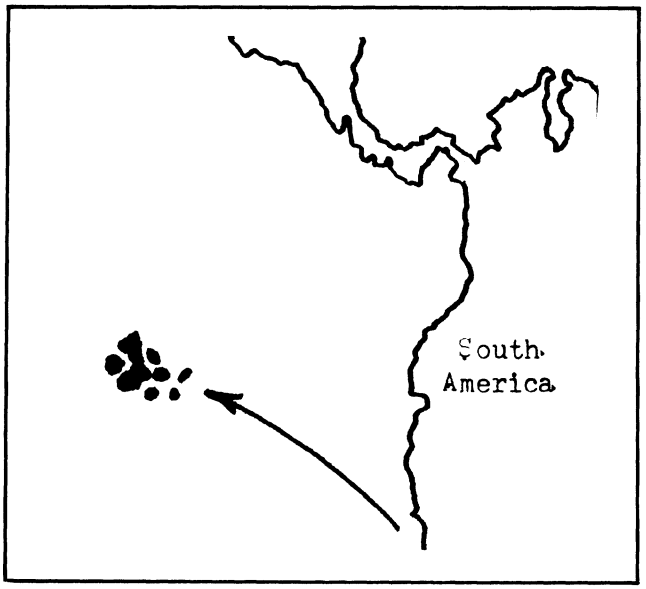

FIGURE 2. Map showing proximity to South America

Plants and Animals of the Galapagos

Let us look at a few of the animal and plant groups present on the islands. The giant Galapagos turtles resemble the South American coastal species that grow no larger than a foot in diameter. Each island has its own race, and some more than one. Several of these races have become extinct as a result of hunting pressure by crews of sailing ships that stopped to restore their meat supply. The most important variation among the turtles is the shape of the upper shell. In the desert group, the front of the shell back of the head is raised, allowing the neck and head to reach for scarce vegetation. The race from the fog vegetation zone has a shell that is much rounder, and that limits the head to grazing near the ground. An interesting relationship exists between the desert turtles with the ability to stretch for food, and the prickly pear cactus that is a staple in the turtle's diet. These cacti are the world's only prickly pears with trunks that allow the pods to grow more than ten feet above the ground. The prickly pears and the turtles apparently coevolved—but we are getting ahead of ourselves.

The Galapagos have two types of iguanas, marine and dry land. The marine type is dark, lava-rock colored; it goes to sea only to feed, and even then only during the hot mid-day. It is adapted for swimming in the ocean and grazing on green algae. The more colorful land iguana can climb shrubs, and feeds mostly on cactus pads. Still the two resemble each other more than either does any continental species.

A number of sea birds that have unique characteristics inhabit the islands, including the blue- and red-footed boobies, the waved albatross, the flightless cormorant, and the only tropical penguin, but add these to the one

TABLE 1. Ecological Facts about the Galapagos

Geology	
Source	Volcanic
Age	1-3 million years
Direction	S.E. to N.W.
Location	Equator and 500 miles west of Ecuador
Climate	
Wet	December-February and all year above 3000 feet—Fog
Dry	March-November
Wind and Current	S.E.E. to N.W.W.
Sun	Intense when not cloudy
Plants	
Algae	Only marine
Lichens	Assortment typical of climate
Plants	About 500—many plant families not present. One genus *Scalesia* highly radiated as the finches.
Animals—all fearless	
Mammals	Sea lions, 2 types (goats, dogs, swine, rats added by humans in recent past)
Birds	Land birds—25, 13 of which are the finches which evolved from one or two types.
	Sea birds—11, 2 unique
Reptiles	Snakes—3
	Turtles—1
	Iguana—2
	Lizards—1
Amphibians	None
Fish	Only marine, many unique
Insects	Few, many unique, tend toward the flightless and the small
Critical Factors	
Few organisms in ecosystem	
The changes in the finches, turtles, scalesia, and iguana stand out sharply.	

outstanding feature of all the Galapagos animals, fearlessness, and they become overwhelming. The sea lions, largest animals on the islands, have no fear of humans. It is as if they were in a zoo behind a moat. In the islands you can stand next to one of these half-sleeping animals, and it will not move.

The most fearless of all the animals is the Galapagos mockingbird. It walks around your feet, searches your shoes or toes for food, jumps right into your beach bag, perches on your head, and pecks your hair. The mockingbird's fearlessness of humans can be explained. No human set foot on the islands before the Spanish arrived in the 16th century. Apparently 400 years of proximity to humans was not enough to produce the fear instinct.

A somewhat less brave bird, the finch, is the most famous of all the islands' inhabitants. A small, common looking, sparrow-like bird, it is ubiquitous on the large islands. It ranges in color from a light buff to a dark gray-black. About half of the dozen species are ground birds and eat a variety of seeds. The size of the seed matches the size of the beak. The other half are tree birds that eat either seeds, insects, or vegetation (leaves and stems), depending on the shape and size of their beaks. When Darwin collected these birds, he made a quick study and then sent them back to England to Professor Gould. It was not until after his return, when he had more time to look and think about the birds, that he discovered that when placed side by side, they presented a smooth gradient from small-to-large-sized beaks. In all other respects, with the exception of coloration, they seem quite similar.

Implications of What Darwin Observed

After he returned to England and had time to think back on his experience in the Galapagos, Darwin began to formulate a series of questions. His first question was, why, if all animals and plants were created in a series of several acts by God only 4,000 years ago, should so many of them be peculiar to, and be found only on those few small islands out in the Pacific? In response he formulated a supposition. Suppose we could allow a longer time for the establishment of these organisms, say one-to three-million years. Then, what if we suppose that only a few types of organisms were able to make the journey, claim a niche, and begin to reproduce. Darwin could begin to see the possibility of the progeny of the first immigrants beginning to change. Each change could be maintained by breeding isolation, probably due to migration to separate islands. This process could have happened again and again until all of the possible food sources or niches were used. This process is called adaptive radiation. The finches have adapted to a greater extent than any other animals in the islands. The original iguana was probably a single type that began to fit separate niches as it changed into two different species. The turtles that had time to evolve to their huge size did not produce new species but only different races. The mockingbirds produced only behavioral changes. The flightless cormorant evolved a useless set of wings, but it did not lose the behavioral practice of drying them. They act as though the wings are still usable for flying and must therefore be dry.

Some migrants may have had a greater built-in capacity for change than others. The rate of change of one organism is inherently different from that of another. The greatest change we see here is the production of new species, and the smallest only a behavioral change. We believe that such recognition will help the student realize how slowly evolution occurs. Once you have the Galapagos story established, you can compare it with the time required to change the peppered moth or a microorganism.

Motion pictures of the Galapagos are available from Harper and Row. They set a visual stage for discussion of the ecology of the islands. Slide sets and film strips are also available. We are planning to publish a set of our own slides, along with a tape to explain the ecology and uniqueness of the animals and plants. If the attention of the students can be captured by visual images of the is-

land life, we think the students will welcome the question posed by Darwin of why so many of these organisms are unique to these islands. They should now be ready to accept the same conclusion as Darwin did. Let them first try to induce the concept of evolution, and then, in turn, deduce the history of any one organism from the evolutionary concept.

Now spring on them the fossils, geological strata, embryo similarities, and they may be able to handle the incomparably long time spans necessary to produce new genera, families, orders, classes, and phyla.

We realize that this short description of the ecology of the Galapagos is very sketchy. It only serves to emphasize the limited number of animals and plants found in the islands. The finches make up half of the 25 or so land birds present there. Combine this dearth or paucity (a word Darwin used to describe the ecology of the islands) of organisms with their novelty, their fearlessness, their uniqueness, and the fact that so many are endemic, and it would make any biologist sit back and wonder. At least that is what happened to Darwin who was an extremely capable observer.

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Adelie Penguins

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tion stability; however, the weather still makes their existence marginal. When human pressures are added to these natural conditions, the penguins' position grows even more tenuous. Only an increased human sensitivity to the plight of these birds will reverse the trend and allow the Adelie penguins to have a place on this earth.

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