Charles Darwin

A Gentle Revolutionary

Most everyone recognizes the name of Charles Darwin. To some he is an icon of rational thinking, to others a devil. His near legendary status has made him seem larger than life. Few people accurately understand the events in his life, his motives, and his contributions to our understanding of biology. Many modern readers wrongly consider Darwin to be the sole developer of evolutionary theory and debunker of religious creationism. In reality, Darwin's work was just one of many forms of evolutionary thinking at the time, and it even included aspects of creationism. Some conservative Christian groups have voiced that evolution cannot be reconciled with their Church's doctrine. Those holding this stance overlook the fact that religious groups of all faiths have long wondered how the diversity of life on our planet arose. The real Darwin was a complex man, very different than common perceptions of him.

Born in 1809, Charles Darwin had a family history of interest and work in science. His grandfather, Erasmus Darwin, had been a successful physician and naturalist, writing his own ideas on evolution in the book Zoonomia. His father, Robert Darwin, had also been a successful physician. Charles remembered his father most fondly, as his mother died when he was only eight years old. Following in his father's footsteps, Charles planned on also being a physician. In 1825 he enrolled at Edinburgh University to obtain his degree as a medical doctor. However, much like students today, he found the lectures boring, and he recoiled in disgust from his anatomy classes, unable to stomach opened cadavers. He wrote:

> The instruction at Edinburgh was altogether by lectures, and these were intolerably dull, with the exception of those on chemistry by Hope; but to my mind there are no advantages and many disadvantages in lectures compared with reading. Dr. Duncan's lectures on Materia Medica at 8 o'clock on a winter's morning are something fearful to remember. Dr. – made his lectures on human anatomy as dull as he was himself, and the subject disgusted me.

Much later when he had become a professional naturalist and dissector of animals, he wished his anatomy professor had forced him to practice dissection more, because of the utility it held for his future work.

A career as a physician was not for Charles. He and his father decided that he should pursue the life of a clergyman. In 1827 Charles moved to Cambridge University where those aspiring to be clergymen took the same challenging classes as those studying to be scientists. Over a hundred years before, Isaac Newton had pursued a life in theology at Cambridge, only to turn away when he deemed the Anglican Church to be full of heresy. Darwin had sent himself down the same path to be a clergyman, but would turn to a different career for a much different reason than dissatisfaction with religious doctrine.

The many theological works Darwin read at Cambridge included Paley's *Natural Theology* and *Evidence of Christianity*. Paley argued that the supreme complexity of life was evidence that all beings had been specifically designed by a Creator. At this time, Darwin accepted the divine creation of species, and found Paley's arguments agreeable. While at Cambridge, Darwin met the luminary scientists William Whewell and John Herschel. Both contributed to Darwin's attitude and efforts toward investigating nature. From Herschel came the balance of observation and experiment. From Whewell came the idea that successful scientific theories draw from many fields of research. Thus, along with being well versed in theology, Darwin became a keen observer and critical investigator in the fields that we now call geology and zoology. Although Cambridge infused Darwin with a scientific spirit, he again found the classes boring and livened his days by gathering and inspecting beetles he found in the courtyards:

> But no pursuit at Cambridge was followed with nearly so much eagerness or gave me so much pleasure as collecting beetles. It was the mere passion for collecting, for I did not dissect them, and rarely compared their external characters with published descriptions, but got them named anyhow. I will give a proof of my zeal: one day, on tearing off some old bark, I saw two rare beetles, and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one which I held in my right hand into my mouth. Alas! it ejected some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost, as was the third one.

Perhaps most important during his time in Cambridge, he met and befriended one of the top geologists of the day, Adam Sedgwick. President of the newly formed Geological Society of London, Sedgwick took the young

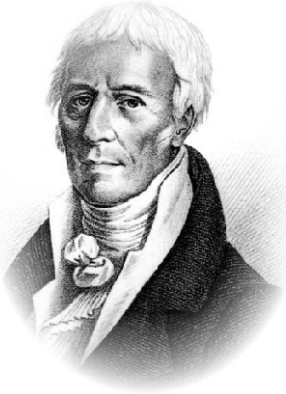
Darwin on geological expeditions to Wales. At the time, Sedgwick advocated a then popular position in geology called 'catastrophism,' which argued that landscapes such as mountains, canyons and lakes formed swiftly through epic hurricanes, earthquakes or floods. Sedgwick advocated this idea to Darwin on the trip to Wales. Darwin had his reservations, but nonetheless developed a passion for studying the natural world. His aspirations to be a clergyman disappeared.

Upon returning from his trip to Wales, Darwin found an irresistible job opportunity waiting for him. Captain FitzRoy of the H.M.S. Beagle was about to set sail in order to survey territory in South America and conduct scientific experiments along the way. Fearing the daily drudgery of interacting with sailors below his social status, the captain had been looking for a scholarly gentleman to lighten the days with intelligent conversation. Darwin accepted the offer, and the ship set sail on December 27, 1831. Early on, Darwin failed at his job of being a conversation piece. While discussing theology or slave trade, both he and FitzRoy often became enraged and unable to communicate. They made peace as the voyage continued, and maintained a friendship as the ship steered along the coast of South America.

Darwin did not set out on this adventure with the intent of undermining the view that all species were divinely created. The situation is better understood as that of a young man, interested in the natural world, who was offered an adventurous opportunity to explore the world. Consider how you might jump at such an opportunity! At this time, evidence overwhelmingly supported the idea that the Earth was very old, but just how old was heavily debated. While ideas regarding the evolution of species had been proposed and discussed prior to this time, Darwin did not appear to find them so compelling that he would set out on this voyage to determine how species originated. Thus, nothing noteworthy appears to have precipitated Darwin's change in thinking while at sea.

Discussions of evolution had been ongoing for over a century by the time the Beagle sailed. For example, the French botanist, Jean-Baptiste Lamarck, had written about the evolution of species in the late-1700s and early-1800s. Lamarck, like many naturalists at that time (including Erasmus Darwin), thought that life spontaneously generated. This 'natural' creation could only be responsible for very simple life forms. He argued that once generated they began climbing up the 'ladder of life' toward advanced life forms. The most advanced forms, humans, were considered to have made the furthest progress. Thus they were considered the oldest beings on the ladder. Simpler species had been more recently generated. One of Lamarck's more lasting contributions to the idea of evolution was the concept of adaptability, although his mechanism of use and disuse for how species adapt has since been discredited. He thought that an organ or limb would become stronger or more pronounced with more use. For example, the more a giraffe stretched its neck for food, the longer it would become. Disuse would result in an organ or limb becoming smaller. He thought these sorts of changes were passed to offspring.

Later, in 1844, Robert Chambers also put forth a popular evolutionary idea. In his book, *Vestiges of Natural Creation*, Chambers combined astronomy, geology, theology, biology, and a lucid writing style to advocate that life forms progressed according to a divine law. God, the maker of the universal laws, had worked them out such that species followed a set progression. Chambers was not a scientist, but he read all the contemporary works on evolution and developed a very influential argument that many in the public took as the best explanation of evolution.



Jean-Baptiste Lamarck

Charles Lyell

Note that ideas regarding the evolution of species did not originate with Darwin. Moreover, people, like Darwin, who believed in God, were often advocating ideas regarding the evolution of species.

Darwin would have read all of these works. One could not be a naturalist in his day without being familiar with Lamarck and the *Vestiges of Natural Creation* (the latter he would have read in 1844, seven years after his return on the Beagle). However, on this expedition, which Darwin famously memorialized in his book Voyage of the Beagle, he made two important observations. The first had to do with geology. In England, Sedgwick had trained Darwin's eye to see geological formations as happening all at once. However, Darwin couldn't accept this view once he viewed the rugged and varied landscapes of South America. Before leaving England, Darwin had acquired a copy of the geologist Charles Lyell's new book *Principles of Geology*, which would become a classic in science. This book essentially countered catastrophism. Lyell argued that things like mountains and rivers did not form all at once,

but gradually over time. As the Beagle passed through Brazil, Darwin noted his approval of Lyell's system, called “uniformitarianism”.

> Along the whole coast of Brazil, for a length of at least 2000 miles, and certainly for a considerable space inland, wherever solid rock occurs, it belongs to a granitic formation. The circumstance of this enormous area being constituted of materials which most geologists believe to have been crystallized when heated under pressure, gives rise to many curious reflections. Was this effect produced beneath the depths of a profound ocean? Or did a covering of strata formerly extend over it, which has since been removed? Can we believe that any power, acting for a time short of infinity, could have denuded the granite over so many thousand square leagues?

Darwin was saying that he couldn't conceive of the granite being produced under an ocean and then exploding up all at once. Instead, he thought it more likely that such a vast landscape had been slowly built up over time. He made many more of these geological observations. They were very important because he began to apply this 'gradualism' to his second important group of observations he made on the trip: living organisms. Lyell, on the other hand, associated his uniformitarianism principle with a steady state viewpoint of the Earth and denied a progressive evolution of species.

As the Beagle skirted the South American coast and pulled in at the major ports of call, Darwin collected and categorized insects, crustaceans, flowers, and made observations of the larger mammals. Once collected, he packed them up and left them at port for the next ship bound for Cambridge. When he returned home, Darwin practically had a library of foreign specimens to examine.

Perhaps the most famous example of his work as a naturalist was conducted on the Galapagos Islands. Arriving in September 1835, Darwin had by now become very interested in the types of creatures inhabiting the islands near the mainland. He noticed that of the birds on the Galapagos, most of the landed birds (short fliers like finches) were entirely unique to the islands. Other birds, like seagulls, could fly back and forth between the islands and the mainland.

This stirred Darwin's imagination. If organisms were uniquely created for their particular climate, then why would island animals be so similar to land animals even if they had completely different climates? In a famous example, Darwin compared the Galapagos finches to the mainland finches of Chile. They were pretty much the same except for variations in their beak. The landscapes, however, were entirely different. The Galapagos were volcanic islands, while Chile was a mountainous region. Darwin was puzzled. If these species were supposedly created especially for the climate of the Galapagos, why would they be only slightly different than the mainland birds? In his own words:

> The naturalist, looking at the inhabitants of these volcanic islands in the Pacific, distant several hundred miles from the continent, yet feels that he is standing on American land. Why should this be so? Why should the species which are supposed to have been created in the Galapagos Archipelago, and nowhere else, bear so plain a stamp of affinity to those created in America?

Then he pushed the question one step further. Why would two distant locales with similar environments, such as Africa and South America, have completely different flora and fauna? Again in Darwin's words:

> On the other hand, there is a considerable degree of resemblance in the volcanic nature of the soil, in climate, height, and size of the islands, between the Galapagos and Cape de Verde Archipelagos: but what an entire and absolute difference in their inhabitants! The inhabitants of the Cape de Verde Islands are related to those of Africa, like those of the Galapagos to America. I believe this grand fact can receive no sort of explanation on the ordinary view of independent creation; whereas on the view here maintained, it is obvious that the Galapagos Islands would be likely to receive colonists, whether by occasional means of transport or by formerly continuous land, from America; and the Cape de Verde Islands from Africa; and that such colonists would be liable to modification; the principle of inheritance still betraying their original birthplace.

In other words, Darwin began questioning that each species had been uniquely created for its particular environments. He doubted the view that every small island in the ocean would have received a special visit from a Creator. Rather, Darwin saw more reasonable the idea that organisms had not been created on the islands. Instead they were somehow transported there from the mainland, and then began the slow changes that developed them into different species. This change from one species to another, often called transmutation, became a staple of Darwin's evolutionary theory.

1. Summarize the evidence and reasoning Darwin uses to support the view that species change to become adapted to their environment rather than having been uniquely created for that environment.

Upon returning to Cambridge in 1837 from his trip on the Beagle, Darwin began the lengthy process of reviewing all his specimens. In these first years back in England, he married and had children, published his *Voyage of the Beagle*, and caught up on research presented while he was at sea. A significant influence on Darwin's thinking was an essay he read and incorporated into his notes in

1838. Roughly 40 years earlier, the clergyman Thomas Malthus had published *An Essay on the Principle of Population*. In that essay he stated that because mankind tended to enjoy procreation, its population would, if uninhibited, increase exponentially. Because resources are limited, a struggle for existence would ensue. Malthus believed this to be a simple fact of God's law, and those without food had a moral obligation to stop having children. Darwin was struck by Malthus' phrase "struggle for existence", and he made a creative leap in applying it to the problem of species adaptation and divergence. When Malthus had written the "struggle for existence", he was referring to wars between Asiatic tribes. Darwin dissociated this idea from Malthus' moral purpose and applied it to species fighting for limited resources. Perhaps some species might have an adaptive advantage over others, and that would partially explain why so much variety existed. The importance of his insight is illustrated by his own words:

> In October 1838… I happened to read for amusement "*Malthus on Population*," and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species. Here then I had at last got a theory by which to work…

After his return on the Beagle, Darwin began suffering from a chronic stomach ailment and frayed nerves, perhaps caused by a sickness he picked up in South America. In 1842 he moved to the countryside for a more quiet and calm life. That same year, Darwin wrote a sketch of his thoughts in case he was to die. He had no intention of publishing his thoughts at this time. He spent nearly twenty more years analyzing his collections, conducting further studies, and discussing ideas with others to garner what he hoped would be overwhelming evidence for his ideas.

In 1844, the same year as the appearance of Chamber's *Vestiges*, Darwin made a first draft of his evolutionary theory. In that essay Darwin argues that small changes in local populations would, in time, accumulate and result in an organism becoming incompatible with its ancestors. This splitting, or speciation, would be gradual with no clear cut-off point. This idea accounted for the trouble naturalists often had determining separate species. However, he didn't want anybody to see the essay because he had not figured out a mechanism responsible for adaptation. Whereas Lamarck and Chambers thought adaptation followed some sort of set plan, Darwin felt that this didn't make sense. A ladder of progression might explain why species changed, but it couldn't explain why they "diverged," or in other words, why so many varied species existed.

2. Scientists are human beings and part of society. Like all humans, their work is influenced by the culture in which they exist.

a) What cultural factors are influencing scientists' thinking that adaptation must follow some sort of plan?

b) How does Darwin's struggles and anxiety indicate he is wrestling with those same cultural influences?

Darwin's ongoing work was expansive and included, but was not limited to, studying pigeon breeding, the geographical distribution of organisms, and barnacles. Darwin knew that breeders carefully paired males and females possessing desired traits to emphasize those traits in the offspring. Darwin knew, of course, that humans were artificially selecting and breeding for desired traits. But artificial breeding provided an analogy for how nature, given far more time, might select for traits and result in organisms adapted to their environment. Darwin reasoned that the random or undirected variation from which breeders select their traits must also exist in nature. This natural selection is analogous to artificial selection, but the former is far more pervasive and creative because it acts continually on every feature in every generation.

As for barnacles, Darwin had collected a wide variety of these little crustaceans, known for clinging to ship hulls. In part, the barnacle research began because Darwin was criticized for discussing species when he was an expert in none. Furthermore, Darwin felt that studying variation in the hapless crustaceans could help him understand why all species undergo change. Prevailing ideas regarding evolution accounted for wide variation in 'advanced' life forms like birds or apes or humans, but it would not be expected in the 'primitive' barnacles. Nonetheless, there was variation and Darwin wanted to understand what caused it. After years of study and reflection, in November, 1854 he outlined his principle of divergence. It stated that divergence and eventual speciation would occur in locations where competition for resources was keen. Key to the process were the ecological pressures acting on populations. Thus natural selection was not the sole factor causing divergence.

Darwin had no "eureka" moment where he suddenly put all the pieces together. Rather, his thinking continually developed and many ideas had to be modified while others abandoned. Around 1854, his thinking was as follows. First, he thought that species did not 'progress' up a ladder, but instead randomly 'diverged'. What this meant was that nature had no plan for how a species would develop, and that species would naturally split off into different types instead of moving toward a determined goal. Second, he realized that the pressure causing this divergence was the

competition for resources. Darwin accepted that long ago God created one or more very primitive life forms. Those original life forms then had the tendency to expand and search for resources, and environmental changes drove adaptation. One could not easily see these changes because life forms did not continuously change. They only changed when environmental factors, such as climate change or access to resources, favored an adaptation. Furthermore, many of these transition species did not appear in the fossil record because fossilization was such a rare occurrence in the first place.

For Darwin, another challenge loomed on the horizon – convincing scientists that his ideas had merit. Fearing the voracious readers of the Victorian age would ruin his life by labeling him a 'materialist' or an 'atheist,' he had thus far withheld publishing his ideas. However, he had long been forging friendships with scientists dissatisfied over the older evolutionary theories. Alfred Russel Wallace was one of these colleagues. Unlike Darwin, Wallace's world travels were, at least in part, motivated by his view that the idea of evolution was compelling.

In June 1858 while working in the Malay Archipelago, Wallace wrote Darwin a letter presenting ideas very similar to Darwin's and seeking Darwin's assessment prior to publishing them. Until this point Darwin had never felt rushed to present his work. Now with Wallace closing in, he acted. Courageously, he first informed Charles Lyell and another mutual friend, Joseph Hooker, of Wallace's letter. Darwin was so concerned about honesty that he asked Lyell, “As I had not intended to publish any sketch, can I do so honorably because Wallace has sent me an outline of his doctrine? I would far rather burn my whole book, than that he or any other man should think that I had behaved in a paltry spirit.” After convening a group of scientists to compare Darwin and Wallace's notes, Darwin was given his rightful priority in the matter. That August, the *Journal of the Proceedings of the Linnean Society of London* published a paper by Darwin alongside Wallace's.

While Wallace had only recently come to his idea and had very little support for it, Darwin raced to his pen and paper and wrote *On the Origin of Species* practically from memory. In the Origin, which Darwin once referred to as “one long argument from the beginning to the end,” he drew upon extensive taxonomical and geological research he had conducted during the past twenty years. In the closing days of November 1859, the first printing of his *On the Origin of Species* appeared in London's bookstores. Darwin's work was rewarded with a first-day sell-out of 1250 copies, a very large printing for the time.

Note that Darwin's theory explaining the evolution of species does not address the origin of life. The title of his book refers to how the diversity of species arose, not how life first arose.

Many scientists and public officials gradually accepted Darwin's ideas on evolution. However, Darwin's primary mechanism, natural selection, was widely rejected by scientists for many years. Many scientists refused to abandon the idea that evolution progressed toward some proper end. Huxley didn't accept gradualism, and thought speciation could occur rapidly. Other scientists advocated a kind of guided evolution. Even Darwin remained tied to the past as illustrated by his admitting a role for Lamarkian adaptation. As with most all advancement in science, change was slow and no single piece of evidence brought about our current understanding of evolution. Darwin's “one long argument” turned into a scientific debate that continued for decades. The idea of evolutionary “progress,” and the rejection of natural selection continued until the synthesis with genetics early in the twentieth century put those arguments to rest in the scientific community.

Darwin's ideas sparked debate and did not instantly convince his scientific peers. This is typical of newly proposed ideas in science and is not at all unique to biological evolution.

Charles Darwin was a complex man who put a lifetime of work into his theory of evolution. Very much a man of his time, he infused his understanding of morality, order, theology, economics, geology, and zoology into his theory. Once published, it did not triumphantly storm the world. In fact, it wouldn't be considered a true landmark of science until geneticists infused natural selection into their work on heredity in the 1930s. In 1879 he published *The Descent of Man*, which emphasized the importance of adapted features in attracting sexual mates, and the application of the theory of evolution to mankind. Contrary to popular opinion, Darwin never claimed that man descended from apes. Rather, he argued that man and apes descended from a common ancestor, diverging gradually and eventually resulting in the separate species we see today. His work, again, was highly controversial both within and outside the scientific community. During the past 100 years, overwhelming evidence has supported Darwin's most fundamental ideas regarding biological evolution.

Darwin's theology at any given time in his work is much debated. While he was never an atheist, Darwin's religiosity had faded by the time of his death, driven not by his theory of evolution, but by his witnessing the painful and early deaths of his daughters. His view that evolution lacked purpose and his reservations about religion undoubtedly caused him emotional and physical stress that plagued him throughout his later life. To this day, some religious groups continue to see Darwin as an embodiment of the devil. This is far from the truth. Believing that ultimately some power must be in charge,

Darwin died an agnostic. Recognizing his significant contributions to science, the powers at that time, including the Church, made sure that he was buried in London at Westminster Abbey. In a service attended by England's dignitaries, Charles Darwin was buried next to another icon in science, Sir Isaac Newton.

Many religious groups came to terms with evolution by the 1900s. One of Darwin's colleagues argued that explaining adaptation through natural selection fit with theists' belief that natural law is an expression of God's will. Some Calvinists used evolutionary thinking to argue that humans were not a product of inevitable progress and had fallen from grace. Today many religious groups have put forth position statements in support of biological evolution. However, some of the more conservative Christian and Muslim religious groups continue to deny evolution. Choosing to ignore that evolution has always been an idea bigger than one man, these conservative groups unfortunately target Darwin as a heretic.

Reactions toward biological evolution have varied greatly. Many religious, science, and science education groups have written position statements supporting biological evolution as a sound scientific idea (http://ncseweb.org/media/voices/religion). This illustrates that public education controversies regarding the teaching of biological evolution are not simply a battle between religion and science.

3. Nobel prize winning scientist Percy Bridgeman once stated that science is "doing one's damndest with one's mind, no holds barred." He was expressing that doing science research demands creativity and that scientists will use most any method that will help them understand the natural world. Many people wrongly think that scientists follow a rigid step-by-step scientific method when doing research. This misconception wrongly leads to another misconception that the value of a scientific claim can only be made through a controlled experiment. Many of the most well established scientific ideas defy investigation by means of a controlled experiment.

a) How might you account for the prevalence of these two significant misconceptions regarding how science research is done?

b) How might the public's adherence to these misconceptions cause them to reject biological evolution?

4. Science's approach to explaining events in the universe without reference to the supernatural is called "methodological naturalism". Individual scientists often have a deep personal faith in a supernatural being, but when doing science, researchers must provide natural rather than supernatural explanations for phenomena. This approach has undeniably been successful and has provided useful scientific explanations for phenomena that in the past were attributed solely to supernatural intervention. How would permitting supernatural explanations in science interfere with the quest to develop explanations humans can understand and use?

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