CHAPTER 7

THE VOYAGE OF THE BEAGLE

"After having been twice driven back by heavy southwestern gales, Her Majesty's sip Beagle, a ten-gun brig, under the command of Captain Fitz Roy, R.N., sailed from Devon-port on the 27th of December, 1831. The object of the expedition was to complete the survey of Patagonia and Tierra del Fuego, commenced under Captain King in 1826 to 1830—to survey the shores of Chile, Peru, and of some islands in the Pacific—and to carry a chain of chronometrical measurements round the World"

Thus begins one of the most remarkable books of all time, The Voyage of the Beagle, by Charles Darwin. This was a most fortuitous voyage. The young Charles was rather lucky to be on board. Born on the same day as Abraham Lincoln and of a distinguished family—his father was a well-known physician and son of the distinguished natural philosopher, Erasmus Darwin, and his mother was a Wedgwood of the Wedgwood China family—Charles had not been too promising a student. He had started medical school but, nauseated by surgery at a time when there was no anesthesia, he abandoned this career. He then tried theology but, to all appearances, seemed to spend his time collecting beetles and hunting, and not passionate about a career in the clergy. Although he formed a close attachment to a minister who was also a naturalist, it was easy to picture him as a ne'er-do-well. Thus, when he proposed following up the lead from his mentor John Stevens Henslow to apply for the position of naturalist and companion to the captain of the Beagle, his father—who considered that the young Charles really should be settling down into a career—offered only the most grudging tolerance: "If you can find any man of common-sense who advises you to go I will give my consent." Luckily, Charles' uncle, Josiah Wedgwood, whom his father highly respected, recommended that he go. One might guess that Mr. Wedgwood was prescient or merely despaired that Charles was going nowhere and, with the time for reflection on a long trip, might yet find a goal in life. There is however evidence that young Charles had shown some spark of talent, for Wedgwood described him as a man of "enlarged curiosity" and Henslow had recommended him by saying, "I consider you to be the best qualified person that is likely to undertake such a situation, amply qualified for collecting, observing, and noting anything worthy to be noted in natural history." Once on board, Darwin earned the nickname "The Philospher" because of his propensity for noticing, questioning, and analyzing everything that went on.

As for Captain Fitz Roy, Darwin was his fourth choice. The captain wanted a traveling companion on the very long trip, a good, intelligent, conversationalist who

could be of service on the boat. Given the conventions of the time, it was a given that the companion should be of good family and well bred. This aspect was most likely what most recommended Darwin to Fitz Roy. In fact, the Beagle already had a naturalist, the ship's senior surgeon Robert McCormick, on board. Charles' easy conversation and culture rather quickly endeared him to the captain, and within four months, McCormick returned home, convinced that Charles was very much the favorite of the captain.

In any case he was an ideal choice for the trip. He had been eagerly reading Lyell's latest findings in geology, which had prepared him both for the argument of gradual change in the surface of the earth and the possibility that these changes took extensive time to accomplish. Furthermore, as he himself concludes, it was now possible to explore the world as never before: *"The short space of sixty years has made an astonishing difference in the facility of distant navigation. Even in the time of Cook, a man who left his fireside for such expeditions underwent severe privations. A yacht now, with every luxury of life, can circumnavigate the globe."* This was indeed an improvement that made this sort of exploration possible, but we should not underestimate what it would take to spend five years at sea. By today's standards it was still very demanding. Over water, Darwin was most of the time seasick. Whenever the boat docked, he went ashore to explore. Although he frequently stayed with English or other families to whom he had an introduction, many of his explorations were by horseback, one to two hundred miles at a time, camping, or climbing to the tops of mountains or through forests so dense that *"Here we were more like fishes struggling in a net than any other animal."* see Figures 7.1 and 7.2

The book itself is remarkable for many reasons. First, it is essentially a diary of a trip by a young man, and mostly it describes the geology and animal and plant life of strange lands. Nevertheless it sold very well. The 19th C was an

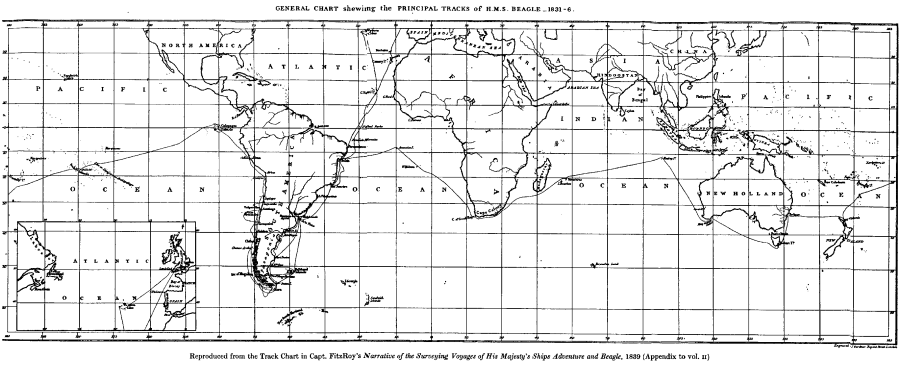

Figure 7.1. The journey of the Beagle as recorded by Captain FitzRoy. This picture has sufficient resolution to be examined using a magnifying glass. Note how long the Beagle stayed at the various ports, and the inland excursions that Darwin undertook. Credits: Charles Darwin's Diary of the voyage of the H.M.S. Beagle edited from the MS by Nora Barlow, Cambridge, University Press, 1933; Kraus Reprint Co. New York, 1969

Southern portion of South America

Figure 7.2. Darwin's inland trips according to his notes. He spent a considerable part of his trip riding inland on horseback, rejoining the boat at a port further along. His diary for these excursions reflects the thoughts that occurred to him, especially in the Pampas of Argentina, at Tierra del Fuego, and in his excursions into Chile. The earthquake was at Concepcion. Credits: Charles Darwin's Diary of the voyage of the H.M.S. Beagle edited from the MS by Nora Barlow, Cambridge, University Press, 1933; Kraus Reprint Co. New York, 1969

exciting time for Europe, with explorers going to examine foreign countries, mostly looking for business opportunities or opportunities to exploit other countries—it was, after all, the period of the building of the British Empire—and many who never left home were eager to learn all they could about these lands that they could not imagine and would never see. Second, written as it is with the ingenuousness of a young man, it provides a wonderful example of his growth and maturation, including his struggles with, and indeed his abhorrence of, the concept and practice of slavery, indenture, and corrupt societies. Third, it most masterfully reveals the fundamentals of science and the mind of a scientist. For Darwin never notices an anomaly but that he questions how it came to be: why some animals and plants are found in one location and not another; why similar islands in different oceans have different flora and fauna; how mountains are raised and valleys are formed; how coral reefs and atolls are formed—in short, how the world works. Finally, the book is tantalizing in that each time Darwin notes something and questions its origin, one sees the roots of what will become The Origin of the Species. As he touches on the edge of these great ideas, he becomes most poetical: *"It is not possible for the mind to comprehend, except by a slow process, any effect which is produced by a cause repeated so often, that the multiplier itself conveys an idea, not more definite than the savage implies when he points to the hairs of his head. As often as I have seen beds of mud, sand, and shingle, accumulated to the thickness of many thousand feet, I have felt inclined to exclaim that causes, such as the present rivers and the present beaches, could never have ground down and produced such masses. But, on the other hand, when listening to the rattling noise of these torrents, and calling to mind that whole races of animals have passed away from the face of the earth, and that during this whole period, night and day, these stones have gone rattling onwards in their course, I have thought to myself, can any mountains, any continent, withstand such waste? .... Daily it is forced home on the mind of the geologist, that nothing, not even the wind that blows, is so unstable as the level of the crust of this earth."* Here he expresses the first inklings of his realization of the great age of the earth, a necessary understanding if there is to be time for evolution to occur. The book is eminently readable, even to a non-scientist, and is highly recommended, for its importance in the culture of the 19th C; for Darwin's vignettes of the social structures of the societies that he visited; and for its image of the growth of a remarkable young man.

When Darwin signed on as a naturalist for the Beagle, he had a large but relatively simple task in front of him. Bolstered by reliable and relatively safe ships and means of identifying both longitude and latitude, as well as the potential of finding new lands and resources for the economy, many nations were exploring the earth. They were interested in the gold, silver, copper, and lumber of the New World, as well as the possibility of converting to Christianity (and most likely subjugating) the inhabitants thereof. Their curiosity was piqued by the strange animals and plants described by the explorers. Given the sense that all living things were made to serve humans, Europeans wanted

to know what was out there and, since the comfortable and certain world of Linnaeus was confused by the new findings, the scientific community was trying to relate the new materials to the ordered structure of the universe. As a further incentive, valuable new animals and plants had been brought back to Europe by earlier explorers. These creatures included American cotton, tomatoes, potatoes, corn, chili peppers, chocolate, avocado, sugar cane, and tobacco, as well as fur-bearing animals such as raccoons and edible animals such as turkeys (misnamed because explorers confused it with the helmeted gamecock or turkeybird, an African bird known in Europe) as well as plants potentially useful for medicinal purposes, many flowers, and other less valuable but nonetheless unusual animals and plants such as armadillos. (Cotton and sugar cane existed in the Middle East and Asia but had not attracted the attention or interest of Europeans.) There was always the hope that more would be found. Thus Darwin's job was to collect, catalog, and classify any plants or animals that he could.

Darwin, however, was also a thoughtful man, considering the relationship of the provocative ideas of his grandfather, Erasmus Darwin to his training in Theology, as well as the exciting ideas of geologists such as Lyell. There were at least two issues that were quite difficult to resolve. First, unless each species was quite constant and discrete, it would be quite difficult to understand how Noah could have accommodated on the Ark the whole gamut of life. Second, if species were not constant but could change, as domesticated animals surely could under selective breeding by humans, could that change have produced everything that exists on earth? In 6000 years one might get different varieties of dogs, but could one generate all types of animals and plants? Many thoughtful "naturalists," including Charles Darwin's grandfather Erasmus Darwin, had formulated suggestions that species could change, but in all cases either their arguments were forced and easily undercut, or no mechanism was suggested and therefore there was no compelling reason to believe these naturalists. What one required was (a) evidence that species were not stable; (b) sufficient time to allow for the change of species; and (c) a mechanism by which evolution could occur. During the voyage of the Beagle, Darwin accumulated the evidence for (a) and observed enough to convince him of (b). Since he continued to ask questions of his questions and doggedly pushed until he had solutions, over the next twenty years he worked out the mechanisms by which the evidence that he had accumulated could be explained. By the time that he published his explanation, in 1859, it was so clear and convincing that, like all great ideas and poetry, one could only ask, "why did I not think of it?" However, it was quite painful, since the argument was that the creation of the species did not need a Creator but could come about through natural mechanisms. To Darwin, admitting this possibility was "like confessing to a murder". Nevertheless, Origin of the Species today is rather boring to read. What makes it boring is that Darwin makes a point, then assiduously documents it with many examples. By the third

example, we are convinced. This is because we are today so thoroughly imbued with the idea that we do not need the convincing that was necessary in the middle of the 19th C.

THE VOYAGE OF THE BEAGLE—DISCOVERIES AND PHENOMENA THAT CAUSED DARWIN TO DOUBT

The first issue that Darwin confronted was the sense of time. Most of the previous efforts to argue the evolution of organisms had foundered on the ridiculousness of the idea that everything on earth could have been produced by any non-Divine mechanism in 6000 years. However, as is discussed in Chapter 12, page 168, Lyell had argued that the great features of the earth could be explained by gradual processes that were known in the present earth: sedimentation, erosion, and earthquakes but that reading the structure of hills and geological formations in this way would suggest far more vast extensions of time. Darwin was reading and thinking about Lyell's arguments while at sea—he dedicated the book to Lyell—and what he saw stunned him. The great plains of Patagonia appeared to be outwash from the far distant Andes Cordillera, itself a magnificent range of mountains reaching in places 23,000 feet. It was this realization that provoked the expostulation quoted above. While he was still mulling these thoughts, the boat reached Concepción, Chile, where there was a great earthquake. When it was over, subtidal flats that had been underwater were now above the sea, having been lifted three to eight feet. Darwin, who had been in the mountains marveling at fossils of seashells 1300 feet above sea level and even up to 14,000 feet, realized that earthquakes such as the one he had witnessed could explain their elevation. Later (though not in *The Voyage of the Beagle*) he would estimate, from Spanish records, the frequency of earthquakes of that magnitude in the Andes and calculate the time it would take to lift the mountains 20,000 feet. His calculation had too many assumptions and was quite inaccurate, but it was well beyond any biblical calculation. By the time that he wrote *Origin of the Species* he was calculating from the rates of erosion of cliffs and the rate of accumulation of sediment the ages of various tracts of land in England. His figures, over 360 million years, were still not correct, but not terribly wrong, and 6,000 times longer than biblical time. It would be sufficient to allow the evolution that he described.

The second issue that became important during the voyage was the apparently idiosyncratic manner in which animals were distributed throughout the world. The farther he goes, the more these issues bother him: the Cabo Verde Islands and the Galapagos Islands are very similar in physical structure and proximity to the equator, but life on these two islands is very different. Why do the living organisms of the Galapagos look similar to those of South America, while those of the Cabo Verde Islands resemble those of Africa? Why is the fauna of islands so limited, in particular, lacking large mammals and frogs? Why does one find the fossils of giant armadillos only in the lands where one now finds small armadillos, and the fossils of giant sloths only in the lands where one now finds smaller sloths? Why

are there camels in Africa, but llamas in South America? Why do similar species not share territories? For instance, there is a large, flightless bird called a rhea in South America (Fig. 7.3); but, in fact, there are two species, as Darwin realized and pointed out, such that one is now named after him. The ranges of the two species abut but do not overlap. Darwin wondered why. If species were created by direction of the Creator, why did they distinctly differ by location, so that some systematists would insist that the variants were different species? Darwin wondered about all of these things. In fact, he wondered why people did not wonder: *"My geological examination of the country generally created a good deal of surprise amongst the Chilenos: it was long before they could be convinced that I was not hunting for mines. This was sometimes troublesome: I found the most ready way of explaining my employment, was to ask them how it was that they themselves were not curious concerning earthquakes and volcanos?—why some springs were hot and others cold? – why there were mountains in Chile and not a hill in La Plata? These bare questions at once satisfied and silenced the greater number; some, however (like a few in England who are a century behindhand), thought that all such inquiries were useless and impious; and that it was quite sufficient that God had thus made the mountains."* It is a matter of some note that, by informal survey, a large number of today's practicing scientists had a nickname "questions" or the equivalent. All children are curious. Many of those who do not lose that curiosity become scientists.

Finally, the Beagle reached the Galapagos Islands (Turtle Islands), a group of volcanic islands approximately 500 miles to the west of Ecuador. As he understood, the islands were of relatively recent origin and had never been connected to land. What he saw on the Galapagos greatly troubled him and, though he did not understand what he saw and even missed one of the most important points, the difference between birds from different islands, so that he lumped them all together. Nevertheless, he sensed that it was terribly important: *"Considering the small size of the islands, we feel the more astonished at the number of their aboriginal beings, and at their confined range. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period geologically recent the unbroken ocean was here spread out. Hence, both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth."*

The islands were named because of their large population of giant turtles and lizards. Consistent with the lack of large, predatory mammals, these reptiles show no fear of humans and, when frightened, run from the sea to shore rather than to the sea. As Darwin learned from residents and observed for himself, the turtles from each island could be readily distinguished. Why should they exist here, of all places, and then vary from island to island? Even more curious were the birds. They were all unique, but relatively similar to each other and there were several varieties, distinguishable by size of their beaks. The beak size was important, for the different birds ate different kinds of seeds. There was even one bird that acted like a woodpecker. Though it did not have a woodpecker's very hard beak and

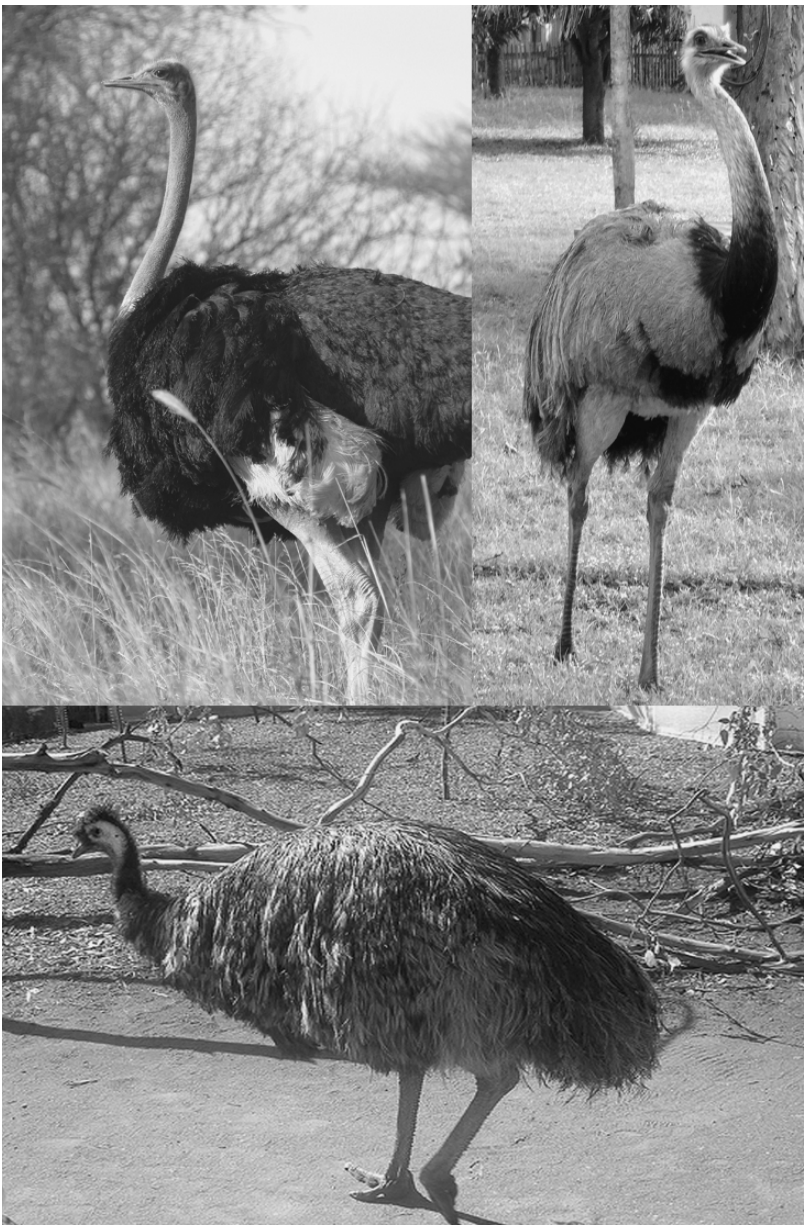

Figure 7.3. Top Left. Ostrich Africa Top Right. Rhea (South America); Bottom: Emu (Australia); Originally these birds were considered to have evolved by convergent evolution, or selection for the same traits among unrelated animals owing to similar circumstances. Today it is recognized that they are descendents of the same ancestor. See Chapter 22. Credits: Ostrich - http://www.dreamstime.com/Ostrich-rimage329921-resi191750 © Photographer: Steffen Foerster | Agency: Dreamstime.com. Emu - (http://www.dreamstime.com/Australian Emu-rimage864548-resi191750 © Photographer: Martina Berg | Agency: Dreamstime.com)

strong neck, it tore spines from cacti and used the spines as probes to dig insects from within the cacti. Even more curious than this, all the birds appeared to be finches, closely related to, but distinct from, a finch found in Ecuador. Why should these several unique species be found only in a small archipelago, 100 miles across, 500 miles from the coast of South America; and why should these birds be similar to a continental species? If God created these species at Creation, why should they not be the same as those found elsewhere in the world, for instance in the Cabo Verde Islands?

A final marvel of *Voyage of the Beagle* is a passage that only indirectly relates to the story of evolution but represents a scientific triumph of itself and for which, among geologists, he is justly famous. For he observed the atolls—curious rings of coral, many miles across, surrounding a shallow lagoon and, sometimes, a central island—of the South Pacific, and he gave the first clear and convincing explanation of their origin. You may have some image of what they may be, for these are the famous and romantic South Sea islands, such as Bikini, the Coral Sea islands, the Caicos Islands, and the Marshall Islands, that are well known idyllic hideaways. What is interesting about Darwin's analysis, though, is his perfect use of ELF logic. Falsification by experiment is not possible, but what he does is to collect as much evidence as possible—the slopes of the sea bottom within and outside of the lagoon; the slope and configuration of the central islands, including rivers and valleys; the biology of the coral-forming organisms, which survive only from the sea surface to a depth of 20–30 feet; the texture and composition of the underlying soils; the similarity of atoll corals to fringing and barrier corals; and many other features. He then applies logic to the assembly of this information, relating the patterns that he sees to known physical forces such as the destructiveness of waves at the top of the coral and what determines a specific angle of slope, and in this manner rules out (falsifies) most of the competing hypotheses, leaving him with the one surviving hypothesis. The surviving hypothesis might be surprising but, in the face of his logic and evidence, is the inevitable conclusion of his argument: that an atoll started life as a volcano. The volcano ultimately became extinct and was ringed with coral. Then, over the course of millennia, the volcano slowly sank in the sea. As it did, new coral grew on top of old coral, maintaining the ring even as the mountain disappeared beneath the waters (Fig. 7.4).

If this argument does not convince you, as it should not, given that no evidence has been presented to support it, you should certainly read the 30-some pages in which he develops his argument. It is a brilliant exposé, and a masterful demonstration of the power of ELF logic. It remains the accepted interpretation of the origin of atolls.

By the time that Darwin returned to England, he had seen a great deal, and he, like any scientist, wanted to know how it worked–how the distributions of species came about. He was deeply troubled by the strange and seemingly idiosyncratic distribution of animals and plants throughout the world; he appreciated the evidence for great age of the earth; he had seen how populations could expand, as had the wild horses in Argentina, which had escaped from the Spanish and now numbered

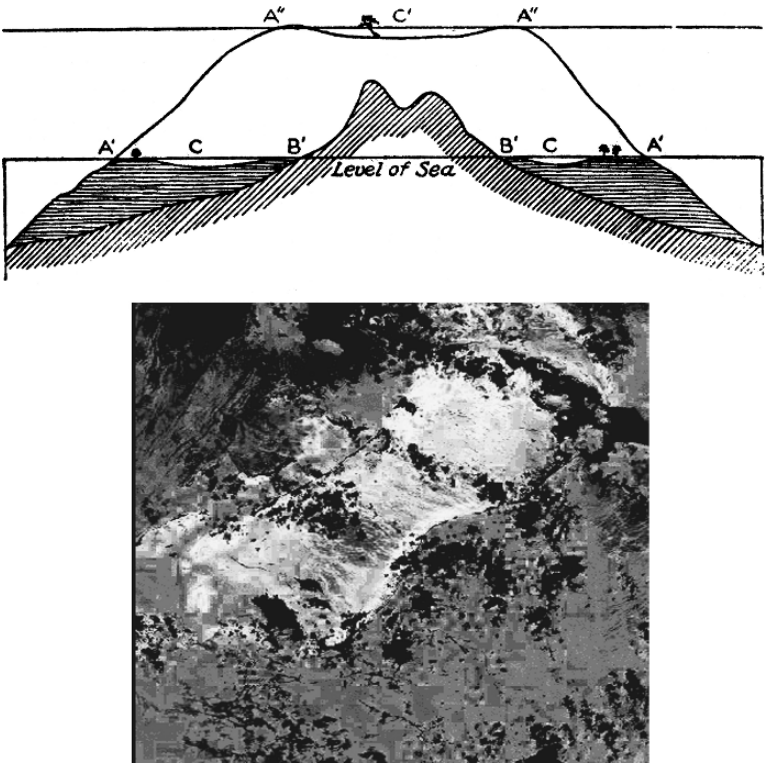

Figure 7.4. Upper: Configuration of an atoll correctly surmised, from the evidence of the slopes of the land beneath the coral and the correspondence of the reef to any island within the atoll, that an atoll started with a volcano projecting above the ocean. Coral reefs grow on the shores of the volcano. Over time, the volcano ceases to be active and, for several reasons, gradually sinks beneath the ocean. However, coral can survive only near the surface of the ocean, where it can get light. As the land sinks, the coral grows upward, building a wall up to the surface. Ultimately the volcano disappears, living only its ring of upwardly-grown coral and a shallow lagoon where the volcano once stood. What is illustrated is his diagram, with the following text:
A'A'. Outer edges of the barrier-reef at the level of the sea, with islets on it. B'B'. The shores of the included island. CC. The lagoon-channel.
A"A". Outer edges of the reef, now converted into an atoll. C'. The lagoon of the new atoll.
N.B.-According to the true scale, the depths of the lagoon-channel and lagoon are much exaggerated.
Lower: A Caribbean atoll, Los Roques. Credits: Configuration of atoll - Charles Darwin's Diary of the voyage of the H.M.S. "Beagle" edited from the MS by Nora Barlow, Cambridge, University Press, 1933; Kraus Reprint Co. New York, 1969. Los Roques - http://eol.jsc.nasa.gov/sseop/clickmap/ image ISS010-E-14222

in the thousands; he had seen species merge into one another, and very similar species, like the greater and lesser rhea, abut territories, but not commingle, while no others existed in the world; and he had seen fossils of unique animals, such as giant armadillos and sloths, in lands where smaller versions existed, but nowhere else. He had even noted in passing a peculiar land crab on the Cocos Islands that

subsisted by eating coconuts. It later would become a major point in *Origin of the Species,* for the crab was adapted, both in behavior and in shape, to eat the coconut. It would first tear away the husk at the end where the eyes of the coconut were found. Then, with one strong pincer it would hammer at one of the eyes until it broke through, and finally it would turn around and with a smaller hind leg it would reach into the coconut to extract the flesh. In the sense of "how does it work?" he would ask himself how it was that one species could so perfectly adapt itself to another species, as did as well hermit crabs that perfectly fit the shells that they had borrowed or how a hawkmoth had a tongue that would just fit into a trumpet-shaped flower that seemed to be designed for the hawkmoth (Fig. 7.5).There was such a flower, an orchid, in which the nectar lay 30 cm (12 in) from the opening. In 1862, Darwin predicted that a hawkmoth with a 12 in tongue would be found. Twenty-one years later, the insect was identified and given the subspecies name *praedicta,* meaning "predicted". Thus, by the time that Darwin returned, he had the evidence. He sought the logic of "how does it work?" which would allow him to construct intellectual arguments to test by attempting to falsify predictions.

Darwin mulled over the implications for many years. A few years after returning to England, he read Malthus' essay (chapter 10), and he realized that the argument that Malthus presented for cities applied also to the animal world. He did not invent the terms—"survival of the fittest" was first used by Herbert Spencer, while "nature red in tooth and claw" was from Tennyson—but he made the connection between variation, the value of some variation, and the culling of a species. Darwin was

Figure 7.5. Left: Adaptation of a hawkmoth to a flower. The flower is tobacco (*Nicotiana*). The inset at the upper right is the head of a hawkmoth that drinks nectar from the flower, at approximately equivalent magnification. The hawkmoth's tongue, here coiled, is long enough so that it can hover over the flower while reaching the nectar at the base of the flower. Right: Darwin's Star Orchid. The nector is at the bottom of long spurs, and reached by a tongue entering in the center of the flower. See text. Credits: Robert Raguso, printed in Int. J. Plant Sci. 2003, 164 (6): 877–892 (reprinted with permission)

to some extent afraid of the type of scandal that greeted Robert Chambers (who was quite viciously attached by scientists, preachers, and newspapers) and to some extent he desired to address every implication of his theory, as he worked toward a grand encyclopedic presentation of his idea, when Alfred Russel Wallace wrote to him. Wallace, likewise a naturalist who had visited Brazil and then worked his way to Malaysia, had observed the geographic and individual variation of species. Then, while recovering from a bout of malaria, he also read Malthus, and he recognized the same connection. In 1858, he drafted an essay to describe the connection between Malthusian logic and the evolution of species, and he sent it to the by-now-renowned Darwin in the hope that Darwin could comment on it and perhaps get it presented. Darwin, an honorable man, got in contact with Lyell, saying that he, Darwin, was obliged to present Wallace's paper as the first publication of the idea. Lyell however knew that Darwin had written notes outlining the theory much before and had published some articles in which the theory was hinted at or quietly mentioned. Therefore Lyell arranged to have both papers presented simultaneously in 1858. Wallace's argument, though less detailed, is very clear and easy reading (9 typewritten pages), and is available on a website (see references). It differs from Darwin's book mainly that it is a précis (a summary of ideas) based on the logic of animal overbreeding and the normal absence of population explosions. He also places more emphasis on the selection of varieties rather than of individuals and considers controlled breeding of domestic animals to be so different from the wild as to be non-instructive, whereas Darwin argued that they were different manifestations of the same process (human selection of traits desired by humans, as opposed to natural selection of traits suited for survival.) Nevertheless the similarity of Wallace's thesis to Darwin's is remarkable, and Wallace's article is highly recommended.

We talk today of Darwin but rarely mention Wallace for a few reasons. First, Darwin was in England, was already known and respected for his analyses of beetles and mollusks, and for his explanation of atolls; and he was the descendent of a distinguished family. Wallace remained in the East, was far less known, and did not have the backing that a more prestigious family would have given. Much of this sounds as if the differences were entirely social, but Darwin followed up by publishing 18 months later what he considered to be an abridgement of his full theory, which was what we consider today the rich and voluminous *Origin of the Species*, while Wallace published far less, was reticent, and ultimately stayed in the background. *Origin of the Species* sold out immediately, was reprinted many times, and was hotly debated. Although Darwin was not in good health and did not do much public speaking, he remained in close contact with his strongest supporters, such as initially Lyell and later Thomas (T.H.) Huxley, who argued his case publicly. Wallace did continue a distinguished career and today is also known for his recognition of what is now known as Wallace's line—an imaginary line running more-or-less east to west through the Malaysian islands. On the north side of the line, the flora and fauna are essentially all Asian, while on the south side of the line, they are predominantly Australian. Today we know that very strong currents and

winds prevented the various species from expanding from their continental origins beyond those islands. The geographical boundaries that Wallace observed helped him to formulate his hypothesis.

The last question is how the theory of natural selection occured to two individuals almost simultaneously. The simultaneity provides an excellent example of the ELF rule. By the mid-19th century, the evidence based on exploration had accumulated and the initial step of the logic was presented by Malthus. The time was now ripe to ask where species came from, and it was a "hot" question at the time, much as there was a race to understand the structure of DNA (Chapter 14, page 191) and to elucidate the genetic code (Chapter 16, page 227). The final component was the falsification, which in this case allowed both Darwin and Wallace to test their hypothesis against several new situations, and to conclude that all other theories fell by the wayside. We shall encounter a similar apparent coincidence in Chapter 13, page 175, in the situation of the simultaneous rediscovery of Mendel's experiments. Again, as here, the intellectual attitude of the moment is very important in driving science.

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STUDY QUESTIONS

1. What was the strongest evidence from the biology that Darwin encountered that led him to his hypothesis?
2. What was the strongest evidence from the geology and geography that led Darwin to his hypothesis?
3. What was the strongest evidence from the fossil record that led Darwin to his hypothesis?
4. What characteristics of Darwin's personality and style were important to assure that he would draw the theories from his experiences?
5. Argue for or against the hypothesis that it is the time or the historical moment, not the individual, that determines when great advances in science are made.