Introduction

The ancient Greeks were not evolutionists (Essay 1, "Origins and the Greeks"). It was not that they had an a priori prejudice against a gradual developmental origin for organisms (including humans) but that they saw no real evidence for it. More importantly, they could not see how blind law – that is to say, natural law without a guiding intelligence – could lead to the intricate complexity of the world, complexity serving the ends of things, particularly organisms. This need to think in terms of consequences or purposes, what Aristotle called "final causes," was taken to speak definitively against natural origins.

It was not until the seventeenth century – what is known as the Age of the Enlightenment – that we get the beginnings of evolutionary thinking (Essay 2, "Evolution before Darwin"). This could have happened only if there was something, an ideology, sufficiently strong to overcome the worry about ends. Such an ideology did appear, that of progress: the belief that through unaided effort humans could themselves improve society and culture. It was natural for many to move straight from progress in the social world to progress in the biological world, and so we find people arguing for a full-scale climb upward from primitive forms, all the way up to the finest and fullest form of being, *Homo sapiens*: from "monad to man," as the saying went (Fig. Introduction.1). It was not generally an atheistic doctrine, being more one in line with "deism," the belief that God works through unbroken law. But it did increasingly challenge any biblical reading of the past, and it went against evangelical claims about Providence, the belief that we humans unaided can do nothing except for the sacrifice of Jesus on the cross.

Radical claims like these did not go unchallenged. Critics, notably the German philosopher Immanuel Kant and his French champion, the comparative anatomist Georges Cuvier, continued to argue that final causes stand in the way of all such speculations. Moreover, particularly after the French Revolution, many thought the idea of progress to be both false and dangerous. For this reason, evolution was hardly a respectable notion. It had all of the markings of a "pseudoscience," like mesmerism (the belief in bodily magnetism) or phrenology (the belief that bumps on the skull give clues to psychological traits). It existed as an epiphenomenon of a cultural ideology; it was valued because it was value laden through and through. This is not to say

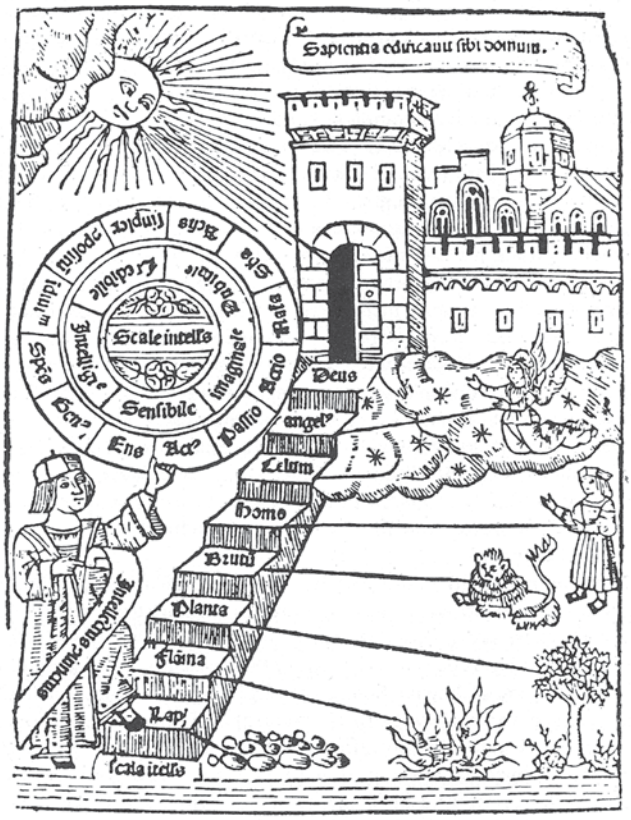


Figure Introduction.1. Particularly popular in medieval times were sketches of the "chain of being," showing the structural order of things, from the simplest of nonliving things (like stones) up to the ultimately important, God. This is from the *Ladder of Ascent and Descent of the Mind* (1305) by the Catalan philosopher Ramon Lull (1232–1315), first printed edition 1512. Although not in itself dynamic, it resonated in the eighteenth century with thoughts of progress and was surely an influencing factor in the thinking of early evolutionists. From M. Ruse, *Monad to Man* (Cambridge, Mass.: Harvard University Press, 1996)

Figure Introduction.2. The anatomist Robert Grant (1793–1874) was an ardent evolutionist and a close acquaintance of Darwin when the latter spent two years in Edinburgh training to be a physician. Darwin was lucky in his teachers and mentors, but clearly he had a nose for picking out those who could instruct and help. Permission: Wellcome

that it was an unpopular idea. As we see in our own day, manifested by such pseudosciences as homeopathy (the belief in the curative power of small doses of the poison that in quantity kills), pseudosciences can be very popular. But enthusiasm lay generally with the public and not with the professional community.

The *Origin of Species* (1859) set out to change all of this. It is important therefore, from the beginning, to get Charles Darwin right. And as a start on this, we must recognize that the autobiography that he penned toward the end of his life, although captivating and very informative, is in many respects highly misleading. Darwin characterizes himself as a charming young man, not terribly directed or motivated, keenest of all on the country sports of shooting and the like, who almost by chance backed into one of the greatest discoveries of all time. This is simply not true. We must keep balance and perspective and not let the English penchant for self-deprecating modesty cloud the story. As an individual, Darwin was genuinely warm and friendly, loyal to family and friends, a good master to his servants, and for all that he was very careful with his money, good at managing it, and generous to those in need. He was loved and with good reason. He was also hard working, even to the point of obsession. He did not have the kind of mind that is good at doing things that impress schoolteachers. He was not that gifted at mathematics, nor was he a brilliant success with languages, dead or living. That put him at a disadvantage, given that back then these were precisely the talents needed for formal academic success. But he was clearly very intelligent; moreover, older people (especially when he went to Cambridge) saw this and almost rushed to be his friends and mentors (see Fig. Introduction.2 and Plate III). Above all, Darwin had an oversized, inventive and discerning eye for a good theory or hypothesis. Added to this is the fact that he was ruthless in his pursuit of an idea and the supporting facts, using others (particularly by courtesy of the penny post introduced in 1840) to gather information for his speculations. He was indeed sick – possibly a psychological sickness but even more possibly purely physical – but he used this sickness to avoid distractions and other commitments. One of his biographers has written of Darwin as having a sliver of ice through his heart, and never were truer words written.[1]

[1] The comment is made by Janet Browne in the introduction to her two-volume biography of Darwin: *Charles Darwin: Voyaging* (1995) and *Charles Darwin: The Power of Place* (2002). In this Introduction, I have relied heavily on this biography for details of Darwin's life and work. I have also used my own earlier writings, including *The Darwinian Revolution: Science Red in Tooth and Claw* (1999a); *Taking*

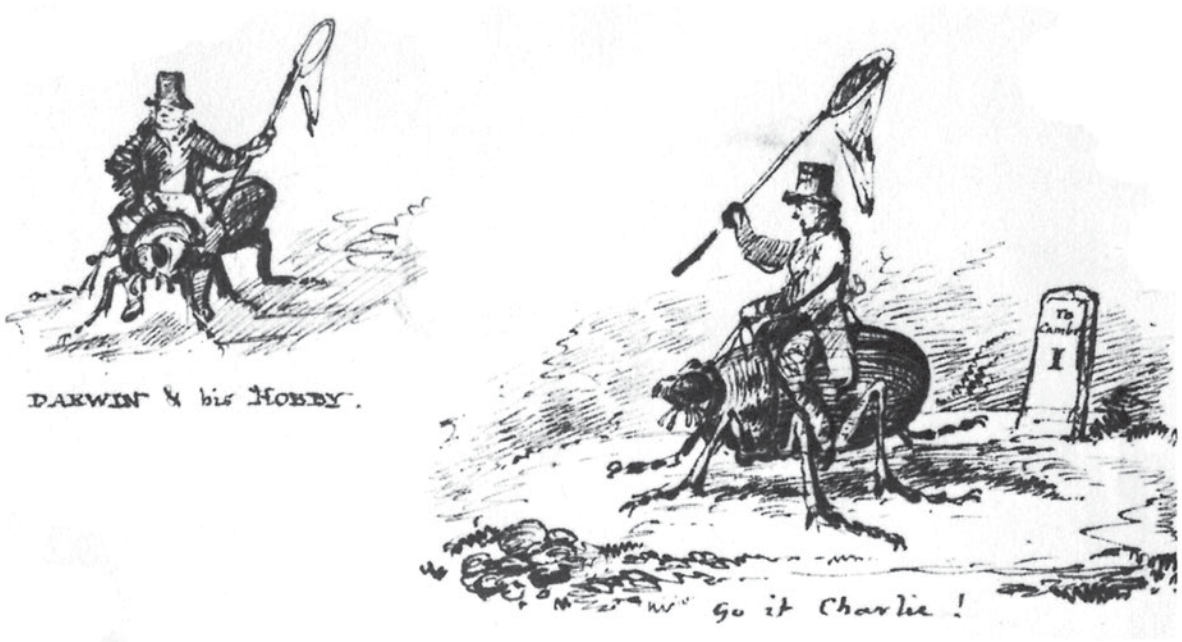


Figure Introduction.3. A cartoon by one of Darwin's fellow Cambridge students (Albert Way) making fun both of Darwin's love of horse riding and of his passion for beetle collecting. Permission: Cambridge University Library

That "Darwin of the *Beagle*" became "Darwin of the *Origin*" was no mere chance. The abilities and drive meshed smoothly with Darwin's background and training. There was a great deal of money in the Darwin-Wedgwood family, and it was kept that way by the frequent intermarriages of which Charles Darwin and his cousin Emma Wedgwood were but one instance. Father Robert was a physician and also a very shrewd businessman, arranging mortgages between those with money to lend (generally industrialists) and those with need of money (often aristocrats with land to provide security). Maternal grandfather Josiah Wedgwood was the founder of the great pottery works, one of the biggest successes in the Industrial Revolution (see Plate IV). Charles inherited the cash, and one immediate payoff was that he never had to work formally to make a living. Not for him the boring jobs of marking papers and sitting on departmental committees. Darwin also inherited much that led to the making of the cash. He was no country bumpkin, nor was he (for all that he had been intended for the church) an ethereal scholar with thoughts fixed only on abstruse points of logic or theology. Science and technology lay behind the revolution, and it was this that grasped Charles Darwin from the beginning. From their earliest days, he and his older brother Erasmus were junior chemists with their own garden-shed laboratory. Then both at Edinburgh and increasingly at Cambridge, Darwin immersed himself in the biological sciences of the day – collecting, reading, listening to others, and attending courses pertinent to these interests (Fig. Introduction.3).

The earth sciences he also pursued, an area of inquiry that was growing and thriving by leaps and bounds. Industry demands fuel, coal now that the trees were vanishing, and materials, iron, copper, and the like. It also has need of transportation, initially waterways, including man-made canals, and then in the nineteenth century the highly successful railway system. All of this demands knowledge of the rocks. No serious businessman wants to invest in a mine that might come up dry after vast expenditures. Equally, no serious businessman wants great effort made to drill tunnels through solid granite when a system of locks going up or around would be much cheaper. Geology holds the key to understanding what exists beyond direct sight, and by the time that Darwin was an undergraduate at Cambridge, the science was a ferment of action and discovery and controversy. That there was a frisson of worry about the time demands of the earth sciences, and the time restrictions of scripture read conservatively, added to its interest – especially given that, almost to a man, the Cambridge professors had to be ordained members of the Church of England.

It was entirely natural that when Darwin set off on the *Beagle* voyage – itself an opportunity to naturalize in new and strange parts of the world – geology should have been something foremost in his mind (Essay 3, "Charles Darwin's Geology: The Root of His Philosophy of the Earth"). It was

Darwin Seriously: A Naturalistic Approach to Philosophy (1986); *Monad to Man: The Concept of Progress in Evolutionary Biology* (1996); *Mystery of Mysteries: Is Evolution a Social Construction?* (1999b); *Can a Darwinian Be a Christian? The Relationship between Science and Religion* (2001); *Darwin and Design: Does Evolution Have a Purpose?* (2003a); *The Evolution-Creation Struggle* (2005); *Darwinism and Its Discontents* (2006); *Charles Darwin* (2008); *Philosophy after Darwin: Classic and Contemporary Readings* (2009c); and *The Philosophy of Human Evolution* (2012).

an exciting time to take up the subject, for opinion (in Britain) was starkly divided, between those (the "catastrophists" represented by one of Darwin's Cambridge mentors, Adam Sedgwick, professor of geology) who thought that every now and then the earth is shaken up by huge earthquakes and the like (after which organisms are created, miraculously, anew) and those (the "uniformitarians" represented by Scottish lawyer-turned-geologist Charles Lyell) who thought that ongoing regular processes, like rain and snow and deposition and erosion, suffice to create the earth's geological history. Lyell had just started publishing his *Principles of Geology* (1830–33), and Darwin devoured it and believed. It was ever the basis for his thinking about earth history and was the foundation of the three books on geology that Darwin published in the ten years after the *Beagle* voyage. No doubt time alone on the ship and the independence forced upon him by the distance from the British scientific community was significant, both in his thinking about geology and also on his mind frame as he now started to work toward the problem of organic origins.

That Darwin, in the mid-1830s – always remember that it was in this decade that Darwin did his creative work, not the future decade of the 1850s when he finally published – was interested in organic origins is no surprise at all. The Cambridge professors loathed and detested evolution, thinking it would subvert both science and religion – they were themselves treading a rather fine, delicate line with their fondness for science and so had to insist to the orthodox that religiously they were purer than pure. Like Mr. Dick in *David Copperfield*, evolution was their King Charles's Head. They could not stay away from the topic. A bright young entrant like Darwin had to sense that there was something of interest here – a sense that would be confirmed when (in 1836) the leading astronomer and philosopher of science John F. W. Herschel wrote to Lyell (in a letter that became public) that origins is the "mystery of mysteries" (Cannon 1961). That it was Charles Darwin of all people who became an evolutionist (the usual word was "transmutation," and "evolution" became generally used for organic origins only in the 1850s and 1860s) is less of a surprise than it might have been. His father's father, Erasmus Darwin – physician, inventor, friend of business – was an ardent evolutionist, and as a youth Charles Darwin had read his grandfather's major work, *Zoonomia*. (Volume 1 was published in 1794 and Volume 2 in 1796. It is in the first volume that the evolutionary speculations occur.) (Fig. Introduction.4). Then, when at Edinburgh, Darwin had been close to one of the very few open evolutionists in Britain at that time, the anatomist Robert Grant. Finally, thanks to Lyell – who gave a detailed exposition in the second volume of his *Principles* – Darwin knew in detail about the evolutionary theory of the Frenchman Jean Baptiste de Lamarck. (Lyell introduced the theory to criticize it. More than one, including Darwin's contemporary and fellow evolutionist Herbert Spencer, read Lyell and was converted to evolution!)

It is always nice and romantic to suppose that new ideas demand a Road to Damascus experience. Probably for Darwin, becoming an evolutionist was a bit more gradual. There is no question but that major influences, along with the geology that was making him think about the operation of laws in nature and implications for such things as time and place, were the fossils that he was collecting on the *Beagle* trip. His finds were almost forcing him to think about origins and changes and causes, and Darwin said as much in his autobiography. We must not exaggerate. Again we see that the young Darwin was, from the first, right in the heart of science in a full-time and professional way. Yet, Darwin was not as skilled and knowledgeable a paleontologist as he was geologist (Essay 4, "Looking Back with 'Great Satisfaction' on Darwin's Vertebrate Paleontology"). It is a field that demanded more biological knowledge than he had in those early years. But equally he was no mere tyro, and certainly, when he returned to England, he was keen to get the best authorities to study his findings – an ambition speaking not just to his own knowledge and abilities but also to his rapidly rising status in the scientific community as one who could expect and get the leaders in the field to work with or for him. Richard Owen, anatomist and paleontologist, was the obvious choice, and (given the quality and freshness of the fossils) it was clearly in the interests of both when Owen did work on Darwin's collection. There is a poignant paradox here, for later it was Owen who became the outstanding opponent of the Darwinians and their theorizing. At first, however, Darwin and Owen were friendly, and although Owen always had yearnings for more metaphysical, German-influenced readings of life's history, one suspects that the two may well have discussed origins and transmutation, not necessarily in an entirely hostile fashion (Rupke 1994). One thing always to be kept in mind is that Owen never had Darwin's privileged

Figure Introduction.4. Erasmus Darwin (1731–1802) was one of the early evolutionists. His *Zoonomia* was widely read, including by his grandson Charles. This is a copy of a painting from 1770 by Joseph Wright of Derby. Permission: Wellcome

start in life or financial independence. He was in the thrall of men who hated evolution. Later, when he himself moved to a public evolutionary stance, one has trouble seeing if his big complaint with the Darwinians is that they are wrong or that they have stolen ideas that he (Owen) had all along.

Along with the fossils, Darwin was certainly set on the path to evolution by the distributions of the organisms – birds and reptiles particularly – that he saw when the *Beagle* in 1835 visited the Galapagos Archipelago in the mid-Pacific. Even more certainly, his thinking solidified early in 1837 when the taxonomist studying his bird collection confirmed that from island to island there are genuinely different species. It was at this point Darwin opened a series of private notebooks (the key species notebooks are B through E, and the key human notebooks are M and N) and jotted down thoughts on evolution. And its causes! Darwin was a graduate of the University of Cambridge, the home two hundred years previously of the great Isaac Newton. Again and again Darwin's mentors stressed that Newton's overriding achievement was to provide causal understanding of the major advances in physics in the Scientific Revolution. Kant, in his *Critique of Judgement* (1790), had denied that there could be a "Newton of the blade of grass." Darwin, determined to show him wrong, set out deliberately to find the cause of evolutionary change, the biological equivalent of Newton's law of gravitational attraction.

The key insight leading to the discovery of the mechanism of natural selection, the systematic differential reproduction of organisms brought on by the limited supplies of food and space, came late in September 1838. It was then that Darwin read the *Essay on a Principle of Population* (1826) by the Reverend Thomas Robert Malthus, who argued the population pressures in humans lead to inevitable struggles for existence. Darwin generalized to all species – actually Malthus mentioned that he got his inspiration from a more general discussion by, of all people, Benjamin Franklin – and then argued that success in the struggle will (on average) be a function of the different variations of the competitors and that this will lead to ongoing change – change moreover of a particular kind, namely in the direction of features or characteristics (like the hand and the eye) that aid their possessors. In other words, this process of natural selection (the term is not used for another two or three years) produces contrivances or adaptations, things that seem as if designed for the ends they serve. That is to say, the process or mechanism gives a natural (in the sense of working according to blind, unguided law) explanation of Aristotelian final causes. There is no need to suppose outside, divine intervention.

Thanks to the notebooks, we can map in some detail the exact route to discovery of the mechanism and the thinking that came thereafter (Essay 5, "The Origins of the *Origin*: Darwin's First Thoughts about the Tree of Life and Natural Selection, 1837–1839"). In a sense, though, we do have somewhat of an embarrassment of riches, especially when you add in our possession of many of the pertinent works that Darwin read (and annotated extensively) at that time. This has led to some controversy about what the later Darwin said, especially in his autobiography, about his discovery and what the jottings seem to reveal. Particularly there are questions about the exact role played in the discovery by the analogy with artificial selection, the ways in which agriculturalists and fanciers choose the specimens they favor and use as breeding stock. Darwin claimed that it was this that led directly to natural selection, but the notebooks (a reading endorsed by the essay given) suggest otherwise. Perhaps the answer is somewhere in the middle. Darwin was certainly conscious of artificial selection and its importance – an industrial revolution demands an agricultural revolution, to feed the workers, and Shrewsbury is in the heart of rural Britain (and the Wedgwoods particularly were interested in breeding) – but whether it played quite the direct role in discovery might be doubted. What is certainly the case – pointed out in no uncertain fashion to Darwin after the *Origin* was published – is that others had also hit on the notion of natural selection. Darwin at this time even read a pamphlet toying with the idea and noted it. He read: "A severe winter, or scarcity of food, by destroying the weak and unhealthy, has all the good effects of the most skilful selection." About this (in the margin), showing that he sees that something pertinent is at work here although he still doesn't quite get the full analogy, Darwin wrote: "In plants man presents mixtures, varies conditions and destroys, the unfavourable kind – could he do this last effectively and keep the same exact conditions for many generations he would make species, which would be infertile with other species." What does seem to be true is that only Darwin was exploring the possibility that selection could lead to full-blown, permanent change. Others deserve a footnote and little more. (The pamphlet is by Sir John Sebright, a noted breeder mentioned in the first chapter of the *Origin*. See Ruse 1975b.)

A mechanism is not a theory. The public Darwin was getting married and starting a family, falling sick, and working and publishing frenetically on geology (Fig. Introduction.5). The private Darwin was thinking furiously and by 1842 felt sufficiently confident to put his ideas on paper in a 35-page preliminary essay (usually known as the "Sketch"), and then some two years later in 1844 he expanded his ideas to a much longer, 230-page essay (usually known as the "Essay.") We know that he did show material to a young botanist, Joseph Hooker (to become one of Darwin's lifelong friends and a source of much material, physical and intellectual), and he left a note to his wife arranging for publication were he to die prematurely – something he thought quite possible. But that was it, and now the flat-out activity rather slowed as Darwin – the professional, public Darwin – turned increasingly away from geology and toward the life sciences. Obviously, they had always been part of his work and life: the fossils, the Galapagos (and many South American) specimens, both animal and plant, and more. Classification, what biologists call "taxonomy," was both a vital tool and (certainly for the private evolutionist) a great font of inspiration. In the century previously, the great Swedish biologist Linnaeus had formulated the basic principles of classification (the "Linnaean system"),

Figure Introduction.5. In 1842 Charles and Emma Darwin moved to Down House, which Darwin's father bought for the young couple for £2,200. They immediately set about making renovations and additions. Darwin lived here for the rest of his life. From H. E. Litchfield, *Emma Darwin, Wife of Charles Darwin: A Century of Family Letters* (Cambridge: privately printed by Cambridge University Press, 1904)

where organisms are assigned hierarchically to nested sets of ever-greater power and generality – from species at the lowest basic level to kingdoms at the highest. For Darwin, especially for a Darwin whose thinking about evolution was ever influenced by those Galapagos organisms hopping from island to island and changing as they went and thus bringing a treelike history to life (very unlike Lamarck's parallel upward progressions), it was almost a truism that his developmental thinking was the explanation of the fanlike, distributive pattern that epitomized Linnaeus's system (Essay 6, "Darwin and Taxonomy").

It is very probable that it was taxonomic thinking that pushed Darwin to what he considered the major conceptual addition to his theory – the "principle of divergence" – that occurred in the years from the "Essay of 1844" to the *Origin*. Why should there be the range of different forms that we find? Is it just accidental, or is there a deeper reason? In the notebooks, things seem to happen almost by default. "The enormous number of animals in the world depends on their varied structure and complexity; hence as the forms became complicated, they opened fresh means of adding to their complexity; but yet there is no necessary tendency in the simple animals to become complicated although all perhaps will have done so from the new relations caused by the advancing complexity of others" (Barrett et al. 1987, 422–3, E, 95). Then, Darwin saw how this all comes about by selection, because it is advantageous to organisms to differ from potential competitors and thus occupy different niches reducing conflict. "The same spot will support more life if occupied by very diverse forms.... Each new variety or species, when formed will generally take the place of and so exterminate its less well-fitted parent. This, I believe, to be the origin of the classification or arrangement of all organic beings at all times. These always *seem* to branch and sub-branch like a tree from a common trunk; the flourishing twigs destroying the less vigorous, – the dead and lost branches rudely representing extinct genera and families" (Darwin 1985–, 6:448–49, letter to Asa Gray, 5 September 1857) (see Fig. Introduction.6).

Publicly taxonomy was now at the fore, as Darwin plunged into what was going to be an eight-year-long study of barnacles, marine invertebrates that had first captured his fancy when on board the *Beagle* (Essay 7, "Darwin and the Barnacles"). This took him right into the next decade and apparently in some quarters made him a bit of a figure of fun, as the archetypal scientist-scholar who devotes his whole life to the study of something that to the layperson seems of unbelievably trivial importance. But why did Darwin, the ambitious Darwin, go off at this tangent? Why barnacles indeed? Although there are comments and moves made that make for fascinating significance, given our knowledge that Darwin was now an

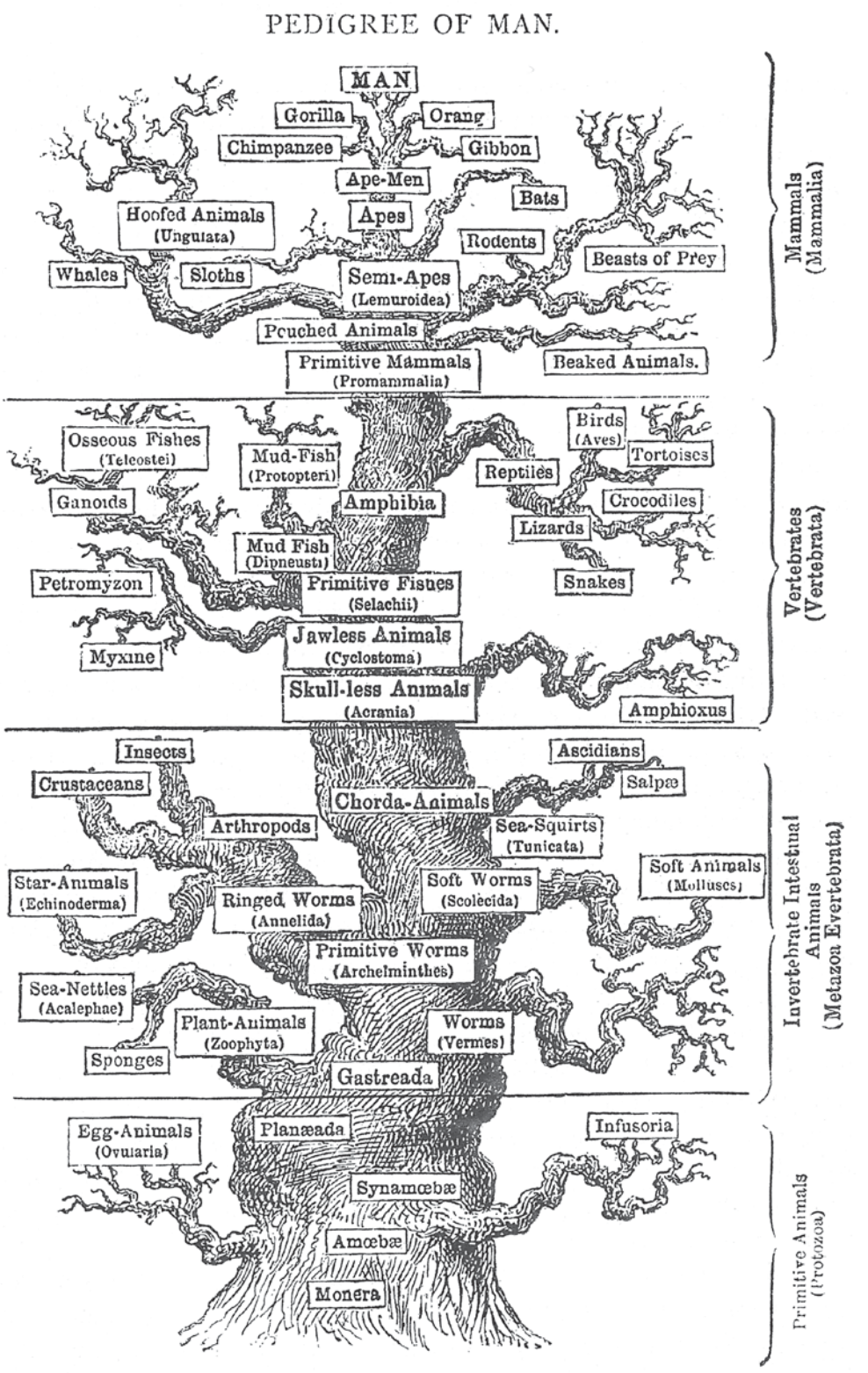


Figure Introduction.6. The tree of life as drawn later in the nineteenth century by Darwin's great German supporter Ernst Haeckel. Note how thoroughly progressionist it is, with simple forms at the bottom (monads) and humans at the top (man). Haeckel used the term "monera," referring to prokaryotes, single-celled organisms without a nucleus. From E. Haeckel, *The Evolution of Man* (New York: Appleton, 1897)

evolutionist, he could not – he certainly did not – come out and profess the convictions that he thought made causal sense of his work. Why did Darwin delay? Why did he not publish the "Essay of 1844"? The note to his wife made it clear that Darwin wanted his thinking made public at some point. Like his sickness, there are as many answers as people who ask the question. Probably various factors were involved. He was sick and felt unable to fight vigorously for his ideas. He never really expected the delay to be so long – twenty-plus years from the Malthus moment to the appearance of the *Origin*. The barnacle studies just stretched and stretched, and the years went by. Most importantly, the public work of the 1830s had paid off. His mentors who had pushed his career were seeing their efforts rewarded. By the mid-1840s Darwin was established as a serious and important scientist. He was cherished by the community, especially by the Cambridge professors and their set who had helped him launch his career. And here's the rub. They went on hating evolution – Cuvier was their scientific hero – and someone going that way would be criticized and ostracized. Added to this, 1844 was the year that the Scottish publisher Robert Chambers published (anonymously) his *Vestiges of the Natural History of Creation*, a pro-evolutionary work that was anathematized by the scientific establishment (as it was equally lauded by the uninformed and ignorant). Darwin, whose great public success was now being reinforced by the general and enthusiastic reception of a book (the *Voyage of the* Beagle) based on his travel years, had no desire to put all in jeopardy.

Finally, however, particularly at the urging of friends who gradually were being let into the secret – after Hooker came Lyell and then in England the young anatomist Thomas Henry Huxley (grandfather of the novelist Aldous Huxley), reinforced in America by the Harvard botanist Asa Gray – Darwin started work on a massive volume, intended to overwhelm with fact and footnote. Huxley always praised Darwin for the delay, arguing that the barnacle work gave him invaluable understanding and experience of the organic world. There may be some truth in this, although one cannot honestly say, despite the principle of divergence, that the differences between the "Essay of 1844" and the *Origin* seem worth quite such a wait and effort. What was important was the growing status and the new network surrounding Darwin, a network that was going to be much more inclined than the older Cambridge set to accept and promote his ideas. But also Darwin did work hard in the 1850s on the empirical evidence for his evolutionary thinking, doing, for instance, careful experiments on the survivability of seeds in salt water, a crucial piece of information for his claims about how organisms could spread around the world, given the barriers of the oceans. (Remember, we are a hundred years too early for plate tectonics.) And it is clear that, whatever may have been the truth back in the late 1830s, by the 1850s the analogy with artificial selection was growing increasingly in his mind. He was delving carefully into the successes of breeders and judging the relevance to his concerns. What does seem probable, and perhaps we should not really be that surprised, is that Darwin was himself fairly selective in this direction, picking out precisely those results that were favorable to his thinking and glossing over those that were not (Essay 8, "The Analogy between Artificial and Natural Selection").

Then came the thunderbolt. In the summer of 1858, Alfred Russel Wallace, a young naturalist and professional collector, formerly in Brazil and now in the Far East, someone with whom Darwin had been corresponding, sent to Darwin (of all people) a short essay with exactly the same ideas that had been fermenting for nigh twenty years (Fig. Introduction.7). Friends, Lyell and Hooker, came to the rescue. Wallace had to be acknowledged but there must be no nonsense about Darwin's priority and so, along with Wallace's essay, pertinent extracts from the "Essay of 1844" and the already-quoted, informative letter sent to Asa Gray (about the principle of divergence) were published in the *Proceedings of the Linnaean Society of London*. Then Darwin sat down to write an overview of his theory. Thus it was that, in the late fall of 1859, the *Origin of Species* arrived on the scene.

Read the essay on the *Origin* in the light of what it is trying to do (Essay 9, "The *Origin of Species*"). It is taking seriously Darwin's own comment that the book contains "one long argument" and is setting out to show the nature of that argument. Because it is exposing the conceptual skeleton of the *Origin* rather than trying to give a full synopsis of the work, one should use the essay as a map to more detailed discussions in later essays, for instance about species or sexual selection or heredity. Note how Darwin runs together the argument for evolution (and the tree of life) and the argument for the mechanism of natural selection. One point of interest will be the extent to which readers separated out these two aims. Darwin never talks explicitly in the *Origin* about those whom he is opposing, those who argue for some kind of non-natural creation of life. Although there were biblical literalists (like today's American creationists) back then, these are not his target. He has in mind real, respectable scientists, like his old friend Adam Sedgwick, professor of geology at Cambridge and, perhaps reaching even further back, the great French anatomist Georges Cuvier. More immediately, the Swiss-born, American-transplant, ichthyologist and geologist (expert on glaciers and their effects) Louis Agassiz would have been in his sights – particularly in light of his neo-Cuvierian *Essay on Classification* published in 1857. Agassiz sent Darwin a copy. In a letter of 13 March 1859, Darwin wrote to Huxley, who admittedly liked to hear these sorts of things, that it was "utterly impracticable rubbish" (Darwin 1985–, 7:262).

Given the central importance of the *Origin*, we must turn and consider in some detail aspects of the argumentation given in the work. The obvious place to start is with the mechanisms of change. Darwin always thought that, although natural selection is by far the most important mechanism of evolutionary change, it is by no means the only one. The major alternative was always a secondary form of selection, so-called sexual selection (Essay 10, "Sexual Selection") This appears even in the "Sketch of 1842," so it is not some late "add on," although it is not until he comes to write his major work on

Figure Introduction.7. Alfred Russel Wallace (1823–1913), the co-discoverer of natural selection, in 1853. He was already an ardent evolutionist. From A. R. Wallace, *My Life* (London: Chapman and Hall, 1905)

our species, *The Descent of Man and Selection in Relation to Sex*, that Darwin gives the mechanism extended treatment. Whereas natural selection involves a struggle against the elements and other organisms for space and food and the like, leading to reproduction, sexual selection occurs only within species and is a function of competition for mates.

Given, whatever the exact relationship, the central importance in Darwin's thinking of the analogy between artificial and natural selection, it is surely plausible to think that Darwin founded his distinction between the two kinds of selection on the distinction one finds in the world of the breeders, between those selecting for profit – fatter pigs, shaggier sheep – and those selection for pleasure – more tuneful birds and fiercer dogs. This supposition gains further strength when one finds that Darwin divided sexual selection into two kinds: selection between males through conflicts for females ("male combat") and selection by females for more desirable males ("female choice") – thus the magnificent antlers of the stag and the gorgeous feathers of the peacock, respectively. These correspond – and Darwin points out the correspondence – to breeders selecting for fighting spirits in their dogs and cocks and breeders selecting for prettier feathers on their budgerigars and like pets.

What is particularly interesting is the fate of sexual selection over the years. Initially, most people inclined to think with Alfred Russel Wallace that truly the distinction is not that significant – certainly not sufficiently significant to overcome worries that the whole process seems fatally anthropomorphic. Why should one suppose that peahens have the same standards of beauty as humans? Starting in the 1960s, however, particularly with the rise of sociobiology (of which more later), sexual selection has come to play a larger and larger role in the thinking of evolutionists. It is thought to be a really significant aspect of the biological world. Darwin, as we shall see, thought it very important in the context of humans, an assumption as controversial then as it is now. Remember that selection (of whatever kind) leads not just to change but to change of a particular kind, namely adaptive change. Put this in the context of the sexual selection of human beings, and you are plunged right into discussions about male-female differences and whether they are natural (meaning biological) or cultural (meaning more environmental). But whether sexual selection is accepted or whether it is rejected, it is realized that it cannot be ignored, and for this reason, if for no other, demands careful and explicit scrutiny.

A lot of not-always-tremendously-helpful things are said about the *Origin*, at the head of which list is the claim that the work is mislabeled because it is not about the origin of species at all. It is true that the work is basically on evolution and its major mechanism of natural selection, but there is much on species, their nature and their causes. What else is the principle of divergence but an attempt to show why the world comes cut up at the joints, to use a phrase of Plato? It is obvious that Darwin is going to have some tricky discussion about the nature of species. On the one hand, he wants them to be things that are real enough to merit discussion about natures and causes. On the other hand, he wants them not to be so fixed that they cannot change and evolve. Some or all are in constant motion and change. So there is a paradox of a kind here, but it is not mysterious and not in Darwin's opinion beyond understanding. What is surely true is that often discussion of the topic has been clouded by later proposals about species, not to mention enthusiasts' eagerness to claim Darwin as one of their precursors – or conversely, to promote their own importance by contrasting their successes with Darwin's supposed failures (Essay 11, "Darwin and Species").

This much we can say, that Darwin surely thought that species are real in some sense. There may be many borderline cases – one hopes that there are borderline cases! – but species are real. We can also say that Darwin was keenly aware that reproductive isolation is an important part of the story. Cabbages and humans don't share offspring. However, there is little doubt that Darwin was unwilling (unlike many taxonomists in the twentieth century) to put the entire burden on reproductive isolation. He thought it broke down too often to be reliable. Also, he was worried about the role of selection in reproductive isolation. Or, rather, he was not so worried about its role – he didn't think it was there when it came to producing hybrid sterility – but about the consequences for such issues as the reality of species. As we shall see shortly, factors like these take us to the heart of some of the most difficult and contentious issues surrounding natural selection, so there is hardly any surprise that Darwin's thinking on the species issue generally causes differences of opinion. These started as soon as he published and continue to this day. If ever proof was needed that scientific understanding is more than simply determining matters of brute fact, demanding also philosophical and like (including historical) judgments, the species problem provides it.

The most (deservedly) influential work in the twentieth century about scientific change was Thomas Kuhn's *The Structure of Scientific Revolutions*. Well known is Kuhn's notion of a "paradigm," a kind of way of thinking within which scientists do all of their work ("normal science") almost all of the time. Equally well known is the claim that sometimes paradigms break down and there is a switch to a new one, a switch not entirely rational and much akin to a political or religious conversion, after which science resumes its normal state and work proceeds now in the new paradigm. I don't think anyone would deny that something of this nature went on in the Darwinian Revolution. Darwin's teachers and elders, men like Adam Sedgwick and William Whewell, really did see the world in one way, and Darwin's followers like Joseph Hooker and Thomas Henry Huxley really did see the world in another way. It is comforting to say that one side is wrong and the other side is right, and in a way this is certainly true. But it is not quite all of the truth. Sedgwick and Whewell were as bright and informed as Hooker and Huxley. A kind of conversion experience had occurred.

Having said this, it is clear that Kuhn often tells only part of the story, and this is certainly true in the Darwinian case. The impression certainly is that everything happens once and

for all in one decisive stroke. Now you believe in miraculous creation of organisms. Now you believe that organisms are made by natural selection. In fact, this was not – or at least only rarely – true. As we shall see, although generally speaking evolution was a terrific success – by about 1870 it was becoming the standard view in much of the Western world (the American South, of course, excepted) – natural selection was far less successful. It was not until the past century was into its fourth and fifth decades that selection really started to catch fire. So certainly, whatever it was in the way of a paradigm that Darwin provided, it was not something within which the scientific community from thenceforth happily worked.

There were various reasons for the caution about natural selection, including a couple of scientific reasons that were very important. The first was the problem of heredity (Essay 12, "Darwin and Heredity"). Natural selection demands a constant supply of new variations, but then it is vital that these variations stay around and be passed on. There is little point in being a winner in the struggle for existence if your offspring don't have the very features that made you a success. Darwin spent a lot of time struggling with these issues, even inventing a hypothesis – "pangenesis" – to explain matters. Basically his problem was that although he could see that sometimes features do persist from generation to generation, he could not get away from the belief that often features, however admirable, get blended away in breeding – half in the next generation, then a quarter, and so forth. Before long even the best new variation is lost. And his critics seized on this point and used it as a refutation of the effectiveness of natural selection. The problem was not to be solved until the beginning of the new century. In Darwin's defense, let us say that no one else had much idea about what to do, except to criticize. It is true, of course, that across Europe in his monastery garden in Brno, in the Austro-Hungarian Empire, the monk Gregor Mendel was doing work on pea plants that was to be recognized as the foundational inquiry that led to modern theories of heredity, genetics. But before one immediately concludes that it was a tragedy that Darwin and Mendel never worked together or symbiotically, one must recognize that Mendel was working on technical issues of plant breeding and not setting out to fill a gap opened by the *Origin*. Indeed, although Darwin never read Mendel – he could have done, had he been searching in that direction – Mendel read the *Origin*. But (as we can tell from his marginalia), Mendel did not see that he had the solution to the problem. To be honest, it does not seem that Mendel was either bowled over by Darwin or horrified. He was interested in evolution, but it was not really his problem (Fairbanks and Rytting 2001).

The other big scientific problem that Darwin faced was that of time (Essay 13, "Darwin and Time"). Today we know that, although evolution can be slow, it can and does at times go really quite quickly. Natural selection can make for major changes in short periods if need be. In any case, there is plenty of time for evolution, fast or slow – life on earth started nearly four billion years ago. Darwin always thought that selection would be slow, probably too slow for us to record in our lifetimes (a point of significance to be noted shortly), and he had little idea about the available time. He made some calculations, suggesting that the earth is pretty old, but these were derided by the geologists. Then, as the physicists started to get involved in the problem, increasingly it seemed as if the time available for change was very short and restricted. People did not take this as a blow against evolution, but they thought it told against natural selection. Darwin – who almost amusingly was made very much aware of the problem by his son George, a brilliant mathematician who was working with William Thomson (later Lord Kelvin), the chief critic of a long-age earth – did what he could to cover up or avoid the problem, but basically he had to hope that some solution would eventually appear. It did, of course, when the physicists discovered that radioactive decay generates heat and that, with this factor acknowledged, the earth is plenty old enough for selection, at whatever intensity or speed.

One should keep a sense of balance. Natural selection had its many critics. Yet not all was gloom and doom. Darwin himself was convinced that his mechanism mattered. Botany was a long-established passion, going back to Darwin's attending lectures on the subject when an undergraduate at Cambridge (Essay 14, "Darwin's Evolutionary Botany"). But it was after the *Origin* that the interest and work really increased – a good strategy for a sick man, living in the countryside, with money to indulge his interests with greenhouses and gardeners, and with well-connected botanical chums like Hooker ever ready to send him specimens. There emerged a string of papers and books on domesticated varieties, on climbing plants, on insectivorous plants, on methods of fertilization, and much more. Making a value judgment, the really delightful studies came early in the 1860s on orchids. It seems clear not only that Darwin was looking for something that would be a relief and welcome change from the strain of writing the *Origin* but that he was also after something where he could show that natural selection really does produce adaptations and that this is something of which the whole biological world should take note. As an example of the new world into which Darwin led us, even to this day there is no better introduction than *On the Various Contrivances by Which British and Foreign Orchids Are Fertilised by Insects, and on the Good Effects of Intercrossing*. It is fascinating, for all that it is in competition for the world's most technical and boring title.

Even better than the flowers were the insects. If you think about it, it is obvious that if natural selection is going to find any supporters, it will be with insect biologists. They are dealing with fast-breeding organisms, where strong and effective adaptations – for survival, for food, for reproduction, above all for avoiding predators – are going to be absolutely crucial. That predator avoidance is fundamental was well known before the *Origin*, and as soon as natural selection appeared on the scene, it was being used to explain the techniques of such avoidance, the adaptive strategies taken by insects (Essay 15, "Mimicry and Camouflage"). Much successful effort was put into explaining mimicry as a product of a differential reproduction brought on by the struggle for existence. It is nice

to be able to report that Darwin was very appreciative of this work, even to the extent of finding the major player (Henry Walter Bates) a good job (albeit one that rather took him away from his science). What is rather puzzling is that, although the work found its way into later editions of the *Origin*, Darwin never moved it quite as much up front and center as one might have expected. This possibly could be related to the point just noted: Darwin always had doubts about testing natural selection, simply because of (what he thought was) its slow-acting nature and ability. Today, as we shall learn later, evolutionists do not have such doubts and qualms, and mimicry and camouflage continue to have an important role in evolutionary studies.

One thing that must be recognized is that, although the problem of final cause was certainly shifted and changed by the *Origin*, it was not obviously expelled or anathematized (Essay 16, "Chance and Design; Essay 17, Darwin and Teleology"). The Greeks had not been able to see how blind, unguided law was able to create objects, organisms particularly, that seem made with ends in view – entities that seem as if designed. The eye exists for the purpose or end of seeing, even if now it is not actually seeing (or if, for some reason, it never did see). Natural selection is supposed to speak to this, because as we know it does not just bring about change but change after a certain fashion, namely in the direction of adaptation or contrivance (to use the term in Darwin's title) or design-like features. The point has been made already that Darwin's creative work occurred in the 1830s, not 1850s. In the former period, the thinking of someone like Cuvier held sway, namely the thinking of someone who agreed with the Greeks that final cause is all important. By the 1850s, anatomists like Owen and Huxley – in their day-to-day science they were often a lot closer to each other than either liked to admit – were focusing much more on homologies, similarities of structure, than on adaptation. After all, the specimens with which they dealt were usually dead, often very long dead, and so the needs of organisms were not pressing issues, and adaptation was downplayed. Structure persists, and finding links and connections was taken to be the major task at hand.

So Darwin was solving a problem that, by the time he published, many did not find pressing. This is obviously another (major) reason why natural selection was not hugely successful. It was solving a problem that many did not really see as needing solving. Although conversely there were others, like the botanist Asa Gray, who not only saw the need but were not sure that selection was quite up to the job. They wanted more, including special shoves in the right direction, from God through the medium of new variations. Darwin had some trouble expressing himself on this issue – in part because of his own evolving thinking about the deity – but he was very clear that, whether or not God exists, he must be kept out of science. In this wise, Darwin certainly looked toward the secular science of today rather than backward to the god-impregnated inquiries that were, for instance, the staple of his Cambridge mentors and teachers.

And finally, before moving on from looking at the *Origin* directly, mention must be made of the fact that the book itself was an exercise in evolution (Essay 18: " The Evolution of the *Origin* (1859–1872)"). It went through six editions and involved a huge amount of rewriting and often expansion. It used to be that it was always the sixth and final edition that was reprinted. But scholarly opinion today has swung against this and toward the first edition. For a start, the first edition is certainly easier to read, not having been torn apart and reworked so often that it really does resemble something produced by a committee. For a second, there are issues about whether the corrections introduced by Darwin were always for the best. At the linguistic level, Darwin added Herbert Spencer's alternative term for natural selection, the "survival of the fittest." This has led to endless mistaken claims that natural selection now reduces to the uninformative "those that survive are those that survive." At the conceptual level, Darwin messed endlessly with his discussion of heredity, digging ever deeper pits into which to jump. He tried to speed things up to account for the (mistaken) constraints on time. And more.

This said, there are some very interesting changes, perhaps most of all on the topic of progress. Before Darwin, it was progress that fueled evolutionary speculation and acceptance. Evolution was a pseudoscience. Darwin changed that. Evolution (at the least) was now accepted fact; it was common sense. But what about progress and what about the status of evolutionary thinking? In a passage quoted earlier, Darwin made it clear that he did not accept an inevitable upward charge, a kind of teleological force producing humankind. On the other hand, he was a good Victorian, living off the wealth of the Industrial Revolution, so he was not about to turn his back on progress in society or progress in biology. The latter, however, had to be done in terms of selection – no god, no special forces, no nothing like that. But Darwin certainly implied that, by defining progress in terms of division of labor (a kind of functioning complexity) and then invoking what today's biologists call arms races – evolving lines compete and the adaptations get better – we get not only comparative improvement but also a kind of absolute improvement leading to human brains and thinking.

> If we look at the differentiation and specialisation of the several organs of each being when adult (and this will include the advancement of the brain for intellectual purposes) as the best standard of highness of organisation, natural selection clearly leads towards highness; for all physiologists admit that the specialisation of organs, inasmuch as they perform in this state their functions better, is an advantage to each being; and hence the accumulation of variations tending towards specialisation is within the scope of natural selection. (Darwin 1861, 134)

What is interesting is that this passage does not come in the first edition of the *Origin* but has to wait until the third, admittedly appearing only two years later in 1861. Perhaps this tells us something about both the status Darwin hoped to achieve for his theory and the success he had in his efforts. Darwin

wanted to hit the jackpot; he wanted to elevate the status of evolutionary thought from that of a pseudoscience to what we might call a "professional science," that is, something done by full-time researchers in the laboratory or the university or the like – the status that something like physics, and physiology for that matter, now held. For this reason, although even in the first edition of the *Origin* there are passages that betray a progressivist commitment, generally Darwin tried to stay away from such frank ideology. This is not the stuff of professional science. The lack of enthusiasm for natural selection suggests that Darwin was not fully successful in his aim, and the (rapid) consequent bringing in of explicit discussion of progress – the very thing that made for pseudoscience status – suggests that Darwin realized that he had not achieved all he wanted. The fact is that when the *Origin* was published, most people immediately read it as a peon to progress, often mixing it up with the thinking of Spencer, a fanatical progressionist. And one suspects that Darwin, who was himself in favor of progress of all kinds, simply decided to go with the flow and get what he could. What this all means for the actual status of evolution after the *Origin* is something to which we will have to return.

Given that Darwin was a biological progressionist, one infers that he thought our species, *Homo sapiens*, is relatively important. This is indeed true, although from the first he was convinced that we are completely and utterly part of the animal world. No special divine interventions are needed to explain our origins. Most probably the *Beagle* voyage, especially the encounter with the Tierra del Fuegians, the denizens of the land at the foot of South America, convinced the ship's naturalist of this (Fig. Introduction.8). Even the highest form of human (aka the English) is but a step from the savage state, a point made heavily by the rapid reversion to the norm of three natives who had been brought to England on a previous voyage, who had been turned into presentable Europeans, and who were now being returned to lift up the general moral and cultural level of their fellows at the foot of the continent. Darwin never had doubts about human evolutionary origins, and indeed the first explicit discussion of natural selection that we find in the notebooks (about a month after Darwin read Malthus) is applying the mechanism not only to humankind but to our brains and intellectual abilities. "An habitual action must some way affect the brain in a manner which can be transmitted.–this is analogous to a blacksmith having children with strong arms.– The other principle of those children. which *chance?* produced with strong arms, outliving the weaker one, may be applicable to the formation of instincts, independently of habits.–" (Barrett et al. 1987, N, 42).

In the *Origin*, Darwin did not want to conceal his views about humans, but neither did he want the discussion swamped before he could get the main points of the theory out on the table. He therefore contented himself with the greatest understatement of the nineteenth century: "Light will be thrown on the origin of man and his history" (Darwin 1859, 488). But no one was deceived. As soon as Darwin published, the world started talking about the "monkey theory,"

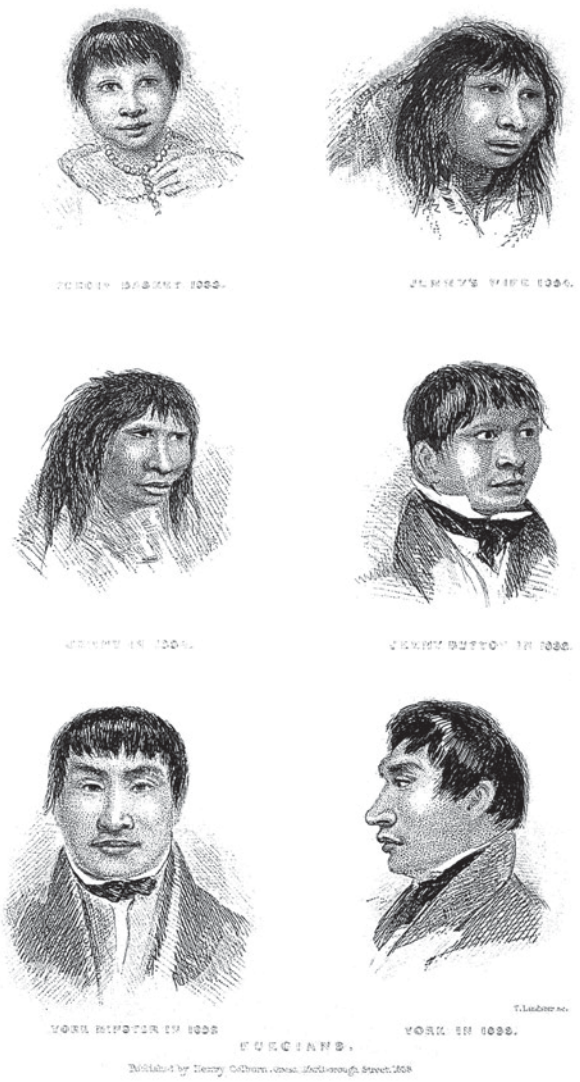


Figure Introduction.8. Darwin's encounters with the Tierra del Fuegians in their natural habitat really disturbed the young naturalist. From then on, he had no doubt but that even the most civilized of human being is but a short step from the "savage." Permission: Wellcome

and no one had any doubt that the real battle was going to be over our species. Thus, for instance, Huxley and Owen battled over the human brain, with the former making us part of the primate world and the latter making us distinct from all other living forms. Book after book started to pour forth on the origins of *Homo sapiens*. And the popular press picked up the idea and ran with it. The comic magazine *Punch* made much of the controversy. For everyone, even if there had been doubt about whether the English are right at the top, there was absolutely none that the Irish are right at the bottom (Fig. Introduction.9). Labored jokes about the doings of Mr. G. O'Rilla became commonplace. For this reason, if for no other, given his extreme reluctance to break from his isolation, one suspects that (whatever his personal views), all other things being equal, Darwin would have stayed out of the debate about our species.

Figure Introduction.9. Darwinism became part of general Victorian culture and was used to support various beliefs and prejudices, as in this cartoon (from the magazine *Puck* in 1882) showing the Irishman as being apelike. It is titled "The King of A-Shantee," thus also bringing in prejudice against Africans, with the pun on shanty (meaning run-down house) and Ashanti (an African tribe from Ghana).

All other things were not equal. Alfred Russel Wallace is interesting not only in his own right but as a contrast with Charles Darwin (Essay 19, "Alfred Russel Wallace"). Coming from a segment of society much down the scale from Darwin – the lowest level of the middle classes rather than the highest – Wallace was an autodidact with respect to everything including science, teaching himself the basics both through reading and then through observations of nature as he pursued a profession as a collector, visiting first South America and then the Malay Peninsula as he sought exotic specimens. Whereas Darwin was completely and utterly the professional scientist, always working within the system, Wallace was anything but. To speak of him as a "maverick" is a kind way of avoiding words like "flake." He was brilliant and capable of serious and lasting science. He discovered natural selection independently, and his success, let there be no mistake, was the end point of a long effort to pin down the origins of organisms. He thought creatively about such issues as mimicry and also about biogeography. But he was always (quite fearlessly for consequences) adopting strange and unconventional ideas, starting with evolution itself in the mid-1840s when, thanks to *Vestiges* (which turned Wallace into an evolutionist), evolution was the epitome of a pseudoscience. This was followed later by enthusiasms for socialism, vegetarianism, land reformism, and more – including, to the horrified amazement of the scientific establishment, total and utter commitment to spiritualism (a cozy belief that he shared, incidentally, with Chambers). In the mid-1860s, Wallace became convinced that only by invoking unseen spirit forces could one explain the evolution of humans. We have features like our hairlessness and our large brains that simply cannot have been produced by natural selection. There must have been SOMETHING MORE.

Darwin was appalled. This would destroy their joint child. He was spurred to action, and in 1871 he produced his own work on our species, *The Descent of Man and Selection in Relation to Sex* (Essay 20, "Darwin and Humans"). It is, as any reader can vouch, a very oddly balanced work, for a full three-fifths is on the secondary mechanism of sexual selection. Interesting as this is, one feels that it is somewhat out of place in a book ostensibly on human evolution. Until, that is, one realizes that it is all a response to Wallace. Darwin agreed with Wallace that there are aspects of human nature that it is hard to put down causally to natural selection. Why, for instance, do we find the racial variations that we do? And it was here that sexual selection came to the rescue, for Darwin argued that human evolution is deeply indebted to the ways in which humans (males in great extent) are into the business of choosing mates. He included some prime nineteenth-century anthropological speculations. Quoting the explorer Richard Burton on the large bottoms of some African women, we learn that the men "are said to choose their wives by ranging them in a line, and by picking her out who projects farthest *a tergo,* Nothing can be more hateful to a negro than the opposite form" (Darwin 1871a, 2:346) (Plate V). Recent scholarship has made it very clear that Darwin's thinking about humankind was greatly influenced by his family's detestation of slavery, a major issue in British circles in the early part of the nineteenth century. The truth of this, however, should not conceal that Darwin is a child of his time in other respects also, and that even a liberal Victorian would have views of non-Europeans that make us blanch today. The question is how easy it is, or if it is truly possible, when faced with someone like Darwin from a culture so different from ours, to distinguish between the objective scientific findings and the subjective cultural prejudices.

Whatever the merits of Darwin's argumentation about humans, no one can deny that one thing that he did was open up and inspire much more fully a host of related inquiries about human nature – inquiries that were gathering steam as researchers spread out across the globe (in the wake of the empire building of the Victorians) gathering comparative information on very diverse societies. One area that received attention from Darwin himself and that was of keen interest to many more generally was that of language or linguistics (Essay 21, "Darwin and Language"). In a way, it was almost natural that this topic would be of such interest, particularly given the exposure not only to the range of European languages, but also now to the languages of the East. Whatever the moral merits, governing a subcontinent demanded knowledge of the local tongues – an urge that was being felt strongly by the time

the *Descent* was published, because after the Indian Mutiny (of 1857) the crown took over the governing of the country and started to introduce significantly more professionalism in its running. With this increasing exposure to and understanding of language, although not all were immediately enthusiastic, the time was ripe for an evolutionary analysis, trying (as did Darwin in the *Descent*) to show how it might have come into being and how it might have diverged as societies themselves diverged and moved apart. One point of some interest was how one was to explain causally the spread and divergence of languages. Although, as we shall see later, the analogical invocation of the pressure of the struggle with consequent selection is still somewhat controversial, it was something that appealed to Darwin. "As [Oxford Sanskritist] Max Müller has well remarked: – 'A struggle for life is constantly going on amongst the words and grammatical forms in each language. The better, the shorter, the easier forms are constantly gaining the upper hand, and they owe their success to their own inherent virtue'" (Darwin 1871a, 1:60).

Morality also was something of great interest to Darwin, and there is an extensive discussion of the topic in the *Descent of Man* (Essay 22, "Darwin and Ethics"). Darwin thought carefully about how a mechanism with a struggle for existence at its heart could nevertheless produce beings that are genuinely thoughtful and caring for the well-being of others. It is worth pointing out that there is a major difference between Darwin's treatment of the topic and that of others, most particularly that of his contemporary Herbert Spencer (Essay 23, "Social Darwinism"). For the latter, the aim is essentially one of justification: how do we ground moral claims, what makes them right? With what many Victorians perceived as the fall of religion and its failure to provide a firm backing for the morality needed in an industrial society, evolution for Spencer and his many followers seemed like an attractive modern, secular alternative. And it was here that progress came into play, for it was taken to be the ground of right action. In his 1857 essay, "Progress: Its Law and Cause," Spencer staked his banner even before the *Origin*: "Now, we propose in the first place to show, that this law of organic progress is the law of all progress. Whether it be in the development of the Earth, in the development of Life upon its surface, in the development of Society, of Government, of Manufactures, of Commerce, of Language, Literature, Science, Art, this same evolution of the simple into the complex, through successive differentiations, holds throughout" (Spencer 1857, 244). In Spencer's mind, and those of his many followers, doing good means cherishing and aiding progress. Doing bad means ignoring or hurting progress. For all that in the *Descent* and elsewhere his own personal moral convictions often shone through, Darwin was not really into this sort of enterprise. He was more working in the role of a scientist, trying to show the nature of morality and how it is that it has come about and stays in action. Having said this, philosophically one does see Darwin in the tradition of British empiricism, where morality is ultimately a matter of emotion rather than correspondence to some disinterested objective truth. What else can one say about a person who actually contemplates a situation where, were selection to dictate such an action, the highest moral imperative might be to kill one's brothers?

Note incidentally just how misleading it is to lump together all who took seriously the possible worth of biology for ethical behavior. Herbert Spencer was drawn to laissez-faire capitalism, thinking that it was this that leads to an upwardly rising society; although, after visiting America, he inclined to think that all work and no play certainly does make Jack a rather dull boy. Wallace, with his inclinations to socialism, was more into group explanations and the eventual emergence of good feelings toward all. Somewhat paradoxically, given that he was not at all keen on the idea of sexual selection through female choice in the animal world, he rather thought it might be effective in the human world. Society will be upgraded by young women choosing only the best young men as breeding partners. If he was basing this on personal family observation, one can only conclude that the Wallace children must have been as odd as their father. Huxley, although he was dedicated to progress, to improving the lot of his fellow countrymen, almost from the first had grave doubts about sunny optimistic readings of the evolutionary process. He saw the necessity of a lot more struggle against our animal nature than did someone like Spencer. He referred to himself as a "Calvinist" and when one thinks of his frequently gloomy take on humankind, there is much truth in this. No doubt the fact that he himself was subject to crushing depressions fed into this philosophy.

In this context, there has been much debate about the category in which we should place Darwin himself. Was Darwin a Social Darwinian? The answer is mixed. If you are thinking about a harsh master, of the kind often found in the novels of Charles Dickens, then clearly not. But he was very much a child of his time, particularly of his manufacturing, capitalist class. As he made clear in a letter to a correspondent (Swiss law professor Heinrich Fick, on July 26, 1872), he had little or no time for working men's unions, writing that "the rule insisted on by all our Trades-Unions, that all workmen, – the good and bad, the strong and weak, – shd all work for the same number of hours and receive the same wages. The unions are also opposed to piece-work, – in short to all competition. I fear that Cooperative Societies, which many look at as the main hope for the future, likewise exclude competition. This seems to me a great evil for the future progress of mankind." More through hope than conviction, he added: "Nevertheless under any system, temperate and frugal workmen will have an advantage and leave more offspring than the drunken and reckless. – " (DCP, 8427f).

One issue that lay behind natural selection from its first introduction and that becomes a matter of real, pressing importance by the time of the discussion of morality in the *Descent* is that of the level at which natural selection might be expected to operate (Essay 24, "Darwin and the Levels of Selection"). When Darwin introduces the struggle in the *Origin*, he makes it clear that it is every individual for itself – that "as more individuals are produced than can possibly survive, there must in every case be a struggle for existence,

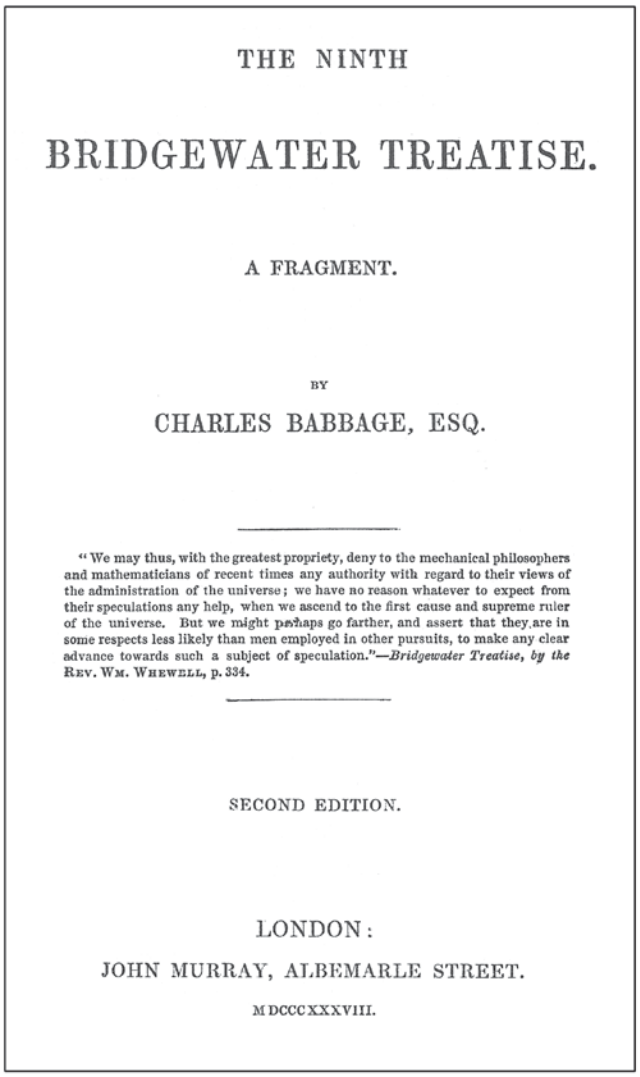
either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life" (Darwin 1859, 63). But how then can he explain what is now known as "altruism," where one organism gives to another even at the cost of its own reproduction? The social insects were particularly troublesome, because here you find sterile female workers, who give their all to the nest and apparently do nothing for themselves. Darwin did not have the insights of modern genetics, so any solution he offered was bound to be at best partial. But he did sense that relatedness was the key – somehow, even the greatest altruist is helping relatives and not mere strangers. Today, we use the term "group selection" (as opposed to "individual selection") to denote selection producing (at cost to oneself) features that help others. The question is whether the term should be restricted to those others who are nonrelatives or whether it can be extended to all, related or not. Most biologists today would restrict the term, in which case Darwin is not a group selectionist in the *Origin*. Call him, if you will, a "family selectionist" or some such thing; but recognize that individual selectionists would claim that as one of their own. Certainly this seems in line with the years after the *Origin*, when Darwin and Wallace thrashed out the topic with Wallace (an ardent socialist) always inclining toward group selection (and incidentally iffy about aspects of sexual selection, something firmly individualist). The *Descent* was and is a matter of great controversy, with even those inclined not to think there is group selection earlier agreeing that, when it comes to morality, Darwin finally softens and allows group selection (involving nonrelatives). The weasel word in the discussion is "tribe." If this includes nonrelatives, then Darwin is truly a group selectionist (as the essay on language in this encyclopedia claims him to be). But don't overlook the letter Darwin wrote later to a son, where explicitly he likened a tribe to a hive of bees or a nest of ants. This suggests that he was consistent to the end, never wanting to go beyond family selection, something more on the individual-selection end of the scale than the group-selection one.

And so we come to the topic of ongoing fascination: Charles Darwin and religion (Essay 25, "Darwin and Religion"). There has been much disagreement, but usually this reflects the diverse interests of those asking and discussing, for actually there is a lot of pertinent material, and the main points are pretty clear. Darwin's religious life fell into three phases. The first from childhood up to the time on the *Beagle* was when he was a fairly conventional and committed Christian, secure in the beliefs of the Church of England. Then his formal commitment started to fade (quite quickly), and he became what should be described as a "deist," that is, one who believes in a kind of god who is an unmoved mover. This is a god who set everything in motion and now sits back and lets events unfold, as by clockwork. Fairly obviously, evolution is a testament to the power and magnificence of such a god, for no miracles are needed. It was a powerful and natural vision for a child of the Industrial Revolution – a god who works through machine rather than by hand – and it was backed by the arguments of the protocomputer inventor Charles Babbage, a good friend of Darwin's brother Erasmus, who (in his *Ninth Bridgewater Treatise*) showed how miraculous-type exceptions could be programmed in and occur occasionally entirely by virtue of unbroken law (Fig. Introduction.10). The deism lasted right through the writing of the *Origin*, but then this too started to fade and vanish. Darwin never became an atheist, in the sense of total denial of any kind of god, but he was certainly happy to adopt Huxley's new term of "agnostic." It should be added that, like many nonbelieving Victorians, it was not science that turned Darwin from religious conviction but theology – he could not stomach the eternal damnation of nonbelievers and that sort of thing.

As the essay on religion points out truly, what does come across very strongly when studying Darwin and his life is just how nonemotionally involved he was in religion. He had to think about it quite a bit, both as he was growing up and then when he had his theory, one that so clearly did impinge on religious belief – but he never seems to agonize over it, nor is it an obsession. In this he contrasts strongly not only with his Cambridge teachers, clergymen down the line, but also with his friends. Lyell, who worshiped with the Unitarians for a while, obsessed about the status of humankind. Huxley, who was the arch nonbeliever, nevertheless kept picking away at religion like a scab that never heals. Darwin just assumes that humans are part of the selective landscape without a hint of a worry. That's just not his fight. And the same is true of the discussion of religion in the *Descent*. Although he covers himself by saying that discussion of origins does not tell you about truth value, his neo-Humean theorizing about the rise of religion – likening it to the antics of his dog on a windy day when the parasol flaps around – suggests that he thinks it all pretty much superstition. Compared to morality, the treatment of religion is brief. For Darwin, that is as it should be. Morality matters. Religion does not.

Having said this, one should never underestimate the extent to which the religion of his early years left its mark on Darwin's thinking. Most obviously there is the obsession with adaptation, a direct result of the heavy influence of British natural theology with its great regard for the argument from design. To this day, ultra-adaptationists tend to have grown up immersed in this theology, and critics tend to be those for whom the tradition is quite alien. Then there is the tree of life, something lifted (metaphorically) right out of Genesis. Even that wonderful concluding passage of the *Origin* may well be a modification of a natural theological peon of praise to the Creator. Compare the earliest version that we have (from the "Sketch of 1842") with a passage, written by the Scottish physicist David Brewster, something read by Darwin just before he discovered natural selection. First Brewster:

> In considering our own globe as having its origin in a gaseous zone, thrown off by the rapidity of the solar rotation, and as consolidated by cooling from the chaos of its



THE NINTH

BRIDGEWATER TREATISE.

A FRAGMENT.

BY

CHARLES BABBAGE, ESQ.

"We may thus, with the greatest propriety, deny to the mechanical philosophers and mathematicians of recent times any authority with regard to their views of the administration of the universe; we have no reason whatever to expect from their speculations any help, when we ascend to the first cause and supreme ruler of the universe. But we might perhaps go farther, and assert that they are in some respects less likely than men employed in other pursuits, to make any clear advance towards such a subject of speculation."—*Bridgewater Treatise, by the* Rev. Wm. Whewell, p. 334.

SECOND EDITION.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

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Figure Introduction.10. Charles Babbage, the inventor of a protocomputer, was a good friend of Charles Darwin's brother Erasmus. This book was an unofficial addition to a series of works on natural theology sponsored by the Earl of Bridgewater. Babbage showed how he could set his computing machine to produce the natural numbers in regular order up to a million and one, and then without interference but according to initial conditions the succession would change to produce all sorts of unexpected numbers (in Babbage's example, 100,010, 002 rather than 100,000,002). The conclusion was drawn that miracles, meaning unexpected occurrences, can be part of the natural order without need of divine intervention. Title page of C. Babbage, *Ninth Bridgewater Treatise* (London: John Murray, 1838)

> elements, we confirm rather than oppose the Mosaic cosmogony, whether allegorically or literally interpreted. . . .
>
> In the grandeur and universality of these views, we forget the insignificant beings which occupy and disturb the planetary domains. Life in all its forms, in all its restlessness, and in all its pageantry, disappears in the magnitude and remoteness of the perspective. The excited mind sees only the gorgeous fabric of the universe, recognises only its Divine architect, and ponders but on its cycle and desolation. (Brewster 1838, 301)

Then Darwin:

> There is a simple *grandeur* in the *view* of *life* with its powers of growth, assimilation and reproduction, being *originally* breathed into matter under one or a few *forms*, and that whilst this our *planet* has gone circling on according to fixed laws, and land and water, in a *cycle* of *change*, have gone on replacing each other, and from so simple an *origin*, through the process of gradual selection of infinitesimal *changes*, endless *forms* most beautiful and most wonderful have been evolved. (Darwin 1909, 52; italicized words are those echoed)

Darwin died in 1882. Even before that, though, the world was starting to pick up and move on, taking his ideas, using them, modifying them, and sometimes rejecting them. Looking at the reception of Darwinism in every country would be a huge task, quite swamping all else. Fortunately, there are now many good surveys, freeing us here to focus more on specific countries and examples. Let us start, as we must, with the two chief Anglophone countries, Britain and America. The former is the home of Darwin and his ideas, and the latter is, by any measure, the country that has done most in working on and developing evolutionary ideas, notwithstanding the paradox that it is also the country where opposition has been highest. Then let us move to the two countries that have the greatest in-depth history of evolutionary theorizing, Germany and France. What happened in those two lands and how did they handle the fact that it was an Englishman, thinking in a very English fashion, that made the major evolutionary moves? After that, the choice becomes more open, and many countries (like Russia) have good reason to be considered and discussed. Included here is an essay on China, illustrating how evolutionary thinking moved right across the world and how it was received in a culture that, although modernizing rapidly, was still (from Western perspectives) alien in the extreme. And concluding is a discussion of Darwin's fate in South America, something fairly deserving attention because it was after all in that part of the world that the young Darwin traveled and began his evolutionary speculations. Throughout the aim is not so much to emphasize specific issues but to give general assessments and to see how social and cultural factors affected the story of Darwin's science.

Already we have been primed for the story of the reception of Darwin's thinking in his home country (Essay 26, "Darwinism in Britain"). Evolution is accepted. In large measure natural selection is not. What does seem clear is that Darwinism, meaning the ideas inspired by his thinking, is – part cause and part effect – a major element in the overall cultural and metaphysical shift that we see in Britain in the second half of the nineteenth century. As already intimated, by midcentury it was becoming very clear that the old norms and ways were simply not adequate for a country that had industrialized and become (almost overnight) an urban-based rather than rural society. For many, religion was increasingly being seen as not just false but irrelevant; new, more professional methods of

running the country (and empire) were needed; science itself was becoming more university based and, although we know it would be very misleading to refer to Darwin as an amateur, the kind of gentleman-researcher that he represented was increasingly becoming rare and out of place; and there was much more, including the arrival of universal male suffrage and state-supported elementary education for all – after the Reform Act of 1867 it was quipped that "we must educate our masters." In an important way, the move was from a spiritually based, oligarchic society to a materialist-based, democratic society, and science and technology had central roles in this new system. There is a reason why the debate (at the British Association in 1860) between the bishop of Oxford Samuel Wilberforce and the professor of mines Thomas Henry Huxley took on such mythic proportions, for the clash was between the old ideology – decked out in Elizabethan clerical robes – and the new – dressed in a modern business suit (see Plates VI and VII).

For Huxley and his supporters, Darwinism was much more than a science – it was a secular substitute for the old religion, a metaphysical foundation for the new order of things. In good reason, this was why the actual mechanism was of less importance. It was what Darwinism represented, blind law working endlessly, to bring on change, that really counted. Although remember what has been noted already. It was not blind law working to no purpose. It was law bringing on progress, in society mirroring progress in biology. Darwin, we know, endorsed this vision, but – a point to which we are already sensitized – above all it was the philosophy of Herbert Spencer. As it happens, by century's end, troubles in the empire, poverty and depressions at home, and military arms races with Germany were making hopes of progress seem empty and shallow. In the light of what was just said, it is little wonder that Huxley was led to write his great essay, "Evolution and Ethics," denying that we see such an upward process. But the underlying vision of a material world, unaided by spirit forces from without, persisted. This is not to say that there was no evolutionary science, but it tended not to be very causal and significantly increasingly it was something to be found more in the museums, places that existed for display and education, than in universities, places for research and the advance of knowledge.

The story of the reception of Darwin in America is a fascinating tale of how preexisting culture and needs affect and condition the reception of new ideas (Essay 27, "Darwinism in the United States, 1859–1930"). The major and well-known clash at the time of Darwin himself was between his champion, Asa Gray, professor of botany at Harvard, and the likewise Harvard-based Louis Agassiz, a strong antievolutionist. Because evolution eventually won the day, the usual assumption is that Gray would have been the major influence in the New World. This was not true, even though it raises the massive paradox that the very person whose ideas were the focus of attack in the *Origin* was he who had the real influence. Agassiz had the students. After the Civil War, in the North, as in Britain, industry and urban society grew exponentially

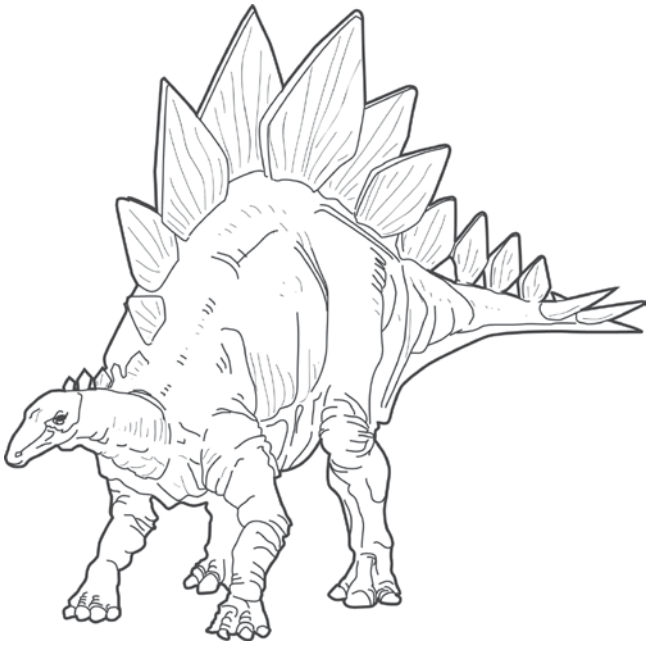

Figure Introduction.11. The stegosaurus, one of the giant dinosaurs discovered in the American West toward the end of the nineteenth century

and, as in Britain, a science- and technology-based world picture grew to dominate. Evolution was at the heart of this vision. It is therefore not surprising that virtually all of those students, including Agassiz's own son, became evolutionists. Expectedly, however, the form of their evolution owed far more to morphology- and homology-exhibiting archetypes – precisely those things cherished by the nonevolutionary Agassiz, student of the *Naturphilosophen* philosopher Friedrich Schelling and anatomist Lorenz Oken – than to natural selection and its explanations of British adaptationism. Naturally, Herbert Spencer, with his message of progress, was deeply appreciated.

Of course, particularly with a country as big and diverse as America was then becoming, one should be careful about sweeping generalizations. Given the demands of agriculture in that country, intensified after the war with the building of the railroads and the opening of the prairies and the routes to the West, there was much interest in methods of breeding, and this certainly spilled over to an appreciation of the merits of natural selection. As in Britain, however, one senses that much that occurred was less than fully focused causally, or invoked causes more liked for the metaphysical (often progressivist) implications than for their scientific merits. The magnificent fossil discoveries in the West of the United States and Canada bolstered the beliefs in evolution as such, but also they contributed to what (as in Britain) was becoming a pattern, where museums became very much the homes of the evolutionist, places of display and education and less of ground-breaking research (Fig. Introduction.11). This was reinforced in the United States particularly with a turn by biological investigators from broad historical studies to much more reductionistic laboratory studies. A bright student went for Germanic-type

training to one of the new universities like Johns Hopkins, spending summers at research institutes like the one at Woods Hole in Massachusetts, rather than roaming the West for fossils or the fields and forests for butterflies.

What of Germany itself? (Essay 28, "The German Reception of Darwin's Theory, 1860–1945") From at least the end of the eighteenth century there were thinkers who accepted some kind of evolutionary perspective or another. It was usually if not always mixed up with analogies with individual development and thus led to a kind of progressivist reading of life's history, the kind that made Darwin so uncomfortable when he separated himself from views about inevitable, upward change. This continued after the *Origin*, especially at the hands of the great morphologist Ernst Haeckel – he who popularized the individual-group connection with his so-called biogenetic law, "ontogeny recapitulates phylogeny." To this day, there are debates about just how much of a Darwinian we should consider Haeckel. Undoubtedly he was an enthusiast for the *Origin*, and nigh hero worshiped Darwin himself. But his writings show strong evidence of his own intellectual heritage, with a taste for tracing trees – that he himself illustrated memorably – rather than working on the ways in which a mechanism like natural selection could produce organisms and their adaptations. This was the same for others too. Perhaps directly as a result of Haeckel's own urges to make a full-blown metaphysical picture of his science – at times, he even gave tremors to Huxley – evolution in Germany in the later years of the nineteenth century was rarely quiet or unchallenged. It figured in debates about society and religion and more. How long-lasting were these effects and what their ultimate outcome is still contested today. American biblical literalists, fundamentalist or creationists (of which more later), combine their critiques of Darwinian evolution as science with the claim that it is morally pernicious, having led in a fairly direct line to the vile doctrines of the National Socialists. As you will learn from the essay given here, the truth is very different. Something had to lead to Hitler and his vile minions, and no one would deny the racism of the nineteenth century – shared pretty much by everyone including Darwin – must have had some input. But to pick out Darwin and his follower Haeckel for special condemnation is to make a politically motivated moral charge on the back of a historical falsehood.

General opinion among English-speaking historians of evolution is that after the *Origin* the French went into a century-plus sulk, from which they are only just now emerging, if that. They did not discover natural selection and, as the country that had done most in the century and a half before to put evolution on the map, the failure and the perceived disgrace was too much to bear. They wanted nothing to do with Darwin or anything connected with him. In fact, as is so often the case with oft-told tales, there is some truth in all of this, but the real story is much more complex and interesting, so much so that there are two essays covering the period from the *Origin* to the present. Certainly today Darwin is genuinely acknowledged and respected for his work. The magnificent Muséum National d'Histoire Naturelle, in the botanic gardens on the bank of the Seine, has an exhibit on evolution that gives Charles Darwin all of the credit that he deserves. But it is true that it was a long time coming. After the *Origin*, Darwin as a scientist was respected, Darwin as a support for all sorts of speculations about human nature and society was eagerly turned to good use – generally, much to the chagrin of Darwin himself – but Darwin as an evolutionist among professional biological circles was a nonstarter (Essay 29: "Darwin and Darwinism in France before 1900"). The great French biological scientists of the day, notably Claude Bernard and Louis Pasteur, set the pace and the standards, and their kind of hard-nosed, bench-based, experimental science was not welcoming toward the kind of naturalist-inspired speculation of the *Origin*. (We shall see the same story with Germany and botany.) And, of course, there was the home-grown Lamarckism ever-ready to provide answers for those who asked the pertinent questions. So overall, we should probably see French reactions as part of a general type of reaction to the *Origin* – eagerness to co-opt for ideological ends and a sense that Darwin's style was out of kilter with the direction of professional biology – and not necessarily as something specific to that particular country.

At the burial of Karl Marx – somewhat amusingly he lies in Highgate Cemetery London, literally facing the remains of Herbert Spencer – his great supporter Friedrich Engels praised Darwin for having done in the biological world what Marx had done in the social world. In fact, Marx's reaction to Darwin was interestingly nuanced. He devoured the *Origin* as soon as it appeared, writing a couple of years later to Engels: "It is remarkable how Darwin rediscovers, among the beasts and plants, the society of England with its division of labour, competition, opening up of new markets, 'inventions' and Malthusian 'struggle for existence'" (Marx and Engels 1975–2005, 41:380; letter from Marx to Engels, June 18, 1862). He did think sufficiently highly of Darwin that he sent a copy of *Das Kapital* to Darwin. (It remained in Darwin's library uncut!) Because of this, in those countries taken over by groups ostensibly following in the footsteps of Marx, Darwin got high praise, even when, judged objectively, the science of the land was being perverted by politically influenced factors, referring especially to the Soviet Union and the disastrous effects of the charlatan agronomist Trofim Lysenko. Expectedly, the praise is usually directed toward the ends of the speakers and their patrons. In Communist China, we find that Darwin is lauded as much for his materialism-atheism as for anything strictly scientific (Essay 30, "Encountering Darwin and Creating Darwinism in China"). You should not think that this use of Darwin for political and social ends was something new. Long before the communists, Chinese intellectuals were using Darwin's ideas – and, as often as not, Herbert Spencer's ideas flying under the colors of Darwinism – in the cause of deserved cultural changes. After the devastating war with Japan at the end of the nineteenth century, Darwin's claims about the struggle for existence found favorable readers, as did various thoughts of progress and of the need to strive for success. One reason why Darwin was praised was

because he showed the kind of reverence for ancestors that the Chinese appreciate. Was he not following in the footsteps of Grandfather Erasmus? Unfortunately the first war with Japan was followed by a second starting in the 1930s, which morphed into the general worldwide conflict ending only in 1945, at which point a civil war took over. Science generally in China suffered, and this affected evolutionary studies in particular. Today, as is well known, particularly thanks to fabulous fossil discoveries, Chinese evolutionary studies are thriving, and it will be interesting to see if they challenge the overall dominance of the West as the country seems to be doing in the economic field.

Finally, there is South America (Essay 31, "Darwinism in Latin America"). There are many different countries in the region with many different challenges, so it is hard to make firm generalizations. Positivism in some version was a major influence on the thinking of scientists and others, including politicians. Here as elsewhere, when one speaks of evolution, it is usually better to think first of Herbert Spencer (and Haeckel to a certain extent) and only secondarily of Darwin, although it is the latter who usually gets the great praise and respect. Some kind of evolutionary positivism or naturalism seems to have been the mark of the forward-looking thinker. Sometimes, perhaps expectedly but regrettably, the ideas of evolution were used to rationalize beliefs and practices that would have shocked the old scientist in his greenhouses down in Kent. This applies particularly to the extermination of the natives in Argentina, something a troubled Darwin wrote about in the *Voyage of the Beagle*. For all of his Victorian views about race, in the *Descent* Darwin made it very clear that his sense of the struggle between races (and the consequent fitter elements) was that the real focus should not be on violence and who beats whom but on the immunity of Western races to diseases that wipe out native populations. What should never be forgotten, however, is that, though the countries of the continent often used evolutionary ideas more for political and social ends than for strict science, Brazil was the home of the German-born Fritz Müller. Given that Bates and Wallace both worked in Brazil, there must be something overwhelmingly inspiring about the insect life in that region, for it was Müller who (following Bates) made significant and lasting contributions to our understanding of mimicry. That part of the world will always have a special place in the hearts of Darwinians.

And now, as we move from Darwin's nineteenth century into the recently finished twentieth century, let us pause again to take the temperature of the times, or rather to assess the status of evolutionary thinking. For the first 150 years of its life, evolution was a pseudoscience, riding on the back of the ideology of progress. Charles Darwin set out to change things. He put together the evidence for evolution so that it became common sense. He provided a mechanism of change, one that spoke to the big problem of final cause. Darwin himself wanted to create a mature science of evolutionary studies, what we can call a professional science – or if you like, normal science working within an established paradigm. We must conclude that he was only partially successful. Obviously there were professional scientists doing evolutionary studies. Ernst Haeckel is a case in point, and it would be wrong to deny that his attempt to work out relationships and histories was professional science. But note how often the work being done was either noncausal or all over the place with respect to what made things work and change. Again and again, people were far more interested in the social implications of evolution than in working on technical problems about the nature of living beings. There was some work using natural selection, but it was very much the exception rather than the norm. And by century's end, evolution was truly much more the science of the museum than it was of the laboratory. Historians of the period talk of the "revolt from morphology," meaning that around the beginning of the new century there was a whole new breed of biologists – people like the geneticist William Bateson in England, the cytologist Edmund B. Wilson, and the future geneticist Thomas Hunt Morgan in America, who were turning to bench studies, highly reductionist in outlook, determined to make of biology a science to stand with any other (namely the physical sciences). Evolutionary studies were out of the loop.

By and large, evolution became what one might call a "popular science" – respectable (more or less) but not cutting-edge science, more philosophical and background than anything else. In some hands, it became virtually a secular religion, an alternative suited for the industrial, urban world, to compensate for the perceived failure of the more conventional religions of the past. It is amusing how often the palaces of evolution, otherwise known as natural history museums, now being built in major city after major city, were so often modeled on medieval cathedrals (see Plate VIII). Instead of going to the Church of Christ on a Sunday morning, the family could go to the Church of Darwin on a Sunday afternoon. Who was responsible for all of this? As we have seen, there were many factors, from the problems of the science to the need of alternative philosophies. Darwin himself was perhaps a major culprit. A rich man who could afford to do as he pleased, he did rather shut himself away, pursuing his own interests, leaving it to lieutenants like Huxley to go out and do the hard work of proselytizing. Had he been prepared to pour some of his considerable fortune into a research institute of selection studies, perhaps things might have been a little different. But it was not to be, and, to be fair, remember, apart from the real handicap of the ongoing sickness, Darwin probably did not think that such an effort would really pay dividends.

And yet, the story did not end there. Today, if anything is a professional science, a paradigm supporting normal science, it is evolutionary biology, and Darwin's contributions are right at the center. His ideas matter. So let us pick up the thread and see what happened next, starting with the rediscovery of the work of Gregor Mendel. It is satisfying to begin the story with botany (Essay 32, "Botany: 1880s to 1920s") – satisfying both because so often botany gets pushed aside in favor of animal studies and because botany, in fact, has always played a vital role in evolutionary studies. Mendel, after all was working on

pea plants, not fruit flies, and the same focus on plants is true of many who followed him, including some of the key figures of the twentieth century such as Ronald A. Fisher. What is important is the way in which we see the beginnings of the move from a rather low-grade science to one that is much more rigorous and professionally acceptable. It did not happen in an easy, straight line because we have Darwin himself using selection and yet, with some good reason, criticized for his rather old-fashioned experimental methods, and then we have leading German researchers like Julius von Sachs, who for all his sophistication did not embrace much by way of evolutionary causation and certainly not selection. But all of this was about to change, and plant studies as much as animal studies were part of the work and evidence.

The rediscovery of Mendel's ideas at the beginning of the twentieth century was the crucial event, moving evolution from its past toward its future. How much Mendel himself truly realized what he had done, and how much later thinkers read back into his work what they wanted to find, are still matters of historical debate. The point is that now the way was being opened for an adequate theory of heredity, something so lacking and so needed by the theory of the *Origin* (Essay 33, "Population Genetics"). What was necessary was that the genetics be extended from individual organisms to factors of heredity working in populations. Unlike Lamarckism, to take an example, natural selection is something that acts not on the individual but is meaningful only in groups. Thanks to some very mathematically gifted biologists, this work was done, and so by around 1930, the framework of a full theory or paradigm of evolutionary change was starting to emerge.

But even with the mathematics done, this, to use an analogy, was just the skeleton. Now, the task turned to the naturalists and the experimentalists to supply the empirical flesh. What was needed was not simply people committed to evolution and trained in the pertinent science, but people with vision, the Thomas Henry Huxleys of their days, able to build groups and find funding and attract students and do all of the things needed to get an area of science functioning as mature work – as normal science, to use Kuhn's phrase, or what has been termed as professional science. In the United States, the key figure was the Russian-born geneticist Theodosius Dobzhansky (Essay 34, "Synthesis Period in Evolutionary Studies"). He took a proposal by the American geneticist Sewall Wright, the "shifting balance theory" – at least, he took the version that used the pictorial metaphor of an "adaptive landscape" (Dobzhansky, to be candid, was never very strong on mathematics) – and used it to pursue studies in the wild and in the laboratory. Following his teacher Morgan in taking the little fruit fly as the model organism, Dobzhansky and his associates and students followed in detail the physical and chromosomal changes over generations, trying to work out how forces of selection and of drift bring on changes. His work and that of those in his orbit (particularly the taxonomist Ernst Mayr, the paleontologist George Gaylord Simpson, and the botanist G. Ledyard Stebbins) did much to establish Darwinian selection as a major force in nature,

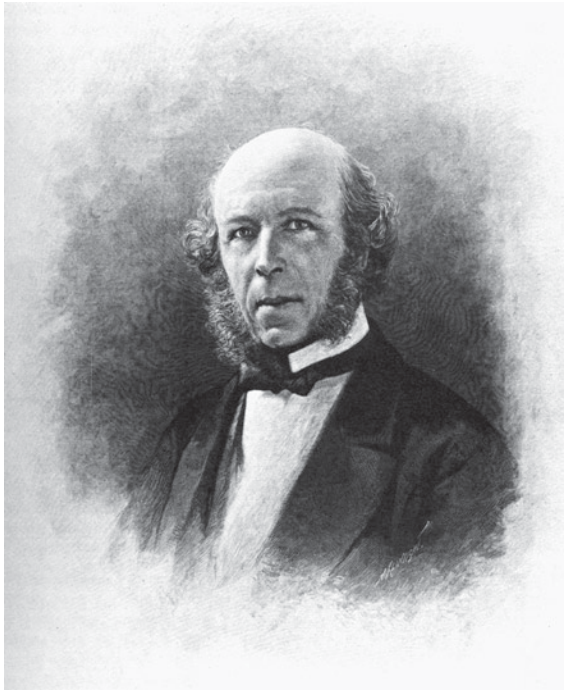

Figure Introduction.12. Herbert Spencer (1820–1903), Darwin's contemporary, was an ardent evolutionist. Wildly popular in his day, at his death his reputation sank like a stone. Nevertheless, his fingerprints are all over twentieth-century evolutionary thinking. From David Duncan, *Herbert Spencer* (London: Williams and Norgate, 1911)

although there was often a non-Darwinian flavor to the work, especially when their thinking was influenced by (what modern scholars are now seeing as the) deep roots that Wright's thinking had in Herbert Spencer as much as Charles Darwin (Fig. Introduction.12).

Socially, what was crucially important was the way in which Dobzhansky and his fellows worked hard to bring evolutionary studies into the universities, making them part of the biological curriculum. Dobzhansky went to Columbia, Mayr left the American Museum of Natural History for Harvard and a year or two later Simpson followed, Stebbins went west and worked at the University of California at Berkeley and then at the new campus at Davis. An evolution society was founded; funds were sought and found to start a journal (*Evolution*), one dedicated to the kinds of causal studies now being effected; grants were awarded (thanks, especially after the Second World War, to the great rise in available federal money through the National Science Foundation); and in Dobzhansky's laboratory especially there was a flow of new graduate students and post-docs. Above all, there was a conscious awareness that evolutionary studies had had low-grade status as a science, and a major factor was the way in which it had acted as a vehicle for nonscientific cultural hopes and aspirations, especially about social progress (being reflected in claims about biological progress). All of these new professional evolutionists were deeply committed to both biological and social progress. All knew that such professions in their science would be fatal to their professionalizing ends. So

thoughts of progress were suppressed and kept out of the university science, reserved for the popular books that poured forth from their pens – as such popular books about evolution continue to pour forth today.

Something very much parallel happened in England also (Essay 35, "Ecological Genetics"). The key figure there was E. B. Ford, universally known as "Henry." He allied himself with Fisher in much the way that Dobzhansky allied himself with Wright, and one immediate consequence was that non-Darwinian notions like genetic drift got short shrift. Working in the British tradition of Bates and Wallace, Ford and his students, including Philip Sheppard, Arthur Cain, and Bernard Kettlewell, did highly influential studies of fast-breeding organisms showing the workings of natural selection in bringing on subtle adaptations. Sheppard and Cain did seminal studies of shell color and banding of snails, showing how the colors and patterns adjust according to the backgrounds – hedges, ditches, forests, and the like – and Kettlewell continued the studies of industrial melanism that had so excited nineteenth-century lepidopterists. No less adept than Dobzhansky at finding funds, Ford convinced one of Britain's largest private research foundations – the Nuffield Foundation, started by England's counterpart to the real Henry Ford of Detroit – that insects are great models for humans. For instance, the studies of his group could tell much about the spread and retentions of various genes, information that could be very important when studying genetic factors in humankind. Also, as was the case with the Dobzhansky group, it is interesting that as biology felt the huge effects of the molecular revolution – epitomized by the discovery in 1953 of the structure of the DNA molecule – it filtered almost seamlessly into evolutionary studies. Fears that molecular studies might replace whole-organism studies entirely were soon followed by the realization that molecular biology could be a very powerful tool for throwing light on hitherto-intractable evolutionary problems.

Let us return to France for a sense of how these ideas started to spread out to other countries. We should not expect to find much action until around 1930 or later, and we do not (Essay 36, "Darwin and Darwinism in France after 1900"). For instance, although to a person the paleontologists were evolutionists, that was about as far as they would go, being even reluctant to speculate on phylogenies. Given the harsh criticism that greeted Teilhard de Chardin's attempts to reconcile science and religion (in his *Phenomenon of Man*, published posthumously in 1955), it is worth noting explicitly that, judged as a paleontologist, Teilhard's brilliant reconstructions stood out as significant exceptions. Where real change did come – as in America and certainly influenced by America – was with respect to population studies of the actions and effects of selection and of how these play out for overall evolutionary changes. As soon as the theoreticians had done their work, eager young French researchers (significantly, with good mathematical strengths) were picking up the ideas and putting them to the test. Indeed, one of the most important experimental innovations – population cages – came from that country. And before long, important work was being done on key issues such as the ways in which selection pressures can vary. It cannot be said that the ideas of neo-Darwinism were universally and immediately welcomed in France – Lamarckism had great staying power – but a beachhead was established, pointing to the universal acceptance of today.

Finally, as part of the story of the making of modern evolutionary biology, botany must again get full mention (Essay 37: "Botany and the Evolutionary Synthesis, 1920–1950"). The importance of getting the right subject to study can never be overestimated. As intimated, the little fruit fly *Drosophila* showed itself a perfect organism for genetic studies – it breeds easily and quickly, requires minimal maintenance, has no odd sexual system, has giant chromosomes that are easy to study, and can be found readily in the wild in accessible places. Mendel got the right plant (the pea) when he sought the principles of heredity – even to the point of having different features of study controlled from different chromosomes, so that there were no immediate complicating factors. The early geneticists of the twentieth century were not so lucky in their choice of the evening primrose, because it proved to have a very complex system that led, among other things, to the belief that changes are large and sudden – saltationism. But by the 1920s, things had righted themselves and then for the next thirty years botanists – notably the Carnegie group at Stanford and others at Berkeley – did path-breaking studies to work out principles of speciation and the like. Animal studies tend perhaps to be more glamorous. But from Darwin on, the plants have provided more than their share of information about the evolutionary process. That Stebbins was a key figure in the making of the evolutionary synthesis was no anomaly.

Somewhat artificially, let us position ourselves now in 1959. It is the 150th anniversary of the birth of Darwin and the 100th anniversary of the publication of the *Origin*. Evolution, as an area of science, is still somewhat tentative in respects and threatened from without by various forces, not the least being the way that molecular studies (for all that they were on the verge of being seized upon as tools by evolutionists) were exploding in size and threatening to take all students and grants of the life sciences. But notwithstanding the worries and insecurities, we have now a functioning, professional science. What then were evolutionists able to do in the half century following? Staying now with the science, it is to this question that we turn next, starting with the problem of the origin of life (Essay 38, " The Emergence of Life on Earth and the Darwinian Revolution").

In a way, this problem reminds one of the problem faced by Sherlock Holmes in the story about Silver Blaze, the missing racehorse. Asked if there was anything to which he wanted to draw attention, Holmes replied that he was puzzled by the dog that barked in the night. But the dog did not bark in the night, came the reply. Exactly! It should have done, and because it didn't Holmes inferred (correctly) that it was an inside job. The same is true of the *Origin of Species* and the origin-of-life question. What does Darwin have to say on the topic? Nothing! And now the question is why, because the

omission had to be deliberate. Before Darwin, people like Lamarck and Chambers assumed automatically that one must discuss life's origins, and the same was true of people like Haeckel after. Darwin realized fully that talking about origins, especially at a time when (over in France) Pasteur was showing that much thinking on the topic was simply wrong, would only lead to trouble. So he spoke simply of life "having been originally breathed into a few forms or into one" and left it at that. Basically, although he had some private thoughts, it was not really his problem, and he pushed it to one side. But of course it could not be sidelined indefinitely, and the past century saw much interesting and fruitful, if far from definitive, work on the problem. The coming of the molecular age obviously transformed things, and today there are many exciting areas of inquiry. Is this Darwinian science? Well, in one sense, perhaps not. In another sense, obviously at some point the evolutionist has to face the topic, and moreover it is clear that even at the earliest molecular stages, when one would hardly want to speak of things as "living," something very much like natural selection is going to be active and important.

The traditional philosophical view of scientific theories sees everything happily integrated into one massive system, generally thought to be an axiom system with high-powered principles or laws at the top, and then everything seen to be deductively connected on the way down to lower-level empirical claims. This view of theories is not entirely wrong – it is almost certainly the one held by Darwin himself – but most today realize that actual science tends to be far messier, with small areas of theory or modeling connected loosely together with others, sharing some ideas and theory but not necessarily entirely consistently throughout. As it has grown, covering as it does so many areas, this lack of systematic purpose has often plagued evolutionary studies (Essay 39, "The Evolution of the Testing of Evolution"). It does not mean that all is lost, for in various areas there is much serious and important work. For instance, the number of studies demonstrating the action of selection in experiment and in the wild, building on the work of the mid-twentieth century, has grown exponentially. But it is clear that researchers are not always as meticulous as they might be in distinguishing their aims. Is the claim, for instance, that everything is adaptive, or only in part? These are points particularly to be kept in mind as we move now through work being done today across the spectrum of topics falling within the Darwinian consilience.

Mimicry and camouflage were important for Darwin studies back in the years immediately following the *Origin*. They continue to be so today (Essay 40, "Mimicry and Camouflage: Part Two"). What is fascinating about this area is how often researchers are working not just in the Darwinian mode but actually with hypotheses that Darwin himself formulated. A good example is the question of sexual dimorphism, where female butterflies mimic other species, whereas the males do not. Darwin suggested that natural selection is the factor in making the female mimics but that sexual selection is the factor making for males to stay with the original species colors and patterns. Recent studies have confirmed the truth of his hypothesis, underlining not just the importance of adaptation as a central biological concept but also that selection does so often work on and for the individual and not the group. Sauce for the goose is not always sauce for the gander. Notice however that, in the tradition of the very best science, solving one problem is not the end of the story. There are always new problems to be solved. Molecular techniques for instance show that complex adaptations are created again and again rather than simply inherited, and now the race is to find the reason why. Critics of evolutionary biology, especially those with religious axes to grind, often point with glee to the unsolved problems of the science. They quite miss the point – something stressed strongly by Kuhn's philosophy of science – that good science throws up new problems constantly. It is always forward moving rather than resting on its laurels.

Darwin always had a somewhat ambiguous attitude toward the actual history of life. It was he after all who established beyond doubt that there is a history of life, one produced by evolution. And if you look at some of his writings, there are heavy hints about what he thinks the course of life truly was. The barnacle work is a case in point. In the *Descent*, he opted explicitly for an African ancestry for humankind. But although he gave a stylized-tree picture – his only diagram – in the *Origin*, he was not much into providing actual histories or phylogenies (see Plate IX). This is perhaps what one might have expected because, ultimately, a great deal of phylogeny tracing is not very Darwinian, if one means doing something using natural selection. Indeed, with reason, natural selection is often thought something of a handicap because it covers up true relationships with superficial adaptations. One must dig beneath, to find homologies, to trace paths. Within bounds, this is much the same today, although the methods of inquiry have become far more sophisticated and reliable, especially in this molecular age (Essay 41: "The Tree of Life"). Moreover, thanks to such new devices such as the "molecular clock" – based on the rate at which mutations occur and change accumulates – we can put some absolute dates on events, hitherto unknown. But is it simply a matter of things meshing, with non-Darwinian work fitting nicely with Darwinian selection studies? One fascinating new finding is about how, thanks to viruses, genes can be passed between very different branches of the tree of life. Does "lateral gene transfer" show that Darwin was wrong? Two comments are in order. First, although it may be a major factor with simple-celled organisms (prokaryotes), it is unlikely to be so great a factor with complex-celled organisms (eukaryotes). Second, even if it did mess up the tree of life significantly, it is not obvious that the importance of Darwinian factors are downgraded. The adaptive values of lateral transfer are not obvious, so no one is saying that natural selection suddenly becomes unimportant.

The study of the evolution of instinct and social behavior, brought together under the name "sociobiology," has been one of the most fertile and controversial areas of evolutionary biology in the past fifty years (Essay 42, "Sociobiology"). After years of ignoring issues to do with the level of selection,

finally in the 1960s biologists started to face the question squarely and (in major reaction to work by the English-born Vero Wynne-Edwards) a thoroughly neo-Darwinian individualist stance was taken. Huge amounts of very profitable work have been done right through the animal kingdom, from the social insects to the primates. New ideas such as "kin selection" (where genes are passed on by proxy, as it were, through close relatives) and "local mate competition" (where sex ratios are skewed because of the waste when siblings compete for the same reproductive opportunities) have been devised and used highly effectively in order to understand the workings of organisms in groups. However, there has always been a minority that has group-selection yearnings, and recently their ranks have been joined by the man who wrote the bible of the whole movement, Edward O. Wilson, author of *Sociobiology: The New Synthesis*. He argues now that a more integrated, "holistic" approach must be taken to animal behavior. Perhaps significantly, Wilson stands in direct intellectual line to an earlier, Harvard ant specialist, William Morton Wheeler – who was in turn much influenced by Herbert Spencer, especially by analogies that the earlier evolutionist drew between the individual and the group. It could be that we are hearing echoes of divisions between evolutionary visions that go back to the middle years of the nineteenth century.

Paleontology also has been vibrant in the past fifty years (Essay 43, "Evolutionary Paleontology"). What is fascinating is the gap between the professional and the public. Most people, if asked why evolution is true, would say "because of the fossils" (the same reply that would be given by those asked to defend their view that evolution is not true). Yet Darwin expended much effort in the *Origin* to saying why the fossil record does not deny his evolutionary thinking and for years afterward paleontologists either ignored the whole question of evolution or went off in search of non-Darwinian mechanisms. The action was within the reduction-happy sciences like genetics, and paleontology was mainly a source of nice fossils for the museums. G. G. Simpson, Dobzhansky's associate, started to change all of that, and since then – particularly with the rise of "paleobiology" – much effort has been made to give paleontology full status within the evolutionary family. Some, if not much of the work, both theoretical and empirical, would bring delight to Darwin. One of the biggest problems he faced in the *Origin* was the total absence of pre-Cambrian fossils, leading to the invention of remarkable ad hoc hypotheses to explain away this worrying phenomenon. Now we have a remarkably detailed record back to the earliest forms of life nearly four billion years ago. More than this, we have lots of very sophisticated adaptationist studies. A classic analysis is of the plates on the backs of the dinosaur stegosaurus, showing how they were almost certainly used for heat regulation.

However, sometimes the thinking of paleontologists is at best neutrally Darwinian, and sometimes verges on the unfriendly. The well-known theory of "punctuated equilibrium" of Niles Eldredge and Stephen Jay Gould, suggesting that the course of evolution is not smooth but goes in fits and starts, went through various incarnations, but in Gould's hands was not particularly selection friendly. The very name of the theory had echoes of a theory, "dynamic equilibrium," from another tradition. In a like vein, John J. Sepkoski Jr. (student of both Gould and Wilson) did sterling work in mapping the major events in life's history, producing neo-Spencerian pictures of the repeated upward spurts of complexity, followed by subsequent balance. It was work that could be given Darwinian underpinnings, but not work starting with Darwinism.

One encounters some of the same sorts of issues when one turns from time to space, from paleontology to biogeography (Essay 44, "Darwin and Geography"). One thing that cannot be overemphasized is just how important the experience of new lands and new flora and fauna were to Darwin. It is hotly contested as to how far one should think of Darwin as being influenced by the romantic movement, but it cannot be denied that his early writings, when he writes of his experiences of nature in its many varieties around the world, show a rapture worthy of Goethe or (closer to home) Wordsworth. Expectedly however, we find that, although this enthusiasm for nature and its variety around our globe found its way firmly into the *Origin*, those who followed in his footsteps as often as not reflected their national trends rather than anything strictly Darwinian. This was notably so when it came to human themes. And as always, the specter of Herbert Spencer loomed in the background. This was especially true in America in the twentieth century as biologists moved to more ecological studies trying to map the differences in organisms in different climates and lands. Mention must also be made of the great effects on biogeographical studies brought by the geological theory of plate tectonics. Many of Darwin's own anomalies – for instance, the similarities between plants in the Southern Hemisphere on lands often separated by vast expanses of ocean – are now seen as the direct result of the slow but steady movement of continents around our planet.

The Galapagos Archipelago has always had a special place in the hearts of Darwinian evolutionists, for it was from his visit and his later reflections that Darwin's move to evolution really started to gather steam (Fig. Introduction.13). There has been some controversy about the exact organisms that really excited and prompted Darwin, but it was not long before the drab little finches of the island started to play a significant role in Darwin's thinking, and these tiny birds continue in that role down to this day (Essay 45, "Darwin and the Finches"). In many respects, the story of the finches is the story of Darwinian evolutionary theory in miniature. Darwin was excited about the finches. Those who came after him thought them interesting and perhaps significant, but in no wise did people want to use them as evidence for natural selection. This continued true even after the population geneticists had brought selection back into style. It was thought that the non-Darwinian genetic drift was the real cause of change. Then the tide changed, and increasingly the finches were seen as paradigmatic end results of a struggle for existence resulting in many different adaptations, for living in the face of both the environment and competing finch forms. Today, thanks particularly to the stunning,

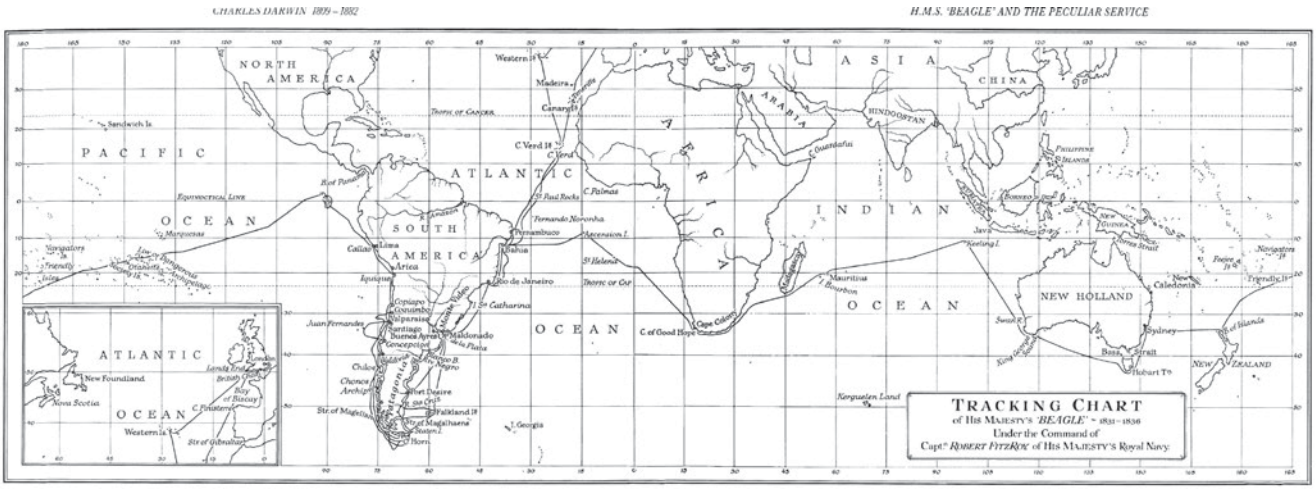

Figure Introduction.13. The voyage of the *Beagle* (1831–36). Note the visit to the Galapagos Archipelago in 1835. From C. Darwin, *Journal of Researches* (London: John Murray, 1845)

long-term studies of the husband and wife team of Peter and Rosemary Grant, the finches are at the top of the list of well-defined selection studies. The results, moreover, are of the best kind of science. They show that Darwin was right in his basic theory but that there is far more to the story than he did or could have dreamed of – about speciation, about adaptation, and (very excitingly) about rates of evolution. Darwin was, for example, completely wrong about the inevitable slow working of natural selection. One likes to think that no one would be more excited than he about this discovery.

Embryology has always had an intricate but somewhat uneasy relationship with Darwinian thinking (Essay 46, "Developmental Evolution"). For Darwin himself in the *Origin*, the discussion of embryology was a triumph of selectionist thinking, of which he was very proud. But although embryology continued for the rest of the nineteenth and into the twentieth century as one of the most important areas of the life sciences, one that was completely bound up with evolutionary thinking, it tended not to be very Darwinian. It was rather used to work out relationships between organisms, in which work (as noted above) adaptations were generally a nuisance taken (with reason) to conceal true homologies, and of course – thanks to the biogenetic law – it was much involved in the tracing of phylogenies, something else that paid scant attention to natural selection. It was perhaps understandable that, when Darwinian selection and Mendelian genetics were synthesized, there was something of a tendency to regard organisms as black boxes with genes making the input and fully grown organisms emerging and not much interest in what happened in between. Things have changed dramatically in the past three or four decades, thanks particularly to the coming of the molecules, and the tracing of development from an evolutionary perspective (evo-devo, so called) is a big business. And some of the findings have been truly astonishing. For instance, we now know that there are significant molecular homologies between the genes controlling development in fruit flies and in humans. It turns out that organisms are built on the Lego principle, with the same building blocks put together in different ways and ratios. Whether this is now all that Darwinian is a different matter. No one denies selection outright, but it must be allowed that sometimes the impression given is that development is where the real evolutionary action occurs and then selection comes along to clean things up, tweaking advances and removing failures. No doubt this is a debate that will continue.

Ecology is the study of living organisms and their relationships to each other and to the environment. Although the term was not invented until the decade after the *Origin* (by Haeckel) and although the concept does not get the separate treatment of, say, paleontology, it is obviously something that is threaded right through Darwin's great work (Essay 47, "Darwin's Evolutionary Ecology"). That Darwin did have very important insights no one would ever deny. He showed in great detail how the welfare of any group of organisms is intricately bound up with the welfares of others, and he made significant contributions to our understanding of key ecological notions like niches. However, care must be taken not to confuse surface similarities with deep differences (Essay 48, "Darwin and the Environment"). The concept of a balance of nature is one deeply embedded in first Greek and then Christian thought. In a way, it almost follows from the biblical story for one would expect God to have ordered things so that the world would continue in happy equilibrium for the benefit of all, especially humans. Darwin certainly made some efforts to capture the notion, arguing that selection would often act to balance things out. But truly the balance does not fit tremendously comfortably with evolution through natural selection. On the one hand, one is always expecting some change, at some point or another. On the other hand, Darwinian selection is (in the opinion of most) never working directly for the good of the whole but for the individual. This means that the balance is never an end in itself, but always a consequence. Once again one must recognize that there were other sources for the enthusiasm about equilibrium positions,

and once again the influence of Spencer cannot be ignored. Today, with the threats of global warming and the like, it is realized how selection can work for the short-term gain rather than the long-term harmony. A point to be noted is how often in discussions about these topics one gets an uneasy mix of the professional and the more popular. The professional evolutionary ecologist is trying to understand the workings of nature, whereas the ecologist in the popular realm invariably has moral or social issues foremost. Referring to Darwin is rarely neutral at these times, as he is alternatively praised as the first person to understand properly the issues at stake or he is condemned as the progenitor of ultimate selfishness in the face of upcoming environmental catastrophe.

Is molecular biology truly no more than a handmaiden to the evolutionary biologist, or does it carry within it deeper threats (Essay 49: "Molecular Biology: Darwin's Precious Gift")? One of the most exciting ideas to emerge from the new approach was that of the neutral theory of evolution. Could it be that down at the molecular level a great deal goes on beneath the reach of selection? Could it therefore be that, at this level, random forces – drift – were the chief causes of change? This idea was seized on with enthusiasm, for at once it seemed that one had a very accurate way of determining relationships between different organisms, perhaps with some real time estimates. One simply works out the rate at which change is occurring, steady change that is occurring, and then one can generate real and accurate phylogenies. As it happens, it now seems that the initial enthusiasm was a little too high; although no one doubts that there is some real truth and value to the idea. This is often spoken of as "non-Darwinian" evolution – the "neutral theory of evolution" – and in a way of course it is. But note that it is not really "anti-Darwinian" evolution. No one is saying that the hand and the eye were produced by drift. Rather that there are dimensions of the biological world where selection does not reach, or (probably) does not reach as readily as it does others.

What is certainly the case is that the molecular revolution is not going to vanish and that the face of evolutionary studies is changed forever. The Human Genome Project is still only on the verge of being fully exploited, as biologists study the vast amount of information that has been revealed about our genetic makeup – and the makeup of many other organisms, also. Obviously many surprises lie ahead. Whether these will finally convince people that Darwinism is now outmoded, on a par with Newtonian theory or (worse) phlogiston theory, is something the future will tell. Most Darwinians today would argue not. But there are, as there always have been, those who beg to differ (Essay 50, "Challenging Darwinism: Expanding, Extending, Replacing"). Part of the time – too much of the time – the differences are more linguistic than substantive. Is individual selection now on its way out? So much depends on how you define your terms. If individual selection can encompass the family, then not obviously; if it cannot, then probably. But there are genuine differences, and one suspects that these are as much philosophical as scientific. From the *Naturphilosophen* on, there have always been those who find

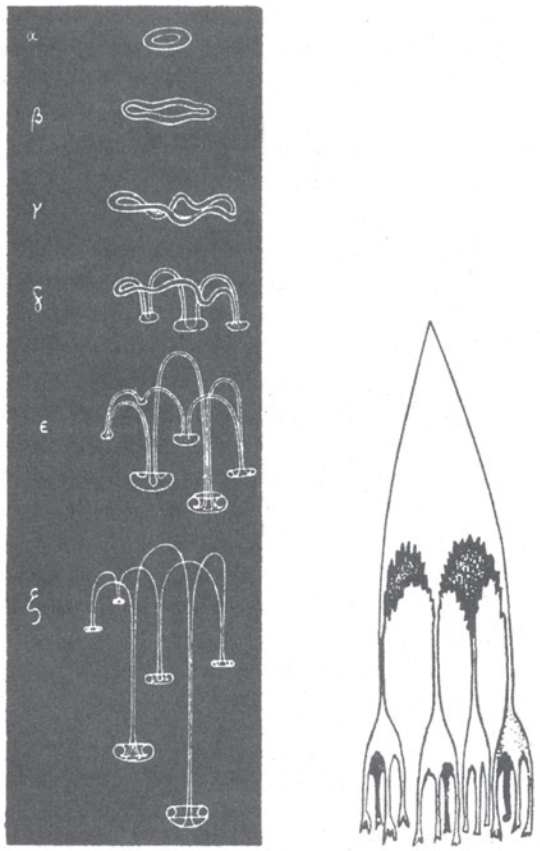

Figure Introduction.14. The Scottish morphologist D'Arcy Wentworth Thompson (1860–1948) believed that much organic form is simply a function of the laws of physics. Here he is trying to show that the shape of the jellyfish is the result of the same laws of physics that determine the descent of more-dense liquids through less-dense ones. From Thompson, *Growth and Form* (Cambridge: Cambridge University Press, 1917)

offensive the kind of blind, reductionistic approach epitomized by Darwinian selection. Today's representatives have seized on the notion (found in Schelling) of "self organization" – there is something inherent in matter itself that makes for organic form no need for selection. We get "order for free." Perhaps its plausibility is best left as an exercise for the reader (Fig. Introduction.14).

If humans were not part of the story, would anyone care very much about evolution? Well, there are people who care about organic chemistry, so probably some, but one much doubts that there would be the intense interest that there has been from the eighteenth century down to the present. It is we who make the subject so fascinating and so fraught with tension for so many. One suspects that even (perhaps especially) the just-mentioned critics of Darwinism have humans somewhere in their minds. Could we just be the product of blind, random force? What is true is that the 150 years since the *Origin* have seen huge effort put into discovering our evolutionary past and, despite setbacks and prejudices and outright fraud, the effort has paid immense dividends (Essay 51, "Human Evolution after Darwin"). There is much fossil evidence, and it is backed by findings from other areas, notably

in recent years from molecular biology. Many hitherto unanswered questions are now settled. Humans came from Africa, not Asia. Humans split from the apes around five or six million years ago, not earlier. Humans got up on their hind legs, and then their brains exploded up in size, rather than conversely. There are still mysteries, including the crucial one about precisely why we came down from the trees in the jungle and walked out over the plains. And always puzzling new finds emerge, most recently the little being (the "hobbit") in Indonesia. Is the work in this area recognizably Darwinian? Obviously, in an overall sense it is, for selection is thought to have played (and still plays) a vital role in human change, although, just as obviously, the science has moved on dramatically from the speculations in the *Descent of Man*. And everyone today is keenly aware of the fallacy that plagued the field long after Darwin, namely the assumption that the closer something is to being European, the more it is favored by natural selection.

In his *Meditations*, published around 1637, the great French philosopher René Descartes held forth on the significance of language: "It is a very remarkable thing that there are no men, not even the insane, so dull and stupid that they cannot put words together in a manner to convey their thoughts. On the contrary, there is no other animal however perfect and fortunately situated it may be, that can do the same." He pointed out that this does not seem to be necessarily an anatomical matter. Magpies can say words as well as we. And deaf and dumb humans find other physical ways to communicate. He concluded that this all "proves not merely animals have less reason than men but that they have none at all, for we see that very little is needed to talk." Like many generations of English dog lovers, Darwin thought this absurd, and he had the theory to back up his beliefs. Language was fascinating to Darwin, and, for evolutionists it has continued to be down to the present (Essay 52, "Language Evolution since Darwin"). It poses major challenges, obviously, because words do not fossilize, but as with other elusive features, ways are devised to overcome this issue. One is comparative studies with other animals, particularly primates, and even more particularly the great apes. Another is by looking for related fossil evidence – for instance, the parts of the brain and of the vocal organs. For a while a (now-refuted) hypothesis was floated that the Neanderthals could not talk properly because they lacked the necessary anatomy. Artifacts are also suggestive. Sophisticated technology implies the ability to communicate efficiently. Famously, one of the most important moves to filling out the story came from the American linguist Noam Chomsky, who argued that all languages share the same innate deep structure. Famously, Chomsky himself denied that this was an evolutionary hypothesis – he was almost with Descartes on the separation of human and beast – although he has now recanted, and his students and collaborators have done major work in showing how the innate structure relates to biology. New hypotheses are still being produced about the nature and origin of language, and today it is one of the most exciting areas of evolutionary study.

The evolution of language slides easily into the more comprehensive topic of the evolution of culture generally. It is an underexaggeration to say that it has been a happy home of many and varied hypotheses (Essay 53, "Cultural Evolution"). Roughly, these can be divided into two camps. First, there are those who argue that culture can be divided into units and that these units function like genes or organisms, struggling for survival and reproduction – that is, being passed on to other thinkers – and knowledge and culture is an outcome of this selective process. Richard Dawkins's (1976) theory of memes is a prime example. Note how readily these views soak up wishes and prejudices – for instance, that memes are parasitic and hence prone to produce (supposed) corruptions of human well-being like religion. Second, there are those who argue that culture is in some sense informed by innate, selection-produced beliefs or traits. Darwin subscribed to something along these lines, writing in his early notebooks: "Plato says in Phaedo that our '*necessary ideas*' arise from the preexistence of the soul, are not derivable from experience. – read monkeys for preexistence – " (Barrett et al. 1987, 551, M, 128, 4 September 1838). Those of our would-be ancestors who took logical and mathematical reasoning seriously survived and reproduced, and those who did not did not. The devil of course is in the details, and much effort today is being put into finding how learning and like abilities are involved in the overall picture.

Creative artists are an important part of culture, and particularly in literature evolution generally and Darwinian ideas more specifically have been picked up and used and transformed and presented favorably or unfavorably as the writer or the times declared (Essay 54, "Literature"). Before the *Origin*, poets and novelists were using evolutionary themes – Tennyson in *In Memoriam* using Robert Chambers's progressivist vision of life's history to suggest that his dead friend Arthur Hallam was a superior specimen who had come too early, Dickens in *Bleak House* using dinosaur examples to suggest that industrial London was the kind of primitive world that would contain such brutes (see Plate X) – and after the *Origin* they continued with such themes, sometimes directly Darwinian and sometimes less so and more Spencerian and indebted to other evolutionists – Samuel Butler, for instance, using recapitulatory ideas in his late novel *The Way of All Flesh*. The worries and hopes of society can be depicted vividly through fiction. H. G. Wells shared the fears of his countrymen at the end of the nineteenth century that progress was over and only decline lay in the future. These worries come starkly in his novel *The Time Machine*, where in the future our race has divided into two, equally unsatisfactory groups: the Eloi above ground, beautiful but childlike; and the Morlocks below ground, intelligent and hardworking, but vile and ugly. In America then and later, we see the themes of struggle and competition being worked out in fiction, by Jack London and others. And this continues to the present, for instance in the work of the English novelist Ian McEwen, who tries to use Darwinian psychology to show the motivations of his characters. No doubt as we extend our understanding of evolution

in different cultures, we shall see more and more evidence of how creative thinkers have used evolutionary ideas to the particular ends and causes that drive them in their writings.

Increasingly, we have become aware of the extent to which gender issues permeate culture, and the contribution of Darwin – both as part of culture and as an aid to explaining culture – has been a topic of much debate (Essay 55, "Darwin and Gender"). The obvious analysis is that Darwin was a Victorian sexist, especially in his discussions in the *Descent of Man*, and that his thinking has been used to legitimate such sexism, from then until the present, as is shown by discussions to be found in such works as Edward O. Wilson's *Sociobiology: The New Synthesis.* That there is truth in this can hardly be denied. Women are simply portrayed as childlike, obviously lower down the evolutionary scale of being. The Darwin family life was much the same with all being focused on the father and then the sons. Of course, things are never that simple. In the family, it is pretty clear that Emma was in charge, and Charles knew and approved. And the whole point about both natural and sexual selection is that, unless in some fundamental way the sexes are equal, things are out of balance. Fisher was good on this. If it is better to be a boy, then parents are going to have boys, and conversely. This is why it cannot be permanent in those societies today (like India and China) where boys are prized over girls and there is real sex selection. Before long girls are going to be such a rare commodity that parents will strive to get them. Some Darwinian evolutionists have made much of points like these, arguing that in fact we see that evolution has compensated for the features males have. These and like ideas are controversial, but right or wrong, reactionary or visionary, Darwin's thinking is still very much part of the debate.

Fifty years ago, the suggestion that Darwinism might make some contribution to philosophical understanding would have been greeted somewhat like a bad smell at a vicarage tea party. This was not always so. The American pragmatists were very keen on Darwinian evolution, thinking it gave keen insights into the nature of knowledge, its acquisition, and its status. No doubt this enthusiasm was a factor in the decline of appreciation of evolution for philosophy. The founders of analytic philosophy like Bertrand Russell rather thought that pragmatism was not just wrong but positively immoral. But when you think about it, this is surely a wrongheaded attitude. That we are the product of a long, slow, natural, nondirected process of change from probably inorganic material rather than the cherished climax of a Good God's week of creative activity has to matter for both the theory of knowledge (epistemology) and the theory of morality (ethics). And increasingly in the past fifty years philosophers have started to agree.

In respects, especially in epistemology, many of the points made about culture generally (especially about the different possible approaches) apply directly (Essay 56, "Evolutionary Epistemology"). One major question has been whether in some sense a Darwinian account of knowledge implies that one is getting ever closer to a true description of an objectively existing world. One might think so. After all, if fire doesn't really burn, why should we think that it does? However, as has been pointed out, ultimately selection does not really care about truth or objectivity. Being successful in the struggle is what really counts. If we are deceived part of the time or even all of the time, so long as we reproduce, that is what matters. Some critics, notably the well-known Calvinist philosopher Alvin Plantinga, have seized upon this to argue against the possibility of any kind of naturalistic approach – one that depends on blind law – to the world and its understanding. Others doubt one need go that far. From Kant on, it has been appreciated that knowledge is never pure and simple – at the least, we structure experience according to our psychology. Perhaps Darwinism simply takes us further down this path, and we must recognize that while we can certainly distinguish good knowledge from bad – Darwin was right and Sedgwick and Agassiz were wrong – there is necessarily an evolutionary input to all understanding.

Evolutionary morality was very heavily criticized in the years after the *Descent* (Essay 57: "Ethics after Darwin"). One should recognize, however, that the main object of attack was not Darwin, who was mainly concerned to show the origins of morality rather than its justification. The focus of fire was Spencer, who used his belief in the nature of evolution to argue that morally we should promote the evolutionary process because that is the way in which value is kept and increased. The philosophers, first Henry Sidgwick and then G. E. Moore (who introduced his famous "naturalistic fallacy"), argued that claims about matter of empirical fact could not support moral claims. The scientists, notably Thomas Henry Huxley, denied that things are all that progressive and pointed out in any case doing the right thing often means going against our animal nature. The past four decades however have seen a great rise in interest in and enthusiasm for an evolutionary approach to morality. Great credit goes to Edward O. Wilson, who in his writings (especially his *On Human Nature*) has argued that evolution is the key to moral understanding and justification. The general public took up the cause with enthusiasm, arguing in a way that would have excited the Spencer of metaphysical excess and appalled the Spencer of lifelong bachelordom, who lived in a drab boardinghouse that he not get too excited and distracted from his life mission, that now we have justification for even our mortal sins. "Do men *need* to cheat on their women?" asked the *Playboy* cover of August 1978. "A new science says yes," it assured its readers. Most of a philosophical vein, however, deny the neo-Spencerian approach taken by Wilson and make other connections. Great controversy has surrounded the claims of some thinkers that a Darwinian approach points to some kind of moral nonrealism, where morality is simply (to use a phrase) "an illusion put in place by our genes to make us social." In fairness, it should be pointed out that the illusion is not morality itself – modern Darwinians are not into unrestricted rape and pillage – but the belief that morality has an objective foundation. The claim is simply that morality has no base beyond human emotions.

We come to religion. It is appropriate to start with Protestant Christianity, for it was within that version of faith

Figure Introduction.15. In 1925 William Jennings Bryan, three times candidate for the presidency, led the prosecution of John Thomas Scopes for teaching evolution in the public schools of Tennessee. Here, Bryan – having offered himself as an expert witness on the Bible – is being examined by the leader of the defense, notorious freethinker Clarence Darrow. Permission: Smithsonian Institution Archives

that Darwin worked and that so influenced the form of his theory. The problem obviously when it comes to discussing reactions to Darwin is that there is as much variation among Protestants as there is variation among animals in the natural world (Essay 58, "Darwin and Protestantism"). And, expectedly, this is reflected in the reactions to Darwin's theorizing. Some were very comfortable with his ideas, starting with the Reverend Baden Powell (father of the scout master), who endorsed Darwin in 1860 in his contribution to the notorious Anglican, iconoclastic volume *Essays and Reviews*. Some liked Darwin's ideas but wanted to supplement them, as did Asa Gray in America, seeking to give some kind of non-natural direction to new variations. And some rejected the whole message, as did the doyen of American Presbyterians, Charles Hodge at Princeton Theological Seminary. *What is Darwinism?* asked one of his books. "It is atheism" came the stern reply. What does seem to be the case overall is that simplistic pictures of science at warfare with religion are just wrong, and even those most critical often find points where agreement is possible. What also seems to be the case as we come into the twentieth century is that Darwin did continue to fascinate and disturb Protestant thinkers, and this continues to this day. This is hardly surprising given the far-reaching, Darwinian implications for such key Christian notions as miracles and morality and original sin. In 2011 an eminent theologian at Calvin College, a leading American liberal arts college, lost his job because he suggested that perhaps modern evolutionary theory is incompatible with a literally existing Adam and Eve. (It is!) (See Plate XI.)

In discussions about the religious implications of Darwin's ideas, much to the dismay of conventional Protestants, most people have in mind the opposition by a large branch of the American evangelical movement to any and all kinds of evolution (Essay 59, "Creationism"). It is important to note, therefore, that so-called creationists (using this in the modern sense and not of the people whom Darwin was countering in the *Origin*) accept a somewhat idiosyncratic form of Protestantism coming out of America in the middle of the nineteenth century. What is surprising, and probably would be to most of today's creationists, is the historical significance of the Seventh-day Adventist movement, with its emphasis on a literal six days of creation, about six thousand years ago. As a widespread phenomenon, this Young Earth Creationism (YEC) is fairly new. Three-time presidential candidate William Jennings Bryan, prosecuting attorney in the Scopes Monkey Trial of 1925, believed in an old earth, where the six days of creation are to be interpreted as six long ages (Fig. Introduction.15). YEC really caught fire only in the 1960s with the publication of *Genesis Flood* by biblical scholar John C. Whitcomb and hydraulic engineer Henry M. Morris. The fondest hope of its advocates is that it be introduced into publicly supported schools (in the United States) alongside teaching about

evolutionary origins. Thus far, the First Amendment separation of church and state has been effective in denying fulfillment of this hope, both for YEC and for its somewhat milder successor "intelligent design theory." Whether this will continue to be the case remains to be seen, as also the extent to which these various views will be able to establish themselves beyond the American borders.

Having found themselves in hot water over the Galileo affair, Catholics generally have been happy to sit back and let Protestants fight the battle over Darwin (Essay 60, "Darwin and Catholicism"). This is not to say that the ideas were universally accepted, even though there were some early Catholic converts to some kind of (generally guided) evolution. There was a condemnation of the materialism thought inherent in all evolutionary theories, especially Darwin's – although in fairness, it should be noted that a lot of the early opposition was primarily a function of general issues facing the church and was part of the general move to a much more conservative position after the unification of Italy. The twentieth century saw a slow but increasing acceptance of evolutionary ideas. Almost paradoxically, the thinker who did most in the twentieth century to bring evolutionary science and Christian religion together fruitfully was the Jesuit priest and paleontologist Pierre Teilhard de Chardin. He was forbidden to publish (while he was alive) by his church, and when his ideas did appear in print (around the time of the hundredth anniversary of the *Origin*), he was scorned by the scientific community. But in the years following, the spirit if not always the details of his thinking has gained more and more respect. Not that this means that, even now, the church thinks all that creatively about evolution, looking for ways in which the science might enrich the theology rather than threaten it. However, the way is open for such thinking, thanks especially to the fact that, almost at the end of the century, Pope John Paul II gave a surprisingly strong endorsement not only of evolution but also of Darwinian ideas. As always, things were somewhat qualified, by insisting that the creation of souls (as nonscientific notions) stands beyond science. But the principle of creative interaction is acknowledged and expected.

Christianity and Darwinism are like parent and child. You think they are different, and then suddenly when least expected, in the half light, you see a staggering similarity – origins, trees, design, humans, and more. Focusing on that relationship is not prejudice against other faiths but simple recognition of history. But, of course, the story does not stand still, it is not finished, and it certainly is not isolated. By the middle of the nineteenth century, Jews in Western Europe particularly were integrating more and more into general society, and this continued and intensified with the great migration across the Atlantic (Essay 61, "Judaism, Jews, and Evolution"). Naturally prizing education and learning, Jewish teachers and intellectuals encountered and starting contributing to science in major ways, and this has continued to the present – in Israel too since the founding of that country. In some significant respects, one sees a mirroring of the Christian response to evolution. The more liberal parts of the group, particularly the Reform branch of Judaism, accepted evolutionary ideas reasonably readily. More conservative parts of the group, particularly the conservative and Orthodox branches, had more trouble, and especially in ultra-Orthodox branches the opposition to evolution continues strongly to this day. But, as with conservative Christians, it is dangerous to generalize too facilely or readily, for there are Orthodox Jews who are very comfortable with evolution, with Darwinism even. What is still far from fully understood or researched are the implications of the differences between Judaism and Christianity. For instance, given that the design argument has not played the role for Judaism that it has for Christianity, does this mean that selection has less hold on the Jewish evolutionist than it has for the Christian (or Christian-cultured) evolutionist? The late Stephen Jay Gould used to claim that, because he had no Christian upbringing, he was no ultra-adaptationist; although in his case perhaps an argument can be made for the secular, very left-wing milieu of his childhood rather than anything specifically Jewish.

The interaction of Darwin and Islam is a rather different story, for here we truly do have the meeting of alien world pictures – a meeting that was bound to be slow at first, because of the widespread illiteracy in Muslim countries and the lack of interest in science generally (Essay 62, "Religion: Islam"). The *Origin* was not translated into Arabic until well into the twentieth century. As was the case of the spread of evolutionary ideas in countries like China and those of South America, often the interest in evolution was less in its virtues as science and more for its supposed ideological components, materialism and so forth. It is not surprising that evolution was popular early in the past century among the reforming "Young Turks" opposed to the status quo in the Ottoman Empire. Moving down toward the present, one finds that (as one might expect, given that Islam is so widespread a religion over many lands and cultures) there are all shades of acceptance of evolution, although (as is still the case with many Christians) often even when positive it is some kind of theistic evolution that is most favored. But, again perhaps a function of ignorance and illiteracy, one finds that most people in Muslim lands either reject evolution or are indifferent to or ignorant of the whole idea. A form of creationism, not entirely unlike its American counterpart, is spreading (especially in places like Turkey). As always, one suspects that underlying the motives are factors more from the cultural and moral or social realm than from pure science. Darwinism is caught up in more general debates about Western culture and its worth.

And so finally we come to evolution and medicine (Essay 63, "From Evolution and Medicine to Evolutionary Medicine"). This has not been left to last by default. Anything but! Rather, it is one of (if not the) newest branches of the Darwinian family, really only just starting to develop and gain ground. It seemed appropriate to end the volume on something that is so very definitely looking forward and not back – if that is not too much of a paradox for a field that derives

its very being from history. Actually, from Darwin on, there was concern about human health and whether evolution can throw light on its problems. Are we breeding the wrong kind of people, the weak and the sick and the profligate? This led to many years of theorizing and of proposing solutions for its amelioration – so called eugenics. Primarily because of the appalling events in Germany under the Third Reich, outright calls for the biological alteration of humankind are now less common, although vestiges of eugenics still persist under such more friendly names as "genetic counseling." But now we have a rather different approach to human health, one that plunges right into questions about sickness and disease and tries to uncover pertinent evolutionary facts and implications. For instance, why do we have fevers and what should we do about them? The usual advice is to take a painkiller and reduce the temperature. But what if the high temperature has some real biological value in fighting infection – a fever is an adaptation? At a more complex level, how should we understand serious problems like high blood pressure in pregnancy? Could it be that it is a result of mother and fetus fighting it out for supremacy, the mother having one set of biological interests and the infant having others?

No one would pretend that we have now a fully fledged area of medical science, and expectedly often the ideas have to fight to be taken seriously. Back in the years after the *Origin*, Huxley was much involved in reforming medical education and working to see that basic biology became part of the training. But although he made anatomy and physiology required subjects for would-be doctors, he never thought to push evolutionary studies as part of the curriculum. He (no big friend of natural selection) could see no good reason for this in the program. Such thinking continues to this day. But evolutionary medicine is growing and gathering more and more supporters, significantly among younger researchers, and the hope is that one day it too will take a full place at the table of Darwinian evolutionary studies.

This is for the future. Now the time is to turn to the individual essays of the *Encyclopedia*. Their broad range and their exciting content speak without need of further proof of the importance of Charles Darwin and his theory of evolution.