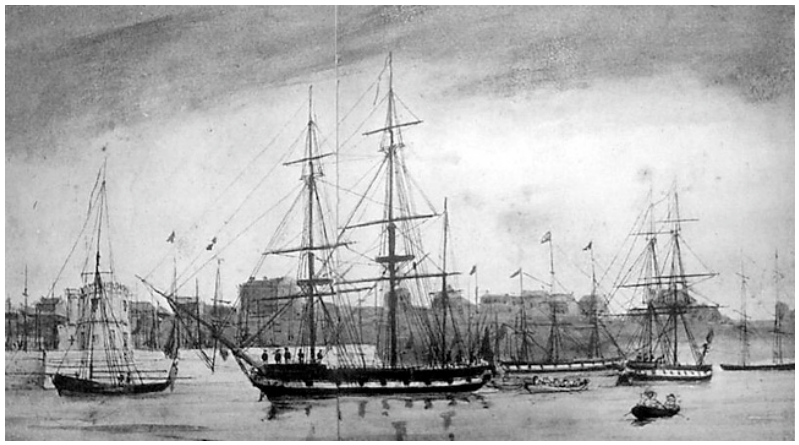
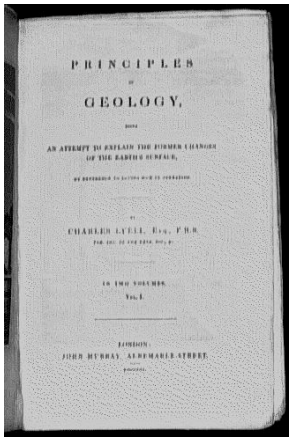
Despite some trouble getting his father's approval, Darwin was finally allowed to go. . .



and *HMS Beagle* left England on December 27, 1831.

Darwin's choice of reading material on *HMS Beagle* changed the course of history. . .



. . . because he brought with him on the *Beagle* Volume I of *Principles of Geology*, by a former lawyer named Charles Lyell.

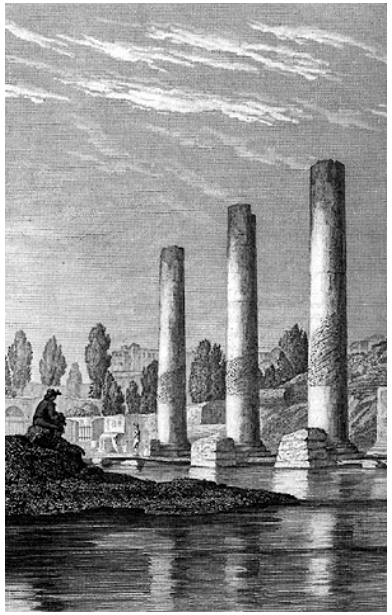
Charles Lyell
(1797-1875)

The "Father of Modern Geology", Lyell devised new ways of thinking about Earth history and using geological evidence. He proposed *uniformitarianism* as an approach to reading the past in the rocks. . .

Lyell's uniformitarianism

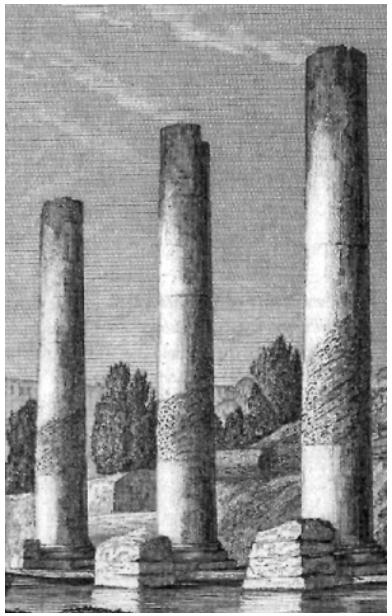
("the present is the key to the past")

- Uniformity of law: the laws of science have not changed over time
- Uniformity of process: the natural processes going on on Earth today have always operated
- Uniformity of rate: the processes affecting the Earth have always operated at the same gradual rates and the same intensities
- Uniformity of state: the Earth has not changed overall

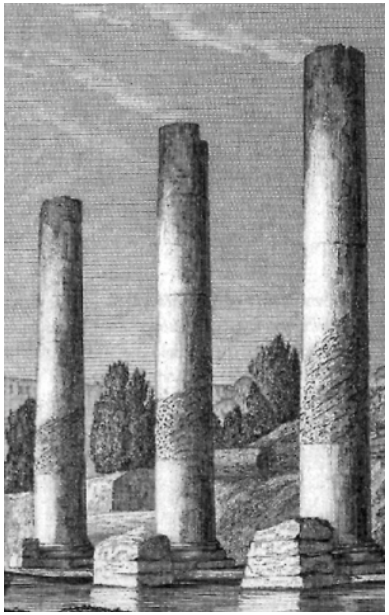


You didn't need to assume that massive catastrophes, unlike anything in human experience, had altered the face of the Earth. All you needed, to explain geology, was (1) processes that can be observed today, and (2) lots and lots of time.

Let's look at the ruined Temple of Serapis, at Puzzuoli, near Naples on the island of Sicily. . .



CONCLUSION: Over less than 2000 years, the temple has sunk, and then been raised, a few tens of feet. If this can happen in a few thousand years. . . what could happen in millions of years?

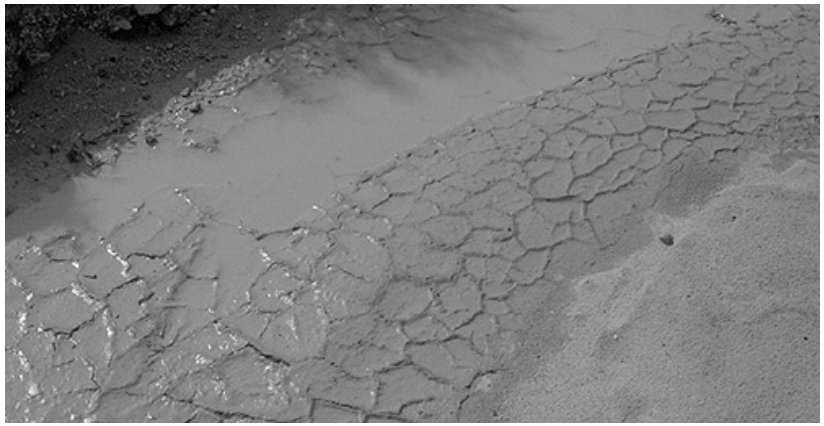


The temple was built on land, and was in use at least up to 200 AD.

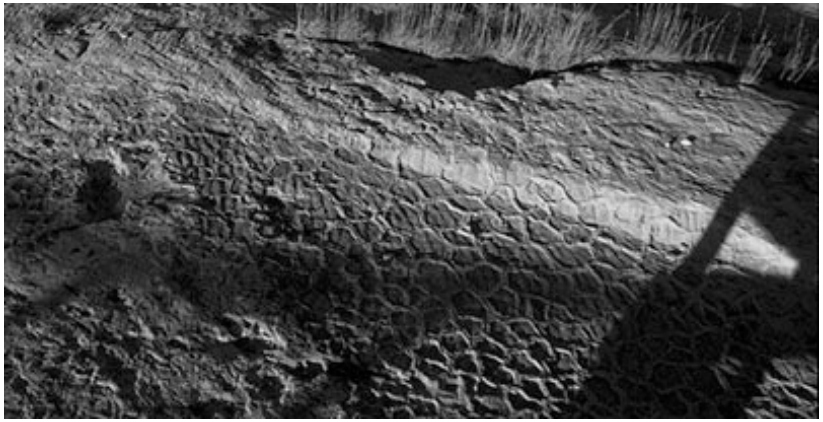
It's now right at the edge of the sea. The old floor is submerged at high tide.

The columns are riddled with holes, made by a type of marine clam that bores into solid rock.

How does process uniformitarianism work? Compare these modern mudcracks, forming as a mud puddle dries out. . .

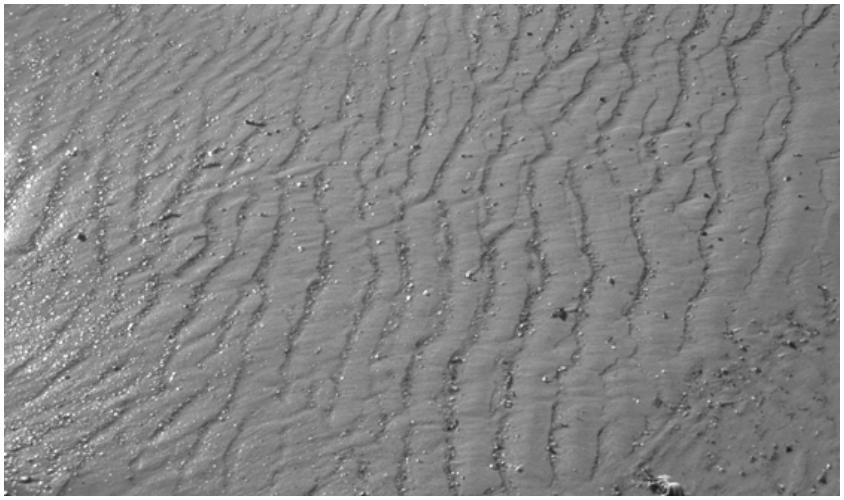


(Grimshaw Lake, southern Inyo County, CA)



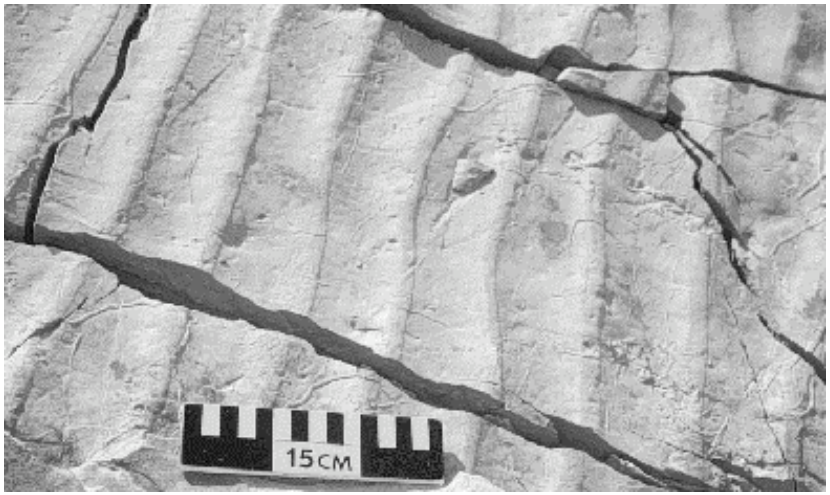
. . . with these ancient mudcracks, preserved in 100 million-year-old rocks!

(Clayton Lake State Park, NM)



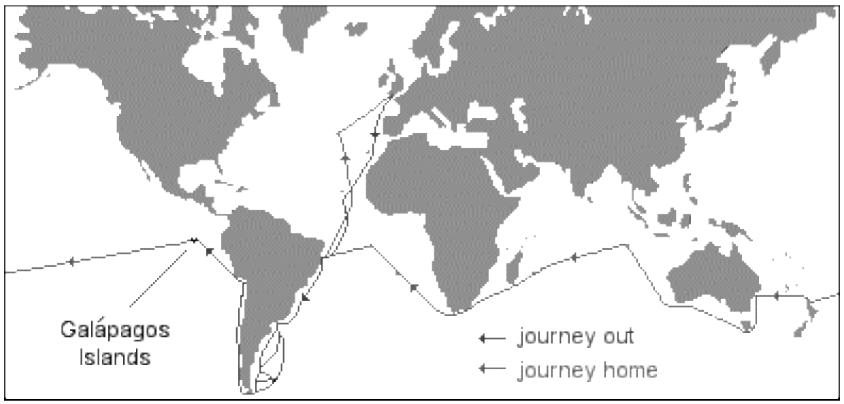
Modern ripple marks forming on a sandy beach

(Newcastle, Australia)



100 million-year-old ripple marks in sandstone

(San Juan Basin, NM)



As Darwin was reading Lyell, the *Beagle* reached South America early in 1832—and spent the next three years traveling up and down the Atlantic and Antarctic coasts.

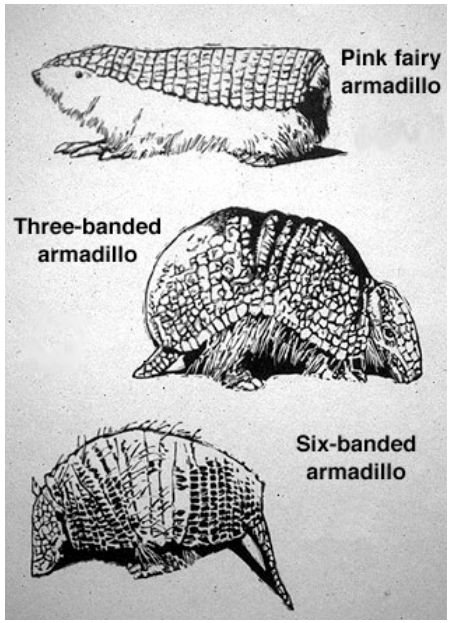
Darwin's Voyage. . .

- Darwin had the time and resources to take long trips inland (which was just as well, since he was usually seasick aboard ship)
- He was able to ship specimens and send letters and writings back to England—these gave him a good reputation among scientists before he even returned
- He later (1845) published a journal of his travels, now known as *Voyage of the Beagle*. Still a great read (you can even read it online)

"Delight itself, however, is a weak term to express the feelings of a naturalist who, for the first time, has wandered by himself in a Brazilian forest."—*Voyage of the Beagle*, 1845

"The Gaucho is invariably most obliging, polite, and hospitable. . . but at the same time a bold, spirited fellow."—*Voyage of the Beagle*, 1845

When not enraptured by the scenery, or riding with the gauchos, Darwin collected South American fossils—including bones of this beast, the extinct *glyptodon*.

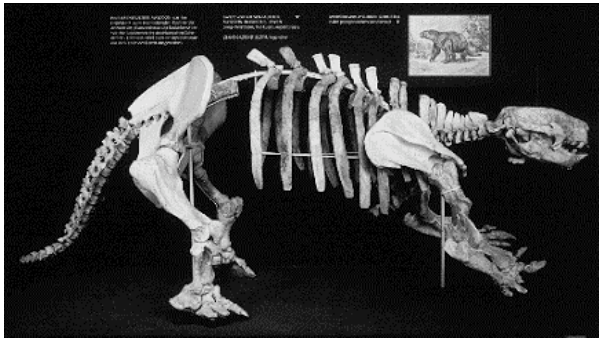


Though unusually large, the glyptodon was clearly very similar to a uniquely South American group of mammals: the armadillos.

This picture shows three of the eleven South American armadillo species. (Incidentally, the nine-banded armadillo, which you're familiar with, is a relatively recent migrant into North America—it didn't cross the Rio Grande until about 1850, and didn't enter Arkansas until about 1920.)

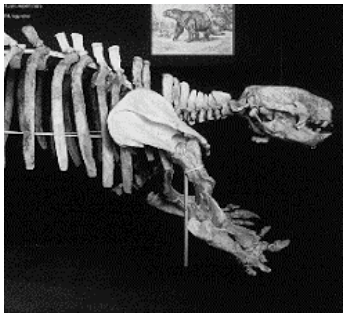
I'm not kidding about the pink fairy armadillo, by the way. . .

And this happened time and again!

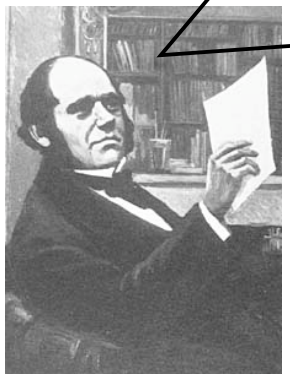


Unique *fossil* vertebrates of South America turned out to be very similar to *living* vertebrates that were also unique to South America. This giant skeleton, *Mylodon*, turned out to be very much like that of a living animal. . .

. . . a South American tree sloth.

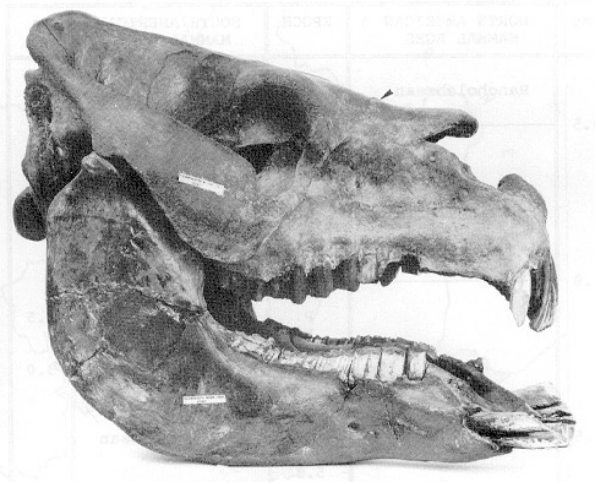


"This wonderful relationship in the same continent between the dead and the living, will, I do not doubt, throw more light on the appearance of organic beings on our earth, and their disappearance from it, than any other class of facts."
—*Voyage of the Beagle*, chapter 8



". . . the structure of its teeth, as Mr. Owen states, proves indisputably that it was intimately related to the Gnawers [rodents]. . . in many details it is allied to the Pachydermata [elephants]: judging from the position of its eyes, ears, and nostrils, it was probably aquatic, like the Dugong and Manatee, to which it is also allied. How wonderfully are the different Orders, at the present time so well separated, blended together in different points of the structure of the Toxodon!"
—*Voyage of the Beagle*, chapter 5

Some of the fossils Darwin found were not like living animals—but *seemed* to combine features of what are now classified as separate classes of animals. Take *Toxodon platensis*, here. . .



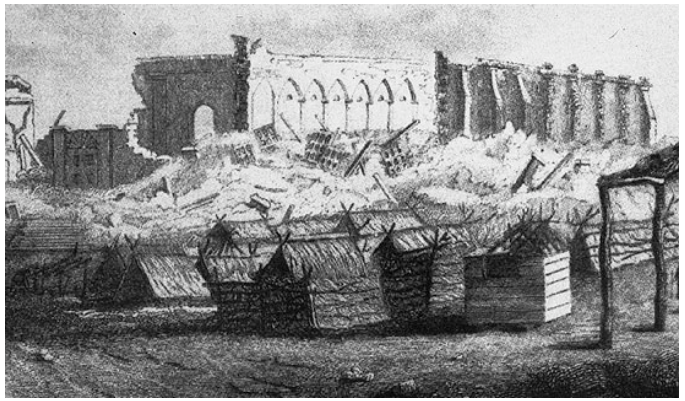
Rounding Cape Horn at the southern tip of South America, the *Beagle* encountered the Fuegians. . .

FitzRoy was returning some Fuegians whom he had captured on a previous voyage and had educated in England, hoping to civilize the tribe. (It didn't work.)

Darwin had been reading Lyell's *Principles of Geology* on the trip. . .

- He was able to see that the earthquake had lifted the shoreline by as much as ten feet
- He had also explored the Andes Mountains, and knew that fossil seashells were found at elevations of thousands of feet
- His conclusion: A long series of quakes was causing the slow, gradual uplift of South America—a fine example of Lyell's uniformitarian thinking!

Sailing up the Pacific coast of Chile, the *Beagle* reached the town of Concepción. . .



which, unfortunately, had just been leveled by an earthquake. (February 20, 1834)

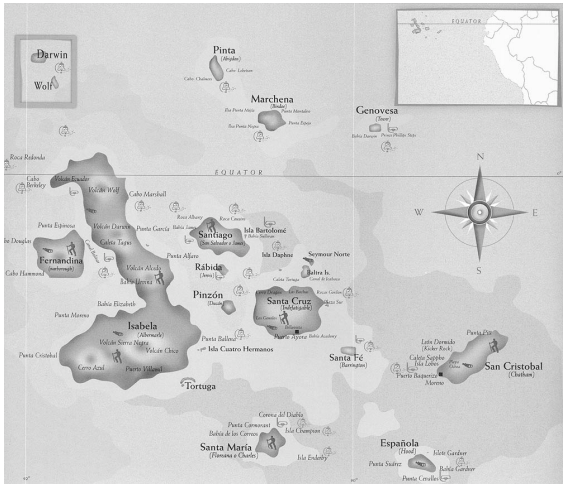
By this time, after three years of sailing, the mission was accomplished and everyone was ready to go home. . .

so the *Beagle* headed for home, sailing across the Pacific to Australia, across the Indian Ocean to South Africa, and back through the Atlantic to England.

And on the way back, they stopped for food and water for a couple of weeks at some small, godsforsaken islands. . .

. . . islands named for the Spanish word for “tortoises”: *Galápagos*.

The Galápagos Islands are about 600 miles off South America—right on the Equator, but kept fairly cool by cold-water currents coming up from the south.



These islands are volcanic— occasional eruptions still happen to this day—and are, relatively speaking, quite young. Much younger than South America.

Congealed lava flow on the Galápagos Islands

Most Galápagos species are similar to South American ones, but NOT identical. . . and found nowhere else in the world. This gull is unique to the Galápagos, although it resembles South American gulls. . .

Larus fuliginosus, the Galápagos gull

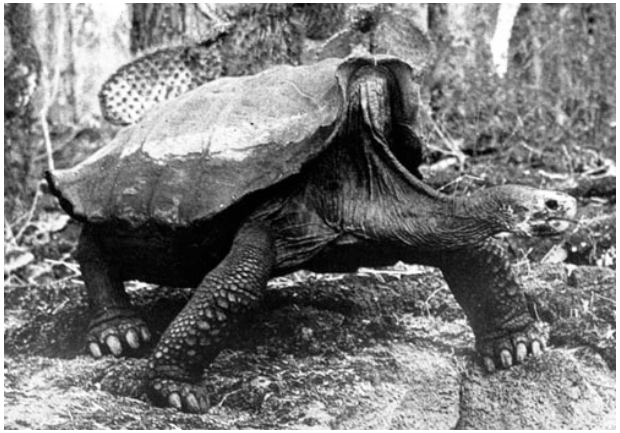
Iguanas are typical of Central and South America, but the Galápagos marine iguana is unique to these islands. . .

Amblyrhynchus cristatus, the Galápagos marine iguana
Picture borrowed from *Botany Online* textbook

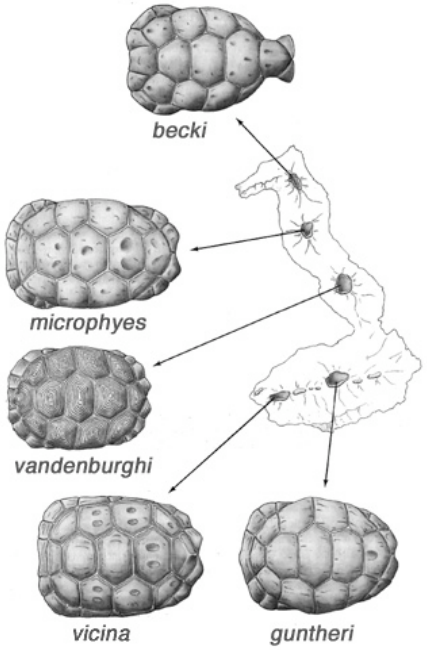
Prickly pear cacti are found in North and South America, but they don't usually form trees. . . except in the Galápagos Islands. . .

Opuntia echiops, the Galápagos prickly pear cactus
Picture borrowed from *Botany Online* textbook

Geochelone elephantopus, the Galápagos tortoise, gave the islands their name—they're similar to American "gopher tortoises", but not the same! (They're much larger, for one thing. . . .)



Darwin found that each island—and sometimes each mountain peak on the same island— has tortoises with consistently different, distinguishable shell shapes. (The map shows the tortoise varieties from just one island in the Galápagos, Isabela, which consists of five major volcanoes.)



Now consider the case of the Galápagos finches. . .

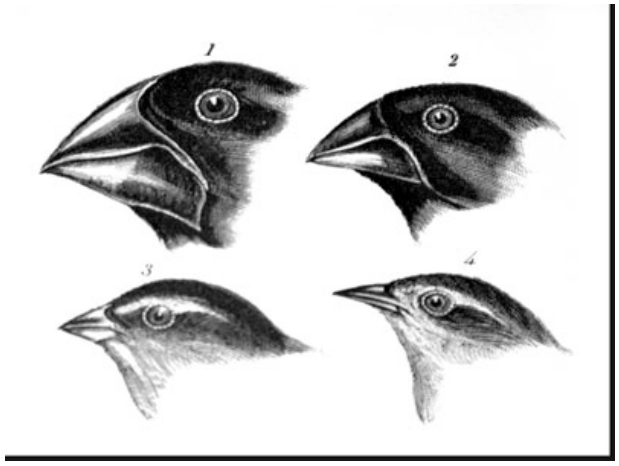
Small ground finch, *Geospiza fuliginosa*
(from the excellent Slides of the Galápagos WWW page)

Not only are the fourteen different species found on different islands (although they often overlap), but each species has a distinctive way of life—sometimes a very un-finchlike way of life—and each shows adaptations to that way of life.

Cactus finch
Geospiza scandens

Large ground finch
Geospiza magnirostris

The finches all share a common structure, and yet with diverse adaptations to different lifestyles. . .

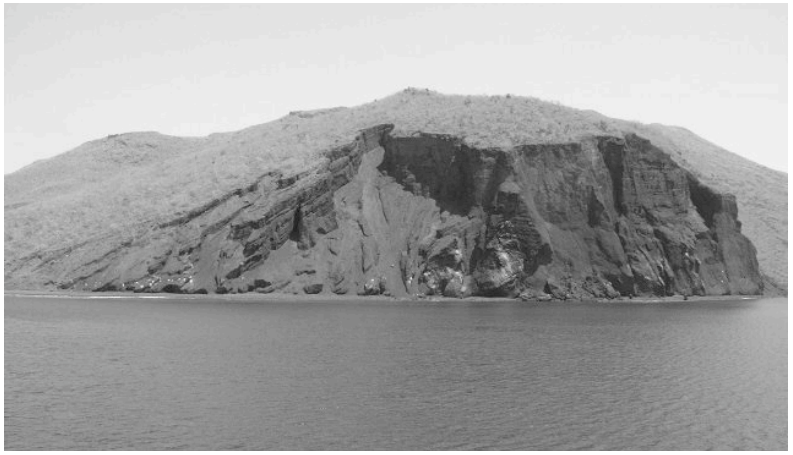


Woodpecker finch
Cactospiza pallida

Vampire finch
Geospiza difficilis

"Seeing this gradation and diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends."—*Voyage of the Beagle,* ch. 17

The *Beagle* left the Galápagos and crossed the Pacific. . .



sugar glider (*Petaurus breviceps*)

quoll (*Dasyurus viverrinus*)

And the *Beagle* stopped off in Australia, where Darwin noticed the uncanny way in which Australian marsupials seemed to mimic mammals from elsewhere in the world.

Darwin also encountered oddball Australian animals such as the duckbilled platypus (an egg-laying mammal), which gave him pause. . .

European mole

Australian marsupial mole

African flying squirrel

Australian sugar glider

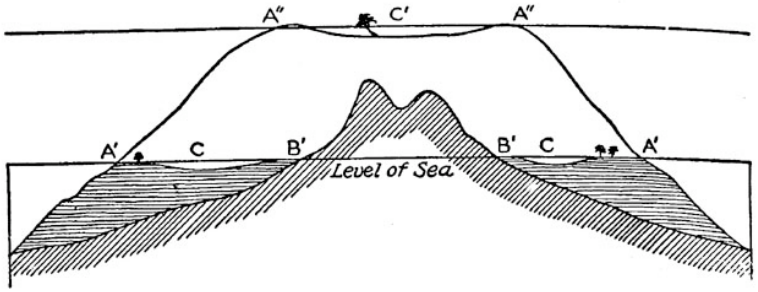
South American anteater

Australian numbat

"Earlier in the evening I had been lying on a sunny bank & was reflecting on the strange character of the Animals of this country as compared to the rest of the World. A Disbeliever in everything beyond his own reason, might exclaim, 'Surely two distinct Creators must have been [at] work; their object however has been the same. . .'"

—Charles Darwin's diary, Jan. 19, 1836

Then the *Beagle* crossed the Indian Ocean, where Darwin came up with some very Lyellian theories for how coral islands formed (which he basically got right—but we don't have time to go into that, unfortunately). . .



. . .rounded Africa, sailed up the Atlantic, and returned to England on October 2, 1836.

Down House, near London, where Darwin lived from 1842 until his death in 1882