CYNTHIA L. MILLS

THE THEORY OF EVOLUTION

WHAT IT IS,
WHERE IT CAME FROM,
AND WHY IT WORKS

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Introduction

How grand is the onward rush of science!
—Charles Darwin to Alfred Russel Wallace, 1872

Few ideas have engendered as much emotional resistance as the theory of evolution. Darwin's announcement generated voluminous and venomous reviews in newspapers, and turned many of his friends into enemies. Here in the twenty-first century, we find the situation little improved, with Christian government officials encouraging teachers in public schools to overlook evolution and Darwin entirely, as if the theory never did turn science entirely on its head. In response, the scientific community reacts with alarm and public ridicule.

Why is the theory of evolution so inflammatory? Why do so many nonscientists feel the need to valiantly attack or defend the idea? Theories like the Big Bang are as contradictory to religious beliefs, yet you seldom see Big Bang bumper stickers. I believe there are two reasons.

First, evolution is personal. It says something about each one of us—that we were once simpler creatures, that we didn't start out as the exalted and unique creations we now assume we are. In fact, we looked like apes. This can come as something of a shock, particularly if one is inclined to look down on our more hirsute cousins.

But another reason has to be that the theory of evolution, and in particular Darwin's theory of natural selection, is so accessible. It has the unmistakable elegance of a great theory; once you read it, you say, as Thomas Huxley did, "Why didn't I think of that?" Darwin's statement of his idea, *The Origin of Species,* is so clearly drawn that anyone can understand it, and understand the evidence he gives to support it. How many other scientific theories are like that? Most of us can't argue with Newtonian physics or Einstein's relativity with anything like expertise, because most of us can't reproduce the mathematics. Darwin himself struggled hard with mathematics. He had to abandon his attempts to quantify his ideas when his cousin Francis Galton pointed out several egregious miscalculations. The solitary graph in *Origin* is easy enough for anyone to understand.

Darwin's theory is so unmathematical that scientists still argue over whether or not it qualifies as a theory. Ernst Mayr, an unabashed Darwinian, describes *Origin* as "one long argument," comparing it to a lawyer's brief rather than a set of postulates and laws. Without a rigorously definite foundation, the theory takes on the air of a narrative—something less than scientific, something assailable.

That very vulnerability encouraged many to attack. Even those who agreed with Darwin felt confident enough to

quibble over details. Maybe they knew Darwin was right about the fact that species change, but they could disagree with natural selection, his idea of how they changed. If they agreed with selection, they rejected his claims that change was gradual. When scientists disagreed with Darwin, they opened the way for nonscientists. If fault could be found among Darwin supporters, the religious detractors felt the theory was a sitting duck.

But the greatest damage to the Darwinian reputation was done by those who would co-opt evolution and natural selection for their own purposes. Darwin's theory was quickly adopted, misinterpreted, and rewritten to promote various unsavory ideologies. No one, certainly not Darwin, would argue there is any real value to social Darwinism. And we need not credit those who would support the role evolutionary theory played in the justification of the Nazi Holocaust.

The saddest yield of all this opposition is the misrepresentation of Darwin himself. He was a product of his times, certainly, and undoubtedly held imperialist and racist views when held to twenty-first-century standards of propriety. At the same time, he was profoundly antislavery, and he couldn't bring himself to entirely agree with his cousin Francis Galton on eugenics. Mainly, he was far from arrogant or egotistical; he was ambitious enough to know he had a good idea and cunning enough to set the stage for it. Still, he clung desperately to his Victorian sense of integrity and honor. He avoided the limelight, but I think he had something he desperately wanted to say about the world. I think he wanted to put us back into nature.

Darwin had a bad case of what E. O. Wilson calls "biophilia." He couldn't look at nature without being absorbed by it, and he couldn't bring himself to feel above or separate from the creatures he saw around him. He saw no big jumps between us and the rest of animalkind; all of nature is made of the same stuff. The difference between a human mind and that of an orangutan was one of degree, not of kind.

This book is not a biography of Darwin, however. And Darwin probably was wrong about much of what he believed. The theory of evolution, like all theories, is larger than its originator. To meet the criteria of a great idea it must take on a life of its own, and evolution has certainly done that. It has built a science, several in fact, creating its own turmoil, without and within. Within biology, factions form to argue over whether species change suddenly or gradually. Other factions argue whether selection is the sole driving force, while others insist on giving it a minor walk-on part. And then there are the outlyers, the creationists and intelligent-design supporters, always looking for a weak point to attack.

The following is a biography of this contentious theory, one that describes its genealogy, birth, growth, education, and its impact; perhaps not its death. Like all scientific theories, it had a long and gradual birth, and a great many premature deliveries. There were a lot of good ideas that laid the groundwork, and many of these same good ideas became bad ones that bogged down progress. But what made evolution such a good idea? How has it withstood critics in greater number and of greater passion than any other scientific concept?

1

Making Up the Western Mind

Once upon a time we humans looked out over a world of nature that didn't change. What we saw with our own eyes was what we got. A duck was a duck because it was supposed to be, because there was some essential nature—an essence—that made it that way.

There was room for argument. Plato and his student Aristotle disagreed over Plato's idea that this essence was preset—as if there were some great ideal model for ducks set by some greater intelligence. Aristotle looked at each creature and decided the essence of the duck came from the duck itself, as if the duck came with the instructions for its own creation. Still, a duck was a duck.

The world didn't change, but it didn't sit still, either. If people watched the skies, they saw that the sun moved, and the planets, and so did the stars. And old things died, and new things were born. But all this story repeated itself over and over. People decided the essence of the world was

circular. Time ran in cycles, coming back again and again to the same place. The heavenly bodies moved, but the earth didn't.

Then came the Dark Ages, and the study of nature took a back seat to religion, in particular to the Christian religion. While scholars debated the details of what Jesus said, they mostly accepted the writings the Greeks left behind about nature. They differed in one important way: with Christianity came a Bible, and the Bible told a story with a beginning and the prophesy of an end. There was no coming back to square one in this book. The Christian world had a future and a past, having more or less invented the concepts.

For a long time this disturbed no one. Indeed, people didn't seem to notice the difference, and didn't change their opinions of nature, perhaps because only a few people thought about nature at all. The others were busy struggling to stay alive, and didn't read or write much. The few scholars that did concentrated on the glory of God, for the most part. Nature, if they considered it at all, was merely appreciated as an example of God's creative genius.

Then the world started to open up. People started to look around. Civilization advanced enough to give some people the spare time to go exploring. And other people began to learn to read and write; more people gained the wherewithal to build their own opinions.

There were the famous travelers. Marco Polo had gone east and returned; Christopher Columbus had gone west.

They brought stories and samples of new peoples, new plants, and new animals. Unimaginable creatures were brought home to gawk at, collect, and study.

These discoveries demonstrated two things: there was far more life on earth, and much more variety, than expected; and each and every species was remarkably well adapted to its way of life. There were so many new creatures, they began to overcrowd the Ark. It became uncomfortably clear that there wouldn't have been enough room on Noah's homebuilt boat for all the world's creatures. Christian scholars could lighten the load by tossing off the birds and marine organisms, but even that wasn't enough. There was another problem. How could creatures so perfectly adapted to one environment, say the polar bear or the rain forest sloth, survive a long migration back home starting in the desert regions of Mt. Ararat?

There was also the discovery of a whole new world. With the invention of the microscope, Anton van Leeuwenhoek's tiny "animalcules" extended biology into an unheard-of realm. Scripture didn't even mention such creation—how could they now be accounted for? The existence of such microscopic creatures also gave support, if false, to the theory of spontaneous generation—the idea that living forms can spontaneously arise from nonliving material. The theory had lost some of its hold after some demonstrations that flies would not arise out of rotten meat if flies were not allowed to lay eggs. But a handful of hay left in water still resulted in the generation a few days later of hundreds of tiny, busy, microscopic creatures. Where had they come from? Though spontaneous generation was later disproven,

it was a theory for the creation of life that didn't require God's hand. The discovery of microscopic forms was yet another chip in the foundation stone of sacred texts.

Yet another world emerged, a world out of time. The ancient Greeks described fossils, and Aristotle, finding their forms consistent with animal forms, likened them to animals. Still, little significance had been attached to their existence. The Greeks explained them as organic forms, arising from some sort of abstract accident. During the Enlightenment, theories linked fossils to spontaneous generation—it was suggested that fossils were the end result of misplaced germs, attempting to come to life in apparently inappropriate surroundings. Still, as it became clear that the visible surface of the earth had a decipherable past, and fossils were parts of that past, more and more scientists collected, analyzed, and described different fossils. It was becoming harder to deny their complexity, and to disavow what they said about the world.

Instead of the old theist worldview, where God takes a direct hand in every creation, God was taking a step back, becoming the watchmaker supreme: the designer of the *forces* that made our universe run. He no longer had to infuse energy and matter with his genius on an everyday basis; he just had to wind it up and let it go. This was the new framework, a perfect mechanism that could be taken apart and explained. And every step of this process brought the investigators a step closer to reading the mind of God.

At the turn of the eighteenth century, Paris was becoming the hub of this new rational biology. Explorations around the world were sending large collections of exotic

plant and animal specimens back to the city, and museums had to be built to house them. The Jardin du Roi, later renamed the Museum of Natural History (or Museum du Histoire Naturelle) became a hotbed of innovative thought and argument. Buffon, Cuvier, Lamarck, and Geoffrey St. Hilaire performed research and debated their ideas there.

BUFFON

Few scientists have represented their time as fully as Georges Louis Leclerc, comte de Buffon. Buffon, as he is commonly known, was born in 1707, the son of a wealthy aristocratic family. He studied one year in England, where he developed a passion for physics and mathematics, and also studied plant physiology. He was especially inspired by reading the works of Isaac Newton, even translating Newton's *Fluxions* into French upon his return.

Although not primarily a biologist, he was recommended for the directorship of the Jardin du Roi. He took to the job with characteristic flair and not a little bluster. He decided his role was to Newtonize biology and set about compiling an encyclopedia of natural history. Buffon wrote thirty-five large volumes, called *Histoire Naturelle,* between 1749 and 1788.

These volumes reflected not only Buffon's ideas (which changed in progress, sometimes radically), they also reflected the political and scientific pressures of the times. Initially, flush with Newtonian fervor and inspired by such social writers as Diderot, Buffon in his first volumes denied the

existence of species at all, claiming there were only individuals. In part he was joining the philosophers in defying religion on behalf of scholarship. He was also trying to draw a picture of biology analogous to Newton's view of the physical world, based on mechanistic principles and not what he saw as obsolete abstractions.

He was also reacting to a trend of the day, the classification of species by a few arbitrary characteristics. In the same vein as Aristotle, Buffon was turning back to observational science, gaining scientific understanding of species by cataloguing specifically what he saw. He was particularly critical of his contemporary, the Swedish botanist Carolus Linnaeus. Linnaeus in particular clung to an essentialist approach—a system declaring that elements of nature, including species, had an ideal and constant essence or quality that did not change. He built his taxonomy based on the presence or absence of selected, predetermined characteristics. Buffon called biologists like Linnauus *nomenclateurs,* insinuating they did nothing but give names.

The possibility of species change, or mutability, reared its ugly head about this time. The realization that fossils represented animals that no longer existed challenged the preconceived ideas of the permanent nature of species. Linnaeus considered the possibility that species were not permanent and unchanging, but rejected it. He considered hybridization as a possible source of new species. Though wrong in this instance, Linnaeus did contribute a great deal to the theory of evolution unintentionally, through his classification system. Linnaeus was the first to group organisms

more or less in parallel, rather than along a single, linear scale of progression. He scrapped any concept of the *scala naturae*—Aristotle's organization of nature in a hierarchical, linear fashion, from the least perfect atom to the epitome of perfection: man. Linnaeus's animal kingdom splayed out into a treelike structure, with species families of equal, if differing, complexity at the ends of branches.

Despite his early bluster, Buffon's later volumes brought species back into the picture—with no apologies and no explanations. He simply could not deny the convenience such classifying "nomenclature" provided. At the same time, he was doing seminal work. He began a new style of comparative anatomy that could detect unity of type across many species; any differences indicated a divergence from type. He conceived of what he called a *moule interiour*, or internal mold, which informed each embryo in its development. Again, like Aristotle, he anticipated genetic coding.

With specimens coming in from explorers around the world, he began to notice similarities in different species from similar climates. He proposed that the environment could have an effect on species, with similar environments changing animals in similar ways. That was how he (and others) explained variation in domesticated animals: they changed to adapt to each climate they arrived in.

This explanation set up a problem. By finding that animals are built on a common plan with modifications, suddenly he could not squelch an idea: Species came from other species. He quickly rejected the idea. In some of his writings it appears that the rejection arose from outside—he

was subject to the powerful influence of the leading academy, the Sorbonne, which remained a strongly religious institution. The conflict is apparent in his writing:

> If it were admitted that the ass is of the family of the horse, and different from the horse only because it has varied from the original form, one could equally well say that the ape is of the family of man, that he is a degenerate man, that man and ape have a common origin; that, in fact, all the families, among plants as well as animals have come from a single stock, and that all animals are descended from a single animal, from which has sprung in the course of time, as a result of progress or of degeneration, all the other races of animals . . . but this is by no means a proper representation of nature. We are assured by the authority of revelation that all animals have participated equally in the grace of direct creation.

Much of Buffon's evolution is degeneration, or de-evolution. Since God created a perfect world, if anything changes it is a fall from grace. The ass and the ape were once perfect—they started as horse and man—but these creatures changed, and not for the better. This was nascent evolution, change for the worse, to some degenerate form.

But even when challenged, Buffon could not shake the essentialist view. He was like someone peering over the end of the high diving board, unable to bring himself to jump. Species were species; they might change, but only into varieties after all. In the end he firmly rejected the idea that an animal can change into a completely different species, giv-

ing three reasons. The first took the long view: during recorded history not a single species had changed into a new species. Not only was there no witnessed change, there was no evidence of change, or some "intermediate" entity. Since Buffon believed in plenitude—the notion that everything that could exist does—there should have been a multitude of species representing the gradual change of one form to another, and there wasn't. Not only were there no living intermediaries, there was a paucity of fossil intermediaries as well. Finally, there was evidence that change would be unsuccessful: hybrids, when they did occur, were sterile.

Ironically, as he stifled the idea, he also gave it impetus. Simply by arguing against evolution he gave it a place at the table. Many of the questions he asked were to be answered, finally, only by evolutionary theory.

LAMARCK

The first person to finally take the leap and assert that species can change was a protege of Buffon, Jean Baptiste Pierre Antoine de Monet, Chevalier de Lamarck. He was the eleventh child born to a noble but poor family with a strong military tradition. Lamarck served in the army and fought in the Seven Years War, staying on as a soldier when peace was declared but finally resigning due to injury. He was left to eke out a living on his tiny pension in Paris. He supplemented his income by writing, at first just for dictionaries. He developed an intense interest in botany, finally writing