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# Galapagos: Darwin, Evolution, and ENT

Charles D. Bluestone, MD

This year is especially important in the history of the theory of evolution; 2009 is the bicentennial anniversary of the birth of Charles Darwin and the sesquicentennial anniversary of his publication, *The Origin of Species*. Darwin visited the Galapagos Islands as a young man, which greatly influenced his thinking. My son Jim and I had the good fortune to visit these islands in January 2009 and see firsthand what led Darwin to arrive at his monumental insights into the origins of life on this planet. I have described my observations and related some of this experience to the ear, nose, and throat, albeit with whimsy in several instances. Nonetheless, some of the adaptations in the animals on these unique islands may have bearing on my hypotheses related to the incidence and pathogenesis of otitis media in humans. It is hoped the reader will share my enthusiasm for the experience we had on these fantastic islands and tour them in the future.

**Key Words:** Galapagos, Darwin, evolution, E.N.T., otitis media.

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## INTRODUCTION

This year, 2009, marks the bicentennial of the birth of Charles R. Darwin in Shrewsbury, England, and the sesquicentennial of the publication of his landmark book, *The Origin of Species, by Means of Natural Selection*.[1] It is interesting to note that his birth date, February 12, 1809, was the same as Abraham Lincoln's, who was born in Illinois. Darwin's book was a result of his trip to the Galapagos Islands and his subsequent review and analysis of his observations. I recently visited the Galapagos Islands in an effort to better understand not only these historic islands, but to gain an insight into what led Darwin to posit his theories related to evolution so that I could relate this experience to my interest and knowledge of otolaryngology, and more specifically the effect of evolution on middle ear disease in humans.

## CHARLES DARWIN

Darwin's father, Robert, was a physician, and young Charles initially attended medical school at the University of Edinburgh. Early on, he found no liking to the profession of medicine and moved on to Cambridge University to study theology. However, his passion proved to be in the natural sciences, not theology. In 1831, soon after graduation at age 22, he undertook a 5-year voyage around the world on the now famous *Beagle* as the ship's naturalist. During this trip in 1835, he spent almost 5 weeks on the four islands in the Galapagos Archipelago, which is about 600 miles west of the Pacific coast of Ecuador. His account of the *Beagle's* voyage, *Journal of Researches*, was published in 1839 (and in later printings was renamed *Voyage of the Beagle*).[2] It included his description of the unique flora and fauna of four of the islands that he visited: San Cristobal, Floriana, Santiago, and Isabela. Following this publication, but more importantly the highly successful *Origin of Species* in 1859, these islands and his monumental insights into evolution have been the subject of ongoing intense debate (and travel) by scientists and tourists over the past century and a half.

## GALAPAGOS ARCHIPELAGO

In January 2009, my son Jim and I sailed around the Galapagos Archipelago on the Lindblad *National Geographic Islander* ship and toured nine of the larger islands, which included not only Floriana, Santiago, and Isabela that Darwin visited, but also Santa Cruz, North Seymour, Baltra, Bartolome, Fernandina, and Espanola. These are very isolated volcanic (in some cases still erupting) desert islands with a population of 23,000; immigration into the islands has been restricted since 1998. The archipelago is now the National Park of Ecuador, which includes the Charles Darwin Research Station. The Station has been designated a biosphere reserve by the United Nations Educational, Scientific

From the Department of Otolaryngology, University of Pittsburgh School of Medicine, Division of Pediatric Otolaryngology, Children's Hospital of Pittsburgh of UPMC, Pittsburgh, Pennsylvania, U.S.A.

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Author's Note: Color photographs of the wonderful and incomparable animals seen while on the trip can be accessed online through the supplementary files. Thus, illustrations have been omitted in the presentation.

Send correspondence to Charles D. Bluestone, MD, Division of Pediatric Otolaryngology, Children's Hospital of Pittsburgh of UPMC, 45th Street and Penn Avenue, Pittsburgh, PA, 15201. E-mail: charles.bluestone@chp.edu

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and Cultural Organization, as it has an ecologically sound coexistence of humans and nature.

What greatly impressed young Darwin was the flora and fauna that occurred nowhere else in the world. In *The Origin of Species*, he wrote that he was fascinated by how tame these animals were when around humans, which he attributed to the lack of exposure to humans as predators. There are 13 endemic species of reptiles and crabs, and only seven endemic mammals, of which the red bat and four species of rat are the only terrestrial ones. As he also observed, there were no amphibians, such as frogs, toads, or newts, as is the case with other remote islands of the world, because amphibians could not have survived the long distance across the Pacific from the mainland to these islands. An endemic species is one that occurs naturally only in a specific location, whereas indigenous species occur naturally, but are present in other parts of the world. Alien species have been introduced onto the islands, such as goats, sheep, and cats, and have been a source of considerable concern, becoming predators of the endemic species and interfering with the natural ecology of the islands. Recently, there has been a concerted effort by environmentalists to eliminate these predators.

The oceanic currents in the Galapagos Archipelago have created a unique mixture of animal species. The Humboldt Current comes up the coast of South America from Antarctica. The Cromwell Current is a cold counter-equatorial current from the west, and the South and North Equatorial Currents are from the northeast, which periodically but relatively frequently bring an El Niño (little child) with its attendant drenching rains onto these islands. As described in detail below, an El Niño was important in recent evolutionary events that affected finches. These currents cause a wide variety of variation in water temperature from season to season and month to month.

## ENDEMIC ANIMALS

There are many famous endemic species of animals on these islands, which have specific features related to the ears, nose, and throat, although in some instances in a somewhat humorous vein.

### *Galapagos Iguanas*

One of the most populous and fascinating of the endemic animals on the islands is the Galapagos marine iguana, the only seagoing lizard in the world. It swims in the ocean and eats algae from lava rocks. In so doing, it swallows huge amount of salt from the sea. Because this reptile is cold blooded (poikilothermic), following swimming and eating in the ocean, it rests under the hot equatorial sun on the beaches in vast numbers to regain body heat. Of some interest to otolaryngologists, while on land it frequently expels salt water through its nose from specialized glands in the nasal cavities; this is a sort of iguana self-induced treatment similar to our over-the-counter Ocean Nasal Spray (Fleming Pharmaceuticals, St. Louis, MO). As the animal sneezes, the spray lands on its head, forming a distinctive "white wig." If it did not eliminate the excess salt, it would die of hypernatremia. This fascinating adaptation from its founder endemic species, the Galapagos land iguana, is a critical survival mechanism. Also of interest to us is that it regurgitates stones from its stomach (gastroliths), which it ingests for ballast for diving in the ocean—a sort of reptilian gastroesophageal reflux. This activity is also an adaptation from its founder species.

Another interest to otolaryngologists is that both species of the Galapagos iguana, the marine and land, have an external tympanum appearing on the lateral surface of the head, but no pinna or external auditory canal. The tympanic membrane is the lateral surface of the middle ear. The middle ear contains a stapes, round and oval windows, and a eustachian tube. The tympanum has been noted to be perforated during fighting, the result of the opposing iguana penetrating the membrane with its long, fingerlike toes. It is said to have low-frequency hearing in the range of 0.5 to 1.5 kHz.

Another species of lizard, the Galapagos lava lizard, differs from the iguanas (and snakes) in that it does have an external ear opening. There are seven endemic species of lizards on the islands, which according to Darwin originated from a single founder species.

### *Galapagos Giant Tortoises*

Probably the most famous of the animals on these islands is the endemic Galapagos giant tortoise. Of the original 13 subspecies, only 11 remain, such as the saddleback and the tabletop. Galapagos is Spanish for saddle (or tortoise). The reason for the reduction in the number of subspecies, and a devastating reduction in the entire population of these unique tortoises, is the indiscriminate killing for food by whalers, buccaneers, and local fishermen during the past 400 years. They are now protected, resulting in a gradual increase in their numbers.

Similar to the Galapagos iguana, this extremely long-lived animal's tympanic membrane is also on the lateral surface of the head. As only vertebrates have ears, the question is: why do we have a pinna and external auditory canal and they do not? It has been said that our outer ear increases the sound pressure level 30- to 100-fold at about the frequency of 3 kHz, which is within the range of the speech frequencies—an evolutionary adaptation for our unique speech. It is suggested that these reptiles have an extremely sensitive ability to feel vibrations that surround them as an enhanced protective mechanism.

While visiting these islands, the Governor General told Darwin that he could tell which island each species came from by the shape of its shell, an observation that greatly interested Darwin when he later reflected on the origin of species. Indeed, different subspecies occur in individual islands and are related to the available food supply. Because they had no natural predators, they developed into their gigantic size over the millennia.

### *Galapagos Mammals*

The bat and rat notwithstanding, there are no endemic terrestrial mammals on these islands, as they

could not have survived an attempted immigration from South America. But, there are two endemic seagoing mammals, the Galapagos sea lion and the Galapagos fur seal. The latter is the smallest of the pinnipeds (fin-footed mammals). Their population was seriously depleted by an El Niño that hit the islands years ago. The sea lion is much more plentiful now, and huge numbers can now be seen lying on the beaches of the islands during the daytime; similar to the other endemic animals on the islands, they are unafraid of humans who can approach them with ease. They have a small ear opening on the side of the head and a very distinctive ear flap (i.e., pinna); the ear flap of the sea lion is smaller than the fur seal and the more familiar California sea lion. It is estimated that the Galapagos sea lion has hearing in the low range of between 1 and 40 kHz. On the beaches, skeletal remains of sea lions can be examined (but never removed by visitors); the craniofacial base appears to be similar to the human.

### *Birds of Galapagos*

Of the 58 species of birds on the islands, 29 are endemic, one of which is very well known—the colorful blue-footed booby. There are two other species of booby, the red-footed and masked booby, but these are native and thus can be seen on the mainland. Bobo in Spanish is clown. The intensity of the blue in the feet is related to the ability of males to attract the female during mating season, a phenomenon identified in animals by Darwin who called it "sexual selection," as detailed in his later treatise, *The Descent of Man*.[3]

Another famous endemic bird is the Galapagos flightless cormorant, the only species of cormorant in the world that has shortened wings and is flightless. This bird has adapted to diving in the waters off these islands for food; full wings would impede its ability to dive deeply. Also, because it has no terrestrial predator, it does not need flight to avoid being another animal's dinner. The Galapagos hawk is also endemic. It eats lizards, snakes, and rodents, and preys only on weak or sick birds.

Of great interest are the endemic Galapagos penguins that migrated north into the tropical equator on the Humboldt current; they are the smallest of the penguin species. Like the flightless cormorant, it too is flightless, but has feathers that trap air. One can commonly see penguins swimming in the same waters as the Galapagos marine iguanas, which is an unusual phenomenon because one is a cold-water bird and the other a warm-water lizard. Similar to the marine iguana, the Galapagos penguins swallow stones for counterweights to enhance diving deeply into the sea.

One of the most colorful endemic birds is the frigatebird of Galapagos. The male blows out his bright red bare-skinned gular sac (throat pouch) to attract the female during mating season, another example of Darwin's sexual selection. It is a unique throat to otolaryngologists, as this is one instance in which a "red throat" does not imply streptococcus pharyngotonsillitis. The Galapagos lava gull and Galapagos waved albatross are two other peerless endemic species of birds.

### *The Famous Galapagos Finches*

The most famous birds of the Galapagos are the Galapagos finches. These birds are often called Darwin's finches, as he collected them on the four islands he visited from the *Beagle* and realized several years later they supported his theory of the origin of the species by natural selection. The 13 species Darwin identified represented a signal event in his theory, as they became separate species by adaptive radiation on the islands. Adaptive radiation is when two or more species are formed from an original colonizer, especially if the gene mutates in a small founder population, which is why the Galapagos Islands are so ideal for developing differing species. In addition, Darwin's finches represent genetic drift in an area with low predation and low interspecies competition. Genetic drift occurred when an errant colonizer of finch from the mainland developed into several new species. Each species of finch had its beak adapted to a specific ecological niche for feeding on one or more of the islands, mainly on seeds, insects, buds, or fruits.

### *Peter and Rosemary Grant's Landmark Contribution*

In the early 1970s, Peter and Rosemary Grant, two world-renowned Princeton evolutionary biologists, went to a small deserted island in the Galapagos, Daphne Major, to study the finches by banding them and returning year after year to determine their habits. There are two species of finches on the island, the large ground finch (*Geospiza magnirostris*), which has a large beak adapted for cracking open big seeds, and the medium ground finch (*Geospiza fortis*), which has a smaller beak adapted to eating smaller seeds. By chance, the Grants were on Daphne during two very different periods of climate that drastically affected the island's ecology, which in turn affected these finches' ability to survive. The Galapagos are desert islands with two main seasons, a warm, wet season from January to June followed by a cool, dry season from July to December. But, in 1977, a severe drought occurred that almost completely eliminated small seeds and resulted in the smaller *G. fortis* finch all but perishing. By contrast, from 1984 to 1985, an El Niño flooded the island, which resulted in severe depletion of large seeds with subsequent drastic reduction in the number of the larger *G. magnirostris* finch. As concluded by the Grants later after analyzing the data, and elegantly described by Jonathan Weiner in his Pulitzer Prize-winning book, *The Beak of the Finch*, these events are convincing evidence of Darwin's theories of natural selection and evolution.[4]

### *Galapagos and Otitis Media*

Does the experience in Galapagos have any bearing on my hypothesis that otitis media is most likely a unique human disease and that evolution has affected its pathogenesis in *Homo sapiens*? I have proposed that if otitis media, with its attendant hearing loss, was present in animals in the wild, they would have been eaten by their predators, as factors related to otitis media

would have been selected out by evolution.[5] I have also suggested that as a consequence of our early birth (12 months too soon), due to bipedalism with subsequent narrowing of the female pelvic outlet, and adaptation to our big brain, humans are susceptible to middle-ear disease in the first year of life.[6] In addition, I have hypothesized that as a consequence of our adaptation to speech, our palate morphology (i.e., shorter) is different from the great apes, which in turn affected the structure and function of the muscles of the eustachian tube that resulted in tubal dysfunction as compared with our immediate ancestors.[5] Because there are no terrestrial mammals on the islands, what can we learn from the Galapagos related to otitis media?

Two events probably apply: 1) adaptation of the maxillofacial complex in relation to eating in the Galapagos finch (the beak) and Galapagos marine iguana, both of which may be comparable to the loss of prognathism in humans, and its affect on the anatomy of the palatal muscles, when compared to the great apes, and 2) the effect of environment on available food supply on specific islands, which affected evolutionary change.

At present, there is no consensus among anthropologists on why humans lost the distinctive snout of apes. But, adaptation of the beak of the 13 different species of finch to fit into a specific ecological niche for eating food present on an individual island may be similar to our facial flattening. The beak can be likened to our maxillofacial complex. One popular hypothesis as to why we lost our snout is that changes in our diet, compared to the nonhuman primate, altered the size and shape of our teeth, as well as the maxilla and mandible; our teeth are crowded into our jaws in a relatively small oral cavity when compared with our immediate ancestors. It has been posited that since early *Homo erectus* began using fire for cooking almost two million years ago, they could eat fibrous fruits and tubers, as well as tough, raw meat, which provided the increased energy to permit the relatively rapid adaptation to our big brain.[7] This theory of why our face flattened seems reasonable but remains hypothetical at present.

The other possible similarity between a Galapagos animal and our adaptation to a short maxillofacial complex is an adaptation that occurred in the marine iguana. This unmatched species of iguana adapted its facial structures to better eat algae from the submerged lava rocks. In fact, its scientific name *Amblys* (short) *rhynchos* (nose) describes it as having a short blunt nose. One could speculate that adaptation of this iguana's mouth and nose to its food source could be likened to our facial flattening with changes in our food source, i.e., advent of cooking.

Another lesson to be learned from the Galapagos history and experience is the impact of environmental changes and alteration in food that occurred on Daphne Major, as observed by the Grants and described earlier. The drought and subsequent El Niño flood resulted in dramatic changes in the type of available ground seeds, which subsequently affected the number of the two species of finch. It is well known today that environment can have a deleterious effect on the incidence of otitis media in infants and young children, especially with the relatively recent advent of child day care center attendance (exposure to viral and bacterial pathogens) and exposure of these youngsters to tobacco smoke. Neither of these environmental hazards were present in days of early man. Also, our food source has changed in infants during the recent past, yet it is well known that breast milk in infants is associated with a lower incidence of otitis media, as compared with infants who are not breast fed.

## CONCLUSION

As concluded by the noted evolutionary geneticist Theodosius Dobzhansky: "Nothing in biology makes sense, except in the light of evolution."[8] Indeed, from my experience in the Galapagos, with its unique flora and fauna, and the observations and subsequent theories proposed by Charles Darwin, we can learn a great deal about the origin of species, including man and his diseases and disorders, such as otitis media. I have concluded that otitis media is a disease of humans in which evolution has had a major role in its pathogenesis as a consequence of adaptations to bipedalism, speech and cooking of food.

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