

Chris Lang
Course Paper
Sophomore College
October 9, 2008

The Divergence of the Marine Iguana: *Amblyrhynchus cristatus*

Abstract---

In this course paper, I address the divergence of the Galapagos Marine Iguana from its earlier land ancestor (what is now the Land Iguana). While both the land and marine iguana remain close relatives of descent, they are coined different species for very notable reasons. In this paper, I attempt to verify the close relatedness of the two species both by DNA testing and sheer common sense. Then, by noting the behavioral and physical structural differences between the two species and explaining them in relation to the environments they live in, I also attempt to verify the idea that natural selection has adapted the traits of the marine iguana to become more suited for a sea-going lifestyle.

Introduction---

The Galapagos marine iguana, scientifically known as *Amblyrhynchus cristatus*, is a fascinating species of iguana as it exists only on the Galapagos and possesses many traits that other iguanas do not have. The Marine Iguana is also one of the best living examples to verify Darwin's coined term evolution via natural selection. Adapted for an amphibious lifestyle, this unique sea-going lizard scavenges the intertidal and subtidal zones for red and green algae.¹ These algae regenerate particularly fast, which makes them a common food source among marine organisms. After spending 5 to 10 minutes diving for food, the iguanas then return to the warm lava rocks to gather up energy for its next feeding dive.

Like all reptiles, the marine iguanas are exothermic, or cold-blooded. This means that their ability to feed in the nutrient rich, but cool water is completely dependent on their ability to regulate body temperature. During times out of water, they absorb heat from the sun in order to maintain a normal body temperature. They tend to bask in the sun until their body temperature reaches an optimal 35 degrees Celsius.²

There are seven different subspecies of Marine Iguanas scattered throughout the Galapagos Islands. They come in many sizes, ranging from 75 centimeters at Genovesa to about 1.3 meters in the northern parts of Isabela³—which is largely an evolutionary result of the different amounts of food that exist throughout the islands. The changes in coloration are also a result of location. On Espanola, for example, the males tend to appear reddish during mating seasons, but elsewhere the iguanas do not change colors as dramatically.

There is little discrepancy among scientists regarding the ancestry of the marine iguana. Scientists assume that the mainland ancestor (what we now call the Green Iguana) found its way to the Galapagos, and that later, about 10 million years ago, the marine iguana diverged from that ancestor. Because there is no sea-going lizard elsewhere that could have swum to the islands, it is safe to assume that the marine iguanas evolved from a land-walking ancestor that was already on the islands. Once isolated on the islands, these iguanas could evolve separately from the ones on the mainland—this was a major contributor to the speciation of the marine iguana. But what caused this divergence towards the water and what were its lasting effects? And why are there no other sea-going lizards elsewhere in the world?

Hypothesis---

I hypothesize that the marine iguana diverged from its land ancestor because of harsh conditions on land. One possible condition could have been a shortage of food on land. Competition on land for vegetation could have forced certain iguanas to look elsewhere for food—and being on an island, the only place to look would be the water. In other words, a shortage of food on land would trigger a change towards a marine diet. Secondly, I also hypothesize that nature's selective pressures then selected for these iguanas to become better suited for an amphibious (marine and land) lifestyle—both in behavior as well as in structure.

Methods---

In trying to find an answer to my questions, I started by looking into the ancestral history of the marine iguana. Once I found convincing data that suggested the South American mainland ancestor was the original colonizer of the Galapagos, and that the marine iguana's closest relative is the Galapagos land iguana, I looked more closely into the change in physical and behavioral features between the two species. Thus, I made the assumption that the current land iguana is the closest comparison to the land ancestor ten million years that the marine iguana diverged from. Looking at the differences in their environments and their characteristics allowed me to make inferences on why these certain traits exist. I extracted from the most apparent differences, such as color and structure shape, based on their diets and habitats. However, I also looked into other beneficial behavioral patterns and determined whether they were either adaptations or exaptations. An adaptation is a structure or behavior that has been naturally selected for its original use, while conferring an organism's fitness. An exaptation, on the other hand, is not selected for its current purpose; however it benefits an organism's fitness

nevertheless. An exaptation is more like a pre-existing trait that becomes beneficial in a new environment.

Findings---

As I stated earlier, my first goal was to verify the close ancestral proximity of the marine iguana and the land iguana. In my research, the land iguana was considered the closest ancestor to compare with the marine iguana in phylogenetic distance.

Immunological analyses of similar reptilian hemoglobin verifies this assumption:

TABLE 2. Immunological correspondence among Galápagos reptile hemoglobins.*

Genus	Common name	Phylogenetic distance
<i>Amblyrhynchus</i>	marine iguana	0
<i>Conolophus</i>	land iguana	6.8
<i>Iguana</i>	green iguana	23.0
<i>Tropidurus</i>	lava lizard	68.5
<i>Dromicus</i>	constrictor snake	79.0

*The hemoglobins of each species were prepared as described in Higgins (1978). Single-point immunoprecipitation of reptilian hemoglobins by rabbit antiserum to *Amblyrhynchus* hemoglobin was done ac-

As you can see in the table 2, the land and marine iguanas are very genetically similar.

The land iguana is only 6.8 units away from the marine iguana, while the mainland green iguana is 23. Other analyses such as testing the types of albumen between the reptiles have proven the same genetic closeness.

Now that I have established that the land iguana is the closest relative to the marine iguana, I am going to look into the behavioral and physical differences that exist between the two close reptiles. The most obvious behavioral differences one may observe are the different habitats in which the two species exist. While the land iguana generally lives on land in the arid lowlands, the marine iguana lives both in and out of the

water on the coastal lava. This difference in habitat would naturally allow for a distinction in their diets, as well. The land iguana feeds on land-growing vegetation like shrubs and cactus; on the other hand, the marine iguana feeds on red and green macrophytic algae. Over enough time, a species can be physically shaped by its behaviors. Observe the difference in head shape between the two species below—this correlates to the efficiency of the intake of their particular diets. The land iguana's head is shaped conically, while the marine iguana's head is shaped bluntly. Only when considering the diets that each species eats does it make sense that their heads are shaped the way they are. The land iguanas need a longer snout to bite out bigger chunks of the cactus. The marine iguanas need a flatter snout to scrape off algae more efficiently from the rocks. Thus, over time nature selected for blunter noses in the marine iguanas, making this an adaptation.



These behavioral differences over time also shaped the marine iguanas to become better suited for a water-going lifestyle. As a result of being in a marine environment, other characteristics were enhanced, as well. Probably one of the most obvious distinctions made between the land and marine iguana is the color of their scales. Unlike the yellowish land iguana, the marine iguana has dark, black scales. The marine environment clearly played a role in how the iguanas were colored because the difference

in habitat is the main variable distinguishing the two species. The most likely explanation for the darker color applied to the marine lifestyle is that darker objects absorb sunlight more efficiently than lighter objects. Because marine iguanas lose a lot of energy to the cold water they swim in, they require a more efficient way of re-absorbing this lost heat; hence, the darker color. Over generations, nature selected for darker scales, which allowed the cold-blooded reptiles to succeed more in the water.

Another adaptation marine iguanas acquired over time were flatter tails. Compare the tails of the land iguana (left) and marine iguana (right) below. Flat tails are common to find in water-going reptiles, such as crocodiles and sea snakes, so it is no surprise to see how they also evolved analogously in the Galapagos marine iguana. Over time the fittest individuals survived and reproduced, and those iguanas best equipped to do so were ones with flatter tails than normal.



Marine iguanas also differ from their land counterparts in the shape of their feet. While land iguana's feet are standard, marine iguanas have partially webbed feet, as well as particularly strong claws to adhere to rocks during tidal motion. Because these characteristics do not exist in the land iguana, these are adaptations. All of these subtle differences have accumulated over millions of years to make marine iguanas more suited for a marine environment.

Other traits that marine iguanas possess which benefit their fitness include a slowed heart rate underwater (bradycardia) and anaerobic metabolism. In order to conserve energy, when marine iguanas go underwater, their heartbeat decreases dramatically. Above water, an adult marine iguana's heartbeat is roughly 43 beats per minute. However, underwater, the heart beat drops down to about 7 to 9 beats per minute⁷. This amazing process called bradycardia is undoubtedly beneficial to the marine iguanas, but it is not an adaptation. Because this trait is common among most reptiles, including its land iguana ancestor, it is only coincidence that the iguana now lives in water and benefits from the process. Slowed heart rate underwater is a process that evolved long before the marine iguanas came to exist. The correct term for this trait is an "exaptation." Marine iguanas also metabolize 70 to 90 percent of their ATP anaerobically⁸, which would appear a result of their feeding underwater, but because the land iguana does so with virtually identical statistics, scientists must name the process an exaptation rather than an adaptation.

Conclusions---

I believe that my first hypothesis—that harsh conditions on land (most likely a shortage of food) triggered a divergence and shift in diets from on land to in the water—was only suggested by the information I gathered, but by no means verified. Because food is a necessity to survive, I place it at the top of the list in terms of importance. While other factors may have induced such a dramatic change in habitat from land to water, food makes the most sense. A change habitat based on the change in diet would then allow other structures to be adapted to better function in that particular environment. I do believe, however, that my second hypothesis was verified. Natural selection had

adapted many body parts of the marine iguana to make them more suited for a sea-going lifestyle. Observing the contrast between the land iguana and marine iguana's appearance and structures alone helps verify my hypothesis.

The marine iguana is endemic to the Galapagos, meaning it is found only there on the earth. This may be a result of unique location of the Galapagos, in the middle of currents and a volcanic hotspot—or it could be the result of pure historical luck. What we do know for sure is that these evolutionary icons are in great danger due to human impact. Introduced species of ferile dogs and cats feed on the iguanas where humans are populated. El Niños also pay a huge toll on marine iguana populations as the warm surface water eliminates most traces of red and green macroalgae, their only source of food. Scientific research also shows that El Niño frequencies are increasing, which could possibly have detrimental effects to *A. cristastus* as a species. Life on the Galapagos is already a struggle for survival. There is no need for the already adapted iguanas to now have to adapt to the obstacles we throw at them. We should take a step back and let nature run the course it's been running for eons, and enjoy the process of evolution that we are all a part of.

Bibliography

Dawson, William R. "A Reappraisal of the Aquatic Specializations of the Galapagos Marine Iguana." Istor 31 (1977): 891-97.

Gallagher, Katie. "Location and Evolution: Habitats Creating Inhabitants." Serendip. 2000. 18 Aug. 2008 <<http://serendip.brynmawr.edu>>.

Gill, Elisa. "The Biogeography of Marine Iguana." 1999. San Francisco State University Department of Geography. 29 Aug. 2008 <<http://bss.sfsu.edu>>.

Higgins, Paul J. "The Galapagos Iguanas: Models of Reptilian Differentiation." American Institute of Biological Sciences 28 (1978): 512-15.

Kricher, John. Galapagos: A Natural History. Princeton, NJ: Princeton UP, 2006. 1-221.

Marine Iguanas. Charles Darwin Foundation. 12 Oct. 2008

<<http://www.darwinfoundation.org>>.

Wikelski, Martin. "Evolution of body size in Galapagos marine iguanas." 24 Aug. 2005.

29 Aug. 2008 <<http://www.princeton.edu>>.

¹ Dawson

² Gallagher

³ Marine Iguanas

⁴ Higgins

⁵ Photos taken by Chris Lang on Galapagos Field Seminar trip

⁶ Photos taken by Chris Lang on Galapagos Field Seminar trip

⁷ Dawson

⁸ Higgins