Charles Darwin was born 200 years ago, on February 12, 1809. He spent his childhood mostly landlocked in the Welsh borderland, collecting beetles, hunting, and being the equivalent of a 19th century intern (in modern parlance) with Adam Sedgwick, one of the great geologists of the 19th century. He spent most of his later life, again, landlocked in the small village of Downe, just a few minutes along the road from the local pub and church, neither of which he frequented. In fact, he mostly occupied his lovely house, tended his garden, and paced the "Sand Walk" again and again. So how can he be called a visionary marine biologist? Even the greatest marine biologist of all time!

Let’s not forget the most momentous experience of his young life. On December 27, 1831 he set out on the H.M.S. Beagle, which circumnavigated the globe in 5 years and gave Darwin the opportunity to see the world through his brilliant intellectual lens. More important, he not only carefully observed nature, he reasoned. It is this combination of observation and reasoning that places him, in my view, on the pedestal of greatest marine biologist.

Consider the way great science works. The way it really works. A sci-
entist gets a feeling, a notion, that something might be true about the natural world. Call it intuition, but it is often a best conclusion based upon a rather integrated thought process. The feeling evolves into a statement, but the scientist realizes that it may not be all that convincing to others. So he must make a case to support the statement, but the sum total of his past experience has already made a convincing case to himself. Then he must articulate the premises of the statement: are they logical? Are they consistent with what we know of the world? Finally, he must show to himself that the consequences of the statement flow from the premises. Such a complete statement, with consistent premises and a logical prediction is known as a hypothesis.

Keep in mind that the grandest of hypotheses, relativity, gravity and many others, all had this sort of development. Einstein conceived of relativity with no mathematics at first. Isaac Newton thought of gravity while watching apples fall from a tree. No matter how these inspirations happened, you can see how "informed intuition" leads great minds to make such statements that are later formalized.

And that precisely is why Darwin towers as a marine biologist. His first great scientific publication was designed to explain, or attempt an explanation, of a paradox concerning coral reefs.

Keep in mind that this level of thinking simply did not exist in marine biology at this time. Darwin articulated the first sophisticated overarching scientific hypothesis about coral reefs, and global geology, based on logic and prediction, in the history of marine biology! If that is not greatness, I don’t know what is.

Darwin knew that corals on reefs grew in well-lit shallow waters and grew fairly rapidly. If that was so, they must be growing upward. But why do we see such enormous coral reef tracts? By Darwin’s time, navigators already knew that coral reefs were often enormous, and were often patently dangerous navigation hazards. Explorers like Captain Cook immediately understood how extensive coral reefs were. Many a sea captain foundered on them, including the famous captain of the Essex, the only ship known to be attacked by a whale. What bad luck to survive such an episode, only to get command of another ship and be dashed on the coral of a western Pacific island.

But I digress. Darwin knew these coral reefs were large and grew in shallow waters. But how could such large coral tracts develop? Well we have the reasonable premises: rapid growth, large extent, and the requirement for growth only in shallow waters. This led to Darwin’s obvious conclusion, which he published in his first major scientific work: “On the Structure and Distribution of Coral Reefs” published in 1842.

The very important conclusion was that the bedrock beneath coral reefs must be sinking, while the reef was growing upward! How else could these reefs be growing upward indefinitely at a rapid rate? Over large amounts of geological time, this sinking of the bedrock beneath would be balanced by upward growth of the reef itself. Suddenly, the worldwide extent of coral reefs in the tropics gave us a new notion of earth history: a continuous sinking of the earth balanced by an upward growth of corals, which kept them always near the surface.
An important detail involved set of different reef types that Darwin interpreted as phases of sinking. He saw small fringing reefs as the first phase, large coastal reefs, like the Great Barrier Reef, as a second phase, and open sea island rings, or atolls, as the final phase.1

This was a truly visionary scientific hypothesis. It was global in scope and built a grand idea from the activities of tiny coral polyps, adding infinitesimally small amounts of carbonate skeleton each year to grow upward. Most importantly, Darwin made a clear prediction. You should be able to drill down into a coral reef, particularly an atoll, and go through large amounts of coral, before encountering another type of geological bedrock beneath. Darwin was now moving out on thin ice, but he even made a prediction: a reef of 5000 feet thickness would be found and bedrock would be found beneath it.

![Image](36x350 to 210x412)

**Figure from Darwin’s original volume on coral reefs, showing his idea of the evolution of reefs from fringing, to barrier, to atolls.**

How successful was this hypothesis? Well, only partially. Investigations over the past hundred years or so demonstrated that many coral reefs were not subsiding steadily, and it is not true that fringing reefs, coastal reefs, and atolls are sequential phases. Darwin also failed to take into account the advances and retreats of glacial ice over the continents. As the ice advanced, sea level lowered as much as 150 m worldwide and as the ice retreated (as it has done over the past few thousand years), the melting ice has caused a rise of sea level. Coral reefs must erode when sea level declines and many have grown upward when sea level rose and still are alive today. So Darwin missed much.

But there is one major class of reefs where Darwin got it exactly right and these are known as atolls. Atolls are ring-shaped groups of islands with fringing coral reefs (e.g., Enewetak atoll in the Marshall Islands of the central Pacific). These reefs sit atop an extinct volcano which has subsided for millions of years. As the sea floor moves laterally, in a phenomenon known as sea floor spreading, the volcano moves into a region of geologically cooler conditions and the crust subsides and the volcano sinks. Coral grows on the fringe of the volcanic rock above the surface at first, but as the volcano sinks, the coral reef grows upward, leaving a very tall cylinder of coral rock on top of the sunken volcano. The geophysicist J. Tuzo Wilson realized that plate tectonics might be behind such sinking, but also occasional uplifts of oceanic volcanos. Drowned reefs atop sunken volcanoes are common throughout the Pacific Ocean.

The truth of Darwin’s sinking hypothesis was tested once and for all by Harry Ladd and colleagues in the 1950s. They drilled into Enewetak atoll and found that they had to drill some 4000 feet before encountering volcanic rock, over 40 million years old. This result was amazingly similar to Darwin’s prediction.

Darwin’s idea was grand but not completely correct. But it reveals an important truth about science: mistakes often are just as important in our understanding of the world as successes.

If you doubt Darwin’s greatness, here is one last thing to ponder. Darwin formed his theory of coral reefs before he ever saw one! As he wrote: “No other work of mine was begun in so deductive a spirit as this, for the whole theory was thought out on the west coast of South America, before I had seen a true coral-reef.”2

Darwin was not only a great and pioneering marine environmental scientist and ecologist, he also was a major pioneer in describing the ocean’s biodiversity. While on the Beagle, he collected thousands and thousands of marine specimens, many of which were distributed to various experts in the appropriate specialties when Darwin returned to England and moved to London to work on his collections. But he kept for himself the great task of describing and classifying the world’s barnacles. In the 1850s he published four volumes on the world’s barnacles and attempted to classify them by means of their morphology. It had not been very long since barnacles were realized to be crustacea, relatives of shrimp and lobsters, and not mollusks, or relatives of snails and clams. Darwin carefully described all of the species he collected but also got more from other collections brought to England, including the giant barnacle *Balanus nubilus*, brought back from Captain George Vancouver’s expedition to the Pacific northwest in the late 1700s. He also used fossil barnacles from his own and other collections. His grouping of

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2 See the Life and Letters of Charles Darwin, 1888, v. i, p. 70.
barnacles into major groups of species (stalked versus unstalked barnacles) and then smaller groupings was based on a careful analysis of a variety of characters. To study the barnacles, Darwin purchased a fine compound microscope. The amazing thing is that his taxonomy was brilliant and has largely stood the test of time. The thinking and publication of these books predated his masterpiece, *The Origin of Species*, by a number of years, but we now know that he was thinking and writing about evolution and natural selection in his famous notebooks years before this. The words barnacles and cirripedes appear 28 times in *The Origin*. So we cannot escape the conclusion that Darwin likely used evolutionary thinking in the construction of his taxonomy of barnacles, and he learned much from them, including the evolutionary loss of characters. Darwin noticed that parasitic barnacles lacked a number of characters found in free-living species, and believed that the evolution of the parasitic condition involved the loss of characteristics (e.g., an external shell) that added unnecessarily to the cost of living of a parasitic form. So Darwin was not only a great ecological marine biologist, he also essentially invented the field of evolutionary marine biology. It might be wrong to give Darwin credit for everything, but his grand style of thinking permeated his forays into marine biology, and these achievements firmly establish his firm grip on the title of Grand Master of Marine Biology.

Today we celebrate Darwin for his genius, his invention of the theory of natural selection. His “one long argument” convinced the educated world that evolution was the only rational explanation for the diversity of life and he greatly advanced science by showing that there are good notions of how to explain the process. But do not forget, Darwin also set the table for marine biology and natural history for decades and centuries to come. His genius ranged far beyond the beak of the finch.

Happy Birthday, Mr. Darwin!!


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Charles Darwin, The Greatest Marine Biologist