The Galapagos

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Take five and twenty heaps of cinders dumped here and there in an outside lot; imagine some of them magnified into mountains and the vacant lot the sea; and you will have a fit idea of the general aspect of the Encantadas.

—Herman Melville

Part I – In The Beginning

Kate stood on the edge of the *caldera* and peered down into the shadows. She could barely make out the movement a thousand feet below. But there, she was sure, was the tortoise she had named Alfredo, slowly making his way among the lava rocks toward the water pool. All 500 pounds of him.Kate marveled at the volcanoes around her. Before she had started this journey, she had read about the Galapagos and their volcanic origins. But she hadn't expected to be so emotionally moved by the islands themselves, by their stark scenery. A young graduate student, she was about to embark on a four-year study of the biology of the longest living animals. Alfredo had been around long before Darwin had arrived in the islands—and here he was, still ambling among the lava.

The origins of the Galapagos were similar to the origins of the Hawaiian Islands, but the Galapagos clearly were younger, more stark and barren. Kate had read that the Galapagos were a chain of islands, some of which no longer broke the surface of the water. How were these islands formed, she wondered. Was it from a hot spot at the bottom of the ocean bubbling up magma at periodic intervals? Somewhere in the sea nearby in the Galapagos Rift there were hydrothermal vents belching sulphurous gases. Some biologists believed that these vents were the sites of the origin of life.

It had been a long-time dream of Kate's to visit the Galapagos Islands, and they hadn't disappointed her. Made up of 13 large islands and dozens of smaller ones, the Galapagos straddle the Equator in the eastern Pacific Ocean, some 600 miles off the coast of mainland Ecuador. Large, jagged outcroppings of lava alternated with small sandy beaches along the shorelines. Isolated patches of mangroves along the shore gave way to cactus in the arid lowlands of the islands, then lush cloud forests in the moist upper regions, and finally tree ferns and scrubby grasses in the otherwise barren uplands.

But it was the astonishing array of animals that took Kate's breath away. Like every other visitor to the islands, from the

first Europeans to set foot on these shores to Darwin some 300 years later in 1835, she was struck by the strangeness and tameness of the fauna. On shore, scores of sea lions lazily sunned themselves on the beaches. Masked boobies courted practically under foot. Among the rocks at the water's edge lived the black iguana, the only marine lizard in the world. In the surrounding seas were stingrays, white-tipped sharks, sea turtles, and the Galapagos penguin. Dozens of endemic species were found here and nowhere else on earth.

And here she was, standing where Charles Darwin had stood 150 years before. Darwin's theories of evolution had depended heavily on his insights into the origins of the life forms on the Galapagos. He had questioned where these animals had come from. How could the flora and the fauna of islands so near one another be so different and yet strangely so similar? Each island seemed to have its own variety of tortoise, its own type of marine iguana, even its own form of prickly-pear cactus.

The finches were particularly interesting. These relatively nondescript birds had beaks with amazing adaptations to eat different types of food. Although most of them were seed-eaters, Darwin had discovered that one of the finches had specialized by using small sharp sticks to probe the recesses of cactus plants for grubs. A woodpecker finch he called it. How could these animals and plants be due to simple creation? Wasn't it more reasonable to think that mainland species had arrived on the islands eons ago and became specialized for different environmental conditions on the different islands?

Kate knew the answers now to Darwin's questions, and yet the islands didn't seem old enough to account for the spectacular diversity she saw all around her. She knew that the Grants, the husband and wife team from Princeton University, were working on a nearby island to resolve the question of the speed of evolution. She had heard at the Charles Darwin Research Station that they had been impressed with the rapid changes that seemed to be brought about by the El Niño climate shifts in the last couple of decades. She resolved to look into this more closely. But right now she had to get back to the research station—gray storm clouds were closing in fast.

Study Questions

1. How did the Galapagos Islands come into existence?
2. Were plate tectonics involved?
3. How old are the Galapagos Islands?
4. What kinds of animals and plants are endemic to the islands?
5. How do species become endemic?
6. Where did the original colonists come from and how did they get to the Galapagos?
7. What kind of special adaptations do the animals and plants have? How do adaptations evolve?
8. How did these islands figure into Darwin's ideas on evolution?

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Part II – Darwin's Finches

"So, Kate, what do you think of the islands?" asked Miguel.

"I think they're fantastic. The Spanish were right to call them 'The Encantadas'." Kate had just entered the library of the Charles Darwin Research Station to find its director sitting at a table.

"Yes, 'The Enchanted Isles' does seem to suit them. The volcanoes have always seemed bewitched to me. Sit down for a minute and tell me how your plans are shaping up." Miguel gestured toward a chair across from him.

"Well, I was on Albemarle two days ago, and I think I could get my research done up there. The chance to study character displacement on the five volcanoes is really exciting. Imagine, five different races of tortoises on the same island. A lot of the tortoises seem to have already been marked by previous researchers, and you seem to have a good handle on some of the history already."

"Yes. In addition, we have some good DNA data on the tortoises here, especially those in our breeding pens. You've seen them, I'm sure."

"Yes, I have. I think it's a terrific breakthrough that at last you can identify which islands some of these animals came from. In fact, it should be possible to identify the parents if enough data were collected. But, who's doing this work? Is it done here at the station?"

"No. We send tissue samples out to labs in the United States for DNA fingerprinting. We don't have the lab facilities here to do Southern Blot procedures or PCR. But tell me, are you committed to working on the tortoises? There are a lot of easier things to study here. The iguanas and the birds are more accessible."

"I've thought about that, especially since the Grants have been so successful working on the finches. How's their work coming?" Kate leaned forward eagerly.

Miguel removed his glasses, tilted his chair back, and began: "I'm sure you know that Peter and Rosemary started trapping and banding all of the finches on Daphne Major over 20 years ago. Sometimes they had only 200 birds on the island; sometimes there were over 2000. And they could recognize them all! The Grants have been able to watch evolution happen; something that Darwin could only imagine."

"He thought evolution was too slow to see," Kate said. "In fact, Creationists have argued that neither evolution nor Divine Creation could be tested. The Grants' work certainly puts a lie to that."

"Yup. Darwin certainly underestimated the speed of evolution. These islands appeared less than five million years ago, and life is evolving here as fast and furiously as the volcanoes because life forms are trapped on separate islands. The top of each volcano is a prison for most of the creatures."

"There never was a bridge to the mainland, was there?"

"No. Anything that has arrived here had to cross at least 600 miles of water from South America. That's how the first finches arrived here, presumably blown off the mainland during a storm."

"So, in the space of a few million years all of the different species had to have adapted to the different conditions on the different islands."

"That's true, but realize the differences are not all due to adaptations and natural selection. I figure a lot of it has to do with genetic drift."

"Of course. But whatever was going on, no one figured it would be as fast as the Grants have discovered. I think one of the neatest techniques that the Grants brought to their study was a way of measuring how the seeds of the different plant species vary in their hardness."

"I agree with you, Kate. Peter and an engineer at McGill University designed a nutcracker, a sort of pliers with a scale attached. They found small soft seeds of *Portulaca* needed only a force of 0.35 newtons to be cracked. Any of the finch species could do that. But the big hard seeds of *Cordia lutea* needed 14 newtons force and only a few large finches can muster that much force. Once they knew how to measure hardness, the Grant team could check the abundance of the seeds and see exactly what the birds selected and ate."

"But that varied with the season, didn't it?"

"Exactly. In the wet season, when small seeds were abundant, the average seed hardness was 0.5, but in the dry season it jumped to over 6 newtons. Lots of finches couldn't eat many of those seeds. If it hadn't been for the fact that the six species began to switch to other foods, severe starvation would have occurred. A great example of resource partitioning—one of your pet subjects, Kate.

"In fact, Rosemary Grant found that switching even occurred among individuals of a single species. In times of plenty, all cactus finches eat the same seeds, but when these seeds are scarce, things change. Those with long beaks open the fruits and probe the cactus flowers, while those with larger, deeper beaks crack the big tough cactus seeds, and those with still deeper beaks strip the bark from the trees to get grubs."

"Everything gets worse when a severe drought happens, doesn't it? Natural selection really gets intense."

"Absolutely. It virtually wipes out the birds with the smaller beaks. The great drought of 1977 taught the Grants that. The population plunged to 200 birds. Before the drought, the average beak size of the *fortis* species was 10.68 mm long and 9.42 mm deep. After the drought, it was 11.07 mm long and 9.96 mm deep. Variations too small to see with the naked eye made the difference between life and death. It altered the sex ratio, too, since males have larger, stronger beaks. After the drought, there were seven times more males than females! In the years following the drought the competition between males for mates was fierce. Amazingly, the females started choosing the males with the largest beaks for breeding. The smaller-beaked males didn't have a chance to mate at all."

Kate nodded. "That's a perfect example of sexual selection in action. Both natural election and sexual selection were working in the same direction: producing birds with large beaks. But were these genetic differences or were they due to the food supply? I mean, wouldn't you expect the well-fed birds to have larger bills, and then they would be the ones to breed and successfully raise young?"

"Of course. One of their graduate students wanted to test that, but it didn't work out, so they have had to resort to indirect evidence to demonstrate that the changes were genetic.

"But let me tell you about the big El Niño events of 1983," Miguel continued. "A huge amount of rain fell that year, a once-in-a-century event! The island went from a desert to a jungle in a few weeks. Food was everywhere.

The birds started breeding like crazy and there were suddenly 2000 finches on Daphne Major. When normal, dry conditions returned, there suddenly wasn't enough food to go around. The birds had overshot the carrying capacity of the island.

"But here's the interesting part: now, birds with smaller beaks were favored. Big males and big females started dying because of insufficient food. That's because there were a lot more small seeds than large ones lying around. The floods of El Niño had washed away many of the large seed-producing cactus trees. Even though the big birds could eat small seeds, they were at a disadvantage because of their size. They had to eat more to survive."

"A lot of hybridization started occurring after El Niño, didn't it?" Kate said.

"Yes, to everyone's great surprise. Hybrids were rare during the lean years. The reproductive barriers kept the species distinct. The isolating mechanisms were primarily differences in song and beak size. But once the conditions dramatically improved, diversity was favored. A lot of finches began to breed with individuals of different species. They didn't seem to care as much what kind of song or beak their mate had. Some people even speculated that the mutation rate actually increased when environmental conditions shifted dramatically.

"Take a look at the finches outside the window," Miguel added. "Here at the research station it's hard to separate the different species because of the hybrids. They sort of fuse together here, where conditions are always good because people feed them. Kate, if you really want a great thesis problem, you couldn't do much better than study finch hybridization around the village. I'm sure that humans are having a terrific impact on both speciation and extinction."

Study Questions

1. What is DNA fingerprinting and how is it done?
2. How can we measure evolution?
3. What is the difference between natural selection and evolution?
4. What is genetic drift and how could it be involved in evolution?
5. What is resource partitioning and character displacement?
6. What is sexual selection?
7. How might one test if beak size is due to genetic or environmental factors?
8. If hybridization occurs during good times, what does this suggest about the degree of genetic differences between species?
9. What are reproductive isolating mechanisms and how do they evolve?
10. Must populations of finches be separated in order to evolve into different species?
11. What causes an El Niño?

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Part III – The Tortoise and the Sea Cucumber

Kate was tired. The last few nights she had stayed on late at the station, typing up her field notes. Her research on the breeding practices of the giant land tortoises in the wild was going well. She had been observing them for a four-month period, primarily in the Alcedo Volcano area on the island of Isabela, home to about 4,500 tortoises. But she was worried that mounting tensions between local fishermen and the Ecuadorian government might disrupt her work. The year before, in response to a decision by the President of Ecuador to cut short the sea cucumber season, armed fishermen had stormed the research station and taken several scientists hostage.

Kate's biggest concern at the moment, however, were the goats on Isabela. With human settlement of the islands had come new kinds of animals—cats, rats, dogs, donkeys, pigs, and goats. The number of goats on Isabela had increased from less than a dozen in 1982 to over 100,000. They were literally eating the tortoises out of house and home, foraging on the shrubs and bushes growing on the mountain's slopes, competing with the tortoises for food, causing widespread erosion of tortoise habitat.

Besides the damage done by goats, wild dogs and pigs dug up the tortoises' nest and ate their eggs in addition to preying upon their hatchlings. On Pinzon Island, another introduced species, the black rat *(Rattus rattus),* had killed every tortoise that had hatched on the island in the last 100 years.

It seemed sad to Kate that the islands' natural heritage was slowly being destroyed by the hand of man. The Galapagos had been named in 1535 by a Spanish navigator, Tomas de Bertanga, for the then-prevalent giant tortoises. When Darwin visited in 1835, he reported tortoises on all of the islands. Since then their populations had dwindled at an alarming rate, and several subspecies had become extinct.

Lately Kate had begun to feel almost a personal responsibility to save the endangered tortoises. She considered the plight of Lonesome George, perhaps the most famous resident at the Charles Darwin Research Station, so named because he was the last surviving member of his subspecies *G. e. abingdoni*. One of the major initiatives of the research station was its captive breeding and rearing program, which was already racking up successes.

The tortoises of the island of Espanola *(G. e. hoodensis)* had been teetering on the verge of extinction. When captive breeding began for this subspecies, only two males and twelve females remained. Later, a third male was returned to the islands by the San Diego Zoo. Since then well over 300 young tortoises had been bred and repatriated, and some of these were now breeding back on the island. Kate was proud that her fieldwork was part of this effort.

Kate switched off her computer. She stuffed some papers into her backpack and the last bite of her sandwich into her mouth and got ready to leave. She thought of stopping by her friend Stephen's house on the way home. Stephen had been a full-time rancher, part-time naturalist in New Zealand before visiting the Galapagos some 15 years before. Enchanted by the place, he had simply stayed on, becoming one of the first government-licensed tour guides.

Much of the islands had been designated a wildlife sanctuary in 1934 by the government of Ecuador. Uninhabited areas were declared a national park in 1959. In 1986, the Galapagos Marine Resources Reserve

was created, administered by the Ecuadorian government with the help of the research station. The reserve made up about 97 percent of the islands' land and 50,000 square kilometers of the surrounding seas. Tourism throughout the islands was strictly controlled. Tourists weren't allowed to wander around. Instead, they had to be accompanied by a licensed tour guide when visiting wildlife sites, and they had to stay on assigned paths. Many islands were off limits entirely.

As she walked to Stephen's house, Kate thought it was ironic that one of the few places on earth where aboriginal man never existed, one of the least-visited corners of the earth for much of modern history, should be practically overrun now by human beings. Last year over 50,000 tourists had visited the islands. Many conservationists were voicing concerns over the impact of tourism on the islands. Still, most scientists agreed that 15 years of tourism hadn't done one-tenth the damage of the recent fishing boom and the mass immigration from the mainland that came in its wake.

Although certain fisheries were long established in the Galapagos and sanctioned by the government, the sea cucumber fishery had become a sort of "gold rush" phenomenon. Fishermen from the mainland had descended on the islands to harvest them illegally from the protected waters. Considered a delicacy in Asian cusisine, sea cucumbers were also in demand throughout the Orient for their purported aphrodisial properties.

Kate thought them one of the more unattractive animals she'd ever encountered. Ranging in length from two inches to five feet, they had soft bodies and a leathery, somewhat slimy skin. Some species were warty.

The role they play in ocean ecology wasn't fully understood. Marine biologists likened them to earthworms. They spent most of their time on the sea floor, where they sucked up mud and sand, from which they extracted nutrients. Kate had overheard one of the researchers at the station saying that sea cucumbers often made up 90 percent of the animal biomass in marine systems. Many scientists feared that a rapid decline in their numbers might have serious consequences for the survival of other species in the food chain.

Harvesting of the *Isostichopus fuscus* sea cucumber had begun in the waters surrounding the Galapagos in 1988 but had been banned by the government in 1992, although illegal fishing continued. The Ecuadorian government simply didn't have the resources to effectively patrol miles of open ocean. In response to increasing pressure from local fishermen, the government lifted the ban and granted a three-month season for harvesting sea cucumbers, beginning in mid-October of 1994. Kate shuddered, picturing the tortoises that reportedly had been found dead, hanging from trees—the form of political pressure the local fishermen had allegedly resorted to. The total take wasn't supposed to exceed 550,000 sea cucumbers, but in the first two months alone an estimated seven million were harvested from the sea floor.

The government stepped in and shut down the fishing season a month early, touching off a series of violent protests that had culminated in several fishermen, wielding axes and machetes, taking hostages at the research station. Government troops had been called out, and the hostages—including Lonesome George—were freed without further violence. In the weeks that followed, the Ecuadorian government placed a moratorium on the sea cucumber fishery until scientists could determine an annual catch that wouldn't wipe out the species. The government asked ORSTOM, the French overseas research agency, and the Darwin Foundation to study the problem.

When Kate got to Stephen's house she found him all worked up over the media's coverage of the crisis in the Galapagos. He was upset because the news stories seemed to imply that all of the inhabitants of the islands were anti-conservationists.

"Tourism brings in over $50 million dollars a year in revenue," he said. "Fishing isn't a major economic factor in the lives of most of the people who live here. Believe me, people here are not fools. They're only too aware that they must

conserve the islands if they are to protect their livelihoods. These people—the fishermen and the politicians who support them and their violent tactics—don't represent the majority. They certainly don't represent me.

"In the short time you've been here, Kate, you've seen that the problems that beset these islands are not simple—they are very complex. We've been left to deal with the aftermath of an uncontrolled mass migration. We've gone from a population of 5,000 in the early '80s to over 15,000. This population explosion is putting enormous pressure on the islands—on other aspects of our economy, for one thing, like our traditional fisheries, which could be at risk next. And now that this ban has put our newest immigrants to the islands out of work, we've got rampant unemployment, and hard on its heels, an increase in crime.

"I'm sympathetic to the plight of these people," Stephen continued. "I know that the poverty they're fleeing from on the mainland is terrible. But I'm not sympathetic to their "get-rich-quick" mentality or their strong-arm tactics. The people from the mainland haven't grown up with an appreciation of the uniqueness of the reserve or the goals of the research station, or an understanding of the tradition of sustained subsistence fishing on the islands. They're just not as sensitive to the extraordinary biodiversity and the natural resources of these islands.

"The Galapagos economy, like that of the rest of Ecuador, is based on its natural resources. Victory for the conservationists is not a defeat for Ecuadorians. What many claim is a war against our own people is simply a refusal to defend the Galapaguenos' "right" to destroy their own future."

Kate sighed. She agreed with Stephen, but she couldn't help thinking of her neighbor Emilia, who had been so kind to her in so many ways. Emilia's husband Adolfo was the head of the fishermen's cooperative on Isabela. According to Adolfo, the sea and its bounty were "the only way out" for the local people. Adolfo had cornered Kate a week ago, almost shouting at her as he waved his arms and argued his point: "The conservationists have to take into account that if they don't allow the development of any other industry, there is no way for us to survive. How are we going to feed our kids? We need to live!"

As Kate got ready to leave, Stephen asked her if she had heard that the Darwin Foundation had finally issued its report:

"It recommends restoring traditional fisheries in the Galapagos and helping poor fishermen return to mainland Ecuador. They intend to make the moratorium on the sea cucumber fishery a permanent thing. That could mean more trouble. Be careful, Kate."

That night Kate slept uneasily. Early the next morning she was wakened by the sound of someone banging on her back door. It was Emilia, carrying her youngest daughter in her arms. Emilia looked frightened. Kate had to ask her twice to repeat herself. When she finally understood what Emilia was trying to tell her, she was horrified. Apparently Congressman Eduardo Veliz and the fishermen he represented had taken over the islands' fisheries and the research facilities. And now they were threatening to set fires, take tourists hostage, and kill rare animals (tortoises, Kate figured) unless the government complied with their demands to reopen the sea cucumber fishery and give local inhabitants of the islands more control over the national park.

Study Questions

1. Should Kate have chosen to work on a different species than the tortoises that are being threatened? Her thesis work might be destroyed by the politics of the islands.
2. Should Kate get involved in the politics of saving the islands, the way Dian Fossey did in trying to save the Mountain Gorilla?
3. Should fishing, tourism, or inhabitants be allowed in the islands?

4. How should the Ecuadorian government deal with the conflicts over the islands?
5. Extinction is a natural phenomenon. Why should we worry about whether a few species on some remote islands in the Pacific survive or not?

Instructions to Students

During the discussion period, each team of students will assume the role of a particular interest group vying for a piece of the action in the Galapagos: fishermen, storeowners, tourists, scientists, Sierra Club members, and politicians in Ecuador. When you receive your roles, you should research the case from your particular perspective and talk over your position within your group, developing a position paper.

When we are ready for a general discussion, members of each interest group will be split up to meet with people from other interest groups, i.e., the instructor will form new consensus-seeking groups, each of which will have one member from each of the interest groups present. So, a consensus group will have a fisherman, a storeowner, a tourist, scientist, Sierra Club representative, and politician. The politician's job is to run a discussion to see if the group can come to some consensus on how to resolve the crisis and write a position paper laying out the group's plan.

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