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Charles Darwin

The English £10 note (about $20) carries a picture of Queen Elizabeth on the front and, on the back, the picture of an old man, with a wonderfully full beard. Every English child knows whose portrait this is, even if many are not really quite sure why he is so famous. It is the picture of Charles Darwin, one of the truly great scientists of all time. Let us learn something about him.

The early years

Charles Robert Darwin was born on February 12, 1809, in the English midlands town of Shrewsbury (the first syllable pronounced to rhyme with "blows" not "blues"), the same day as Abraham Lincoln across the Atlantic (Browne 1995, 2002). He died at home, in the Kentish village of Downe, on April 19, 1882. He was the fourth of five children, the second of two sons, of Dr. Robert Darwin. His paternal grandfather was Dr. Erasmus Darwin, a physician, who died before his birth. Erasmus Darwin was an eighteenth-century figure, well known not just for his skill at medicine (poor, mad King George III tried to get him to come to court), but also for his interest in science and technology (King-Hele 1963). He was one of a number of inventors and businessmen – including Matthew Boulton (the industrialist) and his partner James Watt (inventor and improver of the steam engine), Joseph Priestley (the chemist), Samuel Galton (the gun maker), and William Withering (botanist and discoverer of digitalis) – who were members of the so-called Lunar Society, which met once a month to discuss matters of science and technology and

their application to industrial questions. Erasmus Darwin was also a poet and an evolutionist. He believed that all organisms come from (probably) one original form, and then develop through time into the different kinds that are revealed from the past and around us today. Poetry and evolution often overlapped in the world of Erasmus Darwin, for he was much given to expressing his scientific speculations in verse.

Robert Darwin was a physician like his father, at least as well known and respected for his knowledge and his skills. Dr. Darwin was also a very important money man. Given his wide clientele, he was in a perfect position to bring together aristocrats in need of cash and with lands to mortgage and industrialists with cash to loan and seeking safe investments. As is common in these cases, then and now, this proved very profitable for the middleman, who was soon in the moneylending business himself. Even more wealth poured into the Darwin family from Charles's maternal grandfather, Josiah Wedgwood (a friend of Erasmus Darwin and a fellow "lunatik"), the man who brought the Industrial Revolution to the pottery business, learning and applying the Asian techniques in making what became known as bone china. The marriage settlement of Darwin's mother was very significant.

It is worth emphasizing these points, because at once we can start to put young Charles into context. He was not an aristocrat, but he was a member of the rich, upper-middle classes, the people who had done (and continued to do) very well out of the Industrial Revolution. One would expect him to be a solid citizen with a strong vested interest in his country and to appreciate its overall stability; yet probably more of a liberal, favorable to the innovations that machines and factories were bringing to Britain, than a conservative, who deplored every change to life as it had been in the eighteenth century and earlier; a man who favored reform but not revolt. One would also expect him to be happy with his lot, and not about to reject or repudiate it. In other words, however much of a scientific revolutionary Darwin was to be – and I believe he was a very great scientific revolutionary – he would not be like the Christian God, creating things from nothing. One would expect – and the expectation is fully realized – that Darwin would take what was given and (rather like a kaleidoscope) make of it a new picture. To understand Darwin is – as any evolutionist would have forecast – to understand his past and his influences.

Charles Darwin's genius was always more of the creative-bright than the IQ-bright variety. He was an indifferent student at school, where merit went to those clever at writing Greek and Latin verses or mastering the intricacies of Euclidean geometry. From an early age, however, he was interested in science. Charles and his older brother, also called Erasmus, used to do simple home experiments in chemistry. Given the great importance of that particular science in technological applications of pure theory, this was just what one might have expected of two children of the Industrial Revolution. Expecting to follow in the family profession, at a young age (16) Charles was packed off to Edinburgh, then the home of the finest medical school in Europe. Two years later – revolted by the operations and bored by the professors – he had had enough. Following his own inclinations, he had taken up natural history with a vengeance, but this did not compensate for living with the Scots in their gloomy capital. His family therefore redirected him to the perfect career for a young Englishman with considerable wealth and little obvious talent. He was to become an Anglican (that is, an Episcopalian) clergyman. To achieve this, Darwin had to have a degree from an English university. And so, early in 1828, Charles Darwin enrolled at Christ's College, at the University of Cambridge.

As someone who was already starting to show an interest in science, this was a good time for Darwin to go to Cambridge. Although there was no formal science teaching, a number of the professors were becoming very interested in science and were willing to admit to their number young men who shared their enthusiasms. Darwin soon became friendly with John Henslow, the professor of botany, Adam Sedgwick, the professor of geology, and William Whewell, then the professor of mineralogy but later to become the professor of philosophy (a career change one doubts has been replicated that frequently). Although these professors had no specific obligations in pursuit their subjects – and hitherto no incumbents had felt obliged to pursue them actively – now people were beginning to explore the world of nature and to marvel at its wonders. One should add that, at Cambridge, this was always done in a religious context and generally involved looking at nature to praise the abilities of the Creator. In those days, a professor at an English university (Oxford being the only other) had to be an ordained member of the Church of England (Anglican).

Darwin fit happily into this group, not only because of the science, but because at that early date he himself had no qualms whatsoever about the truths of Christianity or the Thirty-Nine Articles, subscription to which was a necessary condition for those who belonged to the state church. He clearly impressed his seniors because, when he graduated in 1831, through the connections of the Cambridge science group, he was given the opportunity to spend several years on board HMS *Beagle*, a British warship that was to chart the coasts around South America. Postponing his clerical career – the prospect of which was never formally repudiated but gradually and gently faded away – Darwin ended by spending five years on the ship, eventually circumnavigating the globe, before it returned to England in the autumn of 1836. Originally his status on the ship was primarily that of a companion to the captain, but rapidly he became the ship's naturalist, and spent a considerable time studying the flora and fauna of the lands that he visited, sending massive collections back home for study by the appropriate specialists.

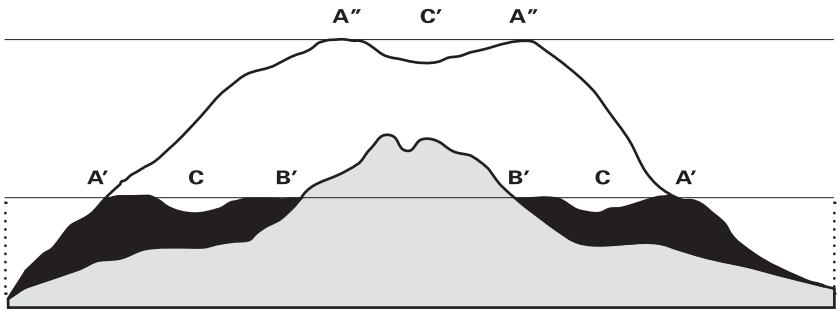
Charles Darwin was to make his great mark as a biologist, but in the early years he focused more on geological questions (Herbert 2005). Around 1830, as Darwin started to enter the ranks of professional scientist, geology was a science with a significant profile, if only because of its commercial importance. Road building, canal digging, mining – all of these were essential activities in the Industrial Revolution, and with the coming of the railways the importance of geology was magnified. No one wanted to tunnel through solid granite, or to lay a track across land that would start immediately to subside. There were two main theories about the earth and its geological past. On the one hand, there were the so-called "catastrophists" (like almost every other scientific term of the day, this was coined by Whewell). They believed that every now and then in earth history there had been massive upheavals of a kind not now experienced, and that these had created the mountains and valleys and rivers and seas that we have around us today. Probably these upheavals were not themselves miraculous – that is, events outside the ordinary lawbound course of nature – although the general opinion was that such events resulted in the creation of new species of organisms and this process

was surely non-natural. On the other hand, there were what Whewell labeled the "uniformitarians." Represented most importantly by the Scottish-born lawyer turned geologist Charles Lyell, they argued that the ordinary everyday processes of nature – rain, snow, freezing, warming, deposition, erosion, earthquakes, volcanoes, and more – could do everything (Rudwick 1969). Everything, that is, if there were a virtually infinite bank of time on which nature could draw repeatedly. In his *Principles of Geology*, the first volume of which appeared in 1830 and the other two in the years succeeding, Lyell argued for an entirely "actualistic" position (as we now call it): there is nothing in the past that was made by processes that do not still occur in the present and at the same intensities. About organisms, Lyell was somewhat more ambiguous, but overall the reader's impression was that (with the exception of humans) their appearance and disappearance was likewise entirely natural, no special, miraculous interventions being necessary. Ambiguity increases because, as we shall see in a moment, whatever the origins of organisms, apparently they were not evolutionary.

Before he left on the *Beagle* voyage, Darwin enjoyed a crash course on geology with Sedgwick, a leading catastrophist. But he took with him the first volume of Lyell's *Principles* (the later volumes being sent out to him), and at once became a total convert to uniformitarianism. This led to Darwin himself doing a notable piece of scientific theorizing. Among the fascinating phenomena that one finds in tropical waters are the rings of coral that surround islands, or sometimes indeed only the rings, with no islands in the center. Lyell had suggested that perhaps these were the rims of now extinct volcanoes, just breaking the surface of the sea. Darwin pointed out how improbable this must be – so many volcanoes and just at the right height – and argued instead that, since coral can grow only at the surface of the sea, perhaps the islands were sinking and the coral kept growing up to stay at the same (surface) level. Even where there were now no islands, there had once been such lands poking above the waters (Figure 1.1).

Today, general opinion is that Darwin was right. For us, however, the coral reef theory is more than the first fruits of Darwin's creative thinking. It shows how firmly Darwin's worldview was embedded in the Lyellian system. Underlying the catastrophist/uniformitarian

Section of coral reef



A′A′	Outer edges of the barrier reef at the level of the sea with islets on it.
B′B′	The shores of the included island.
CC	The lagoon channel.
A″A″	Outer edges of the reef, now converted into an atoll.
C′	The lagoon of the new atoll.
	NB According to the true scale, the depths of the lagoon channel are much exaggerated.

Figure 1.1 Darwin's illustration of his coral reef theory (redrawn from Charles Darwin, *The Structure and Distribution of Coral Reefs.* London: Smith, Elder and Company, 1842, p. 100)

debate was a difference about the putative direction of our planet's history. The catastrophists generally saw the history of the earth as being directional, from hotter to cooler. They tied this direction in with the different organisms that are revealed in the fossil record, arguing that only now was our globe fit to support humankind and the other extant plants and animals. Lyell, to the contrary, saw the earth in a kind of steady state. There may be some fluctuations, but, as with a sine curve, the changes are always within fixed limits. How then could one account for such changes as there were – notably (what the catastrophists held up as their prime piece of evidence) the fact that the fossil plants around Paris suggest that in the past the area was very much warmer than it is today? To speak to this, Lyell introduced what he called his "grand theory of climate" – that the

relative temperatures of land and sea are not, as one might think, a function of the distance from the equator, but more of the overall distributions of land and sea around the globe. As these change, so the climates change. Using as his primary evidence the warming effects on Britain of the Gulf Stream, Lyell argued that limited changes occur because the earth is a bit like (to use a modern metaphor) a water bed. Deposition in one area causes the underlying land to sink. This is matched by rising in other areas, thanks to erosion.

Darwin's coral reef theory was a perfect exemplar of the theory of climate. The land beneath the islands was sinking because of the ever increasing buildup of coral. Elsewhere the land must be rising. As it happens, just after the *Beagle* voyage Darwin thought that he had found just such an instance in the Scottish highlands. There is a small valley, Glen Roy, with parallel tracks or roads around its sides. Reasoning that these are the beaches from now vanished water, Darwin argued that once the sea ran into the glen, but since then the land has risen and the sea has vanished – the rising land being a counterpoint to the sinking islands. A nice solution, albeit false: Darwin was quite mistaken. In the last Ice Age, the entrance to the glen was blocked by a glacier. When it melted, the lake that had accumulated behind it ran out.

Darwin the evolutionist

With hindsight, we can see that Darwin's commitment to the climate theory was truly crucial. It explains the sorts of things that he was directed to study. Any scientist will tell you that the answers are easy. The hard part is finding the questions. Following Lyell, Darwin became fascinated with the distributions of organisms, both through time as shown in the fossil record, and through space as shown by geographical distributions. Although he was opaque about the actual origins of organisms, Lyell thought that new organisms tend to be much like those just a little older. Hence, by looking at successive layers in the fossil record one can get ideas about whether or not the land has risen, and by looking at living organisms today one can get ideas about how the geology has changed over the ages. If, say, the animals on either side of a mountain range are very similar, then this suggests that the range is fairly new.

Thus primed, the crucial event for evolutionary thinking came when, in 1835, the *Beagle* visited the group of islands on the equator in the Pacific, the Galapagos archipelago. It is not easy to say just how much the whole question of evolution was now of interest to Darwin. He certainly knew about evolutionary ideas. He had read *Zoonomia*, his grandfather's major prose work on the subject. He had discussed evolution when a teenager at Edinburgh with an enthusiast for the idea, and no doubt the topic was aired at Cambridge by the senior scientists, who were anything but enthusiasts for the idea. Then, in the second volume of the *Principles*, Lyell had discussed the evolutionary ideas of the French biologist Jean-Baptiste Lamarck (1809). Lyell's verdict was negative, leading one to suspect that his silence on the positive aspects of organism appearance was truly a function of total ignorance. Nevertheless, although Lyell himself did not sign up to the Frenchman's ideas, his review was sufficiently thorough that more than one person was converted to evolutionism by the discussion. And Lyell's own ambiguity on the topic of organic origins was certainly enough to stimulate the thinking of a bright young disciple. Indeed, piqued by the less than adequate musings of Lyell, the philosopher and astronomer John F. W. Herschel shortly afterwards described the whole question of the origins of organisms as the "mystery of mysteries" – a phrase that Darwin was to use later to preface his own public announcements on the topic (Cannon 1961).

So we know that, as the *Beagle* voyage was coming to an end, Darwin was at least aware of these issues. However, there was to be no immediate road-to-Damascus experience. The Galapagos Islands are very close together, most just a few miles apart. As was his custom, Darwin started making collections of the life found there, particularly the little birds (finches and mockingbirds) on the various islands. There were clearly different species, but it never dawned on Darwin that it might matter which islands the birds occupied. After all, he had just spent several years in South America (Darwin spent much time on land as the *Beagle* worked on charting the coast) and he had seen that, for some species, their members are often in very different and distant habitats. Then the sun did rise and shine. By dining with the governor of the Galapagos, Darwin began to recognize the island differences. Famously, the Galapagos are home to giant tortoises and Darwin learnt that there are recognizably different species on different islands (Figure 1.2). The same was almost certainly true of the

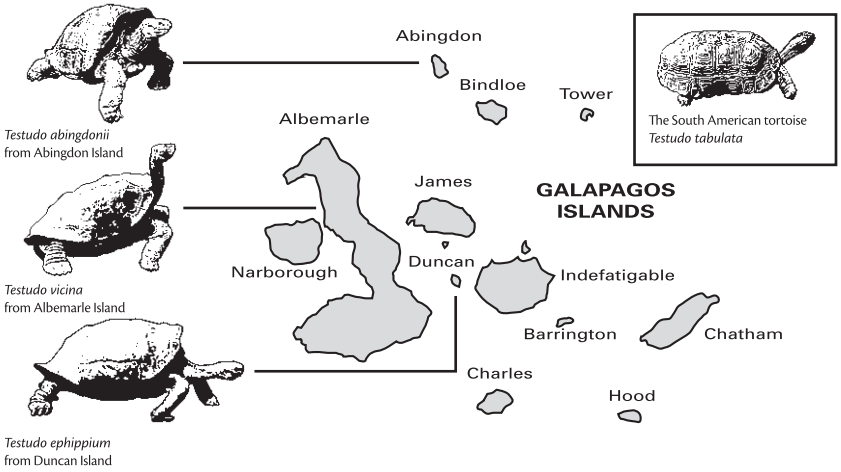


Figure 1.2 Distribution of Galapagos tortoises

birds, and to a Lyellian geologist this surely had to mean something. Biogeography does not happen by chance, and it was clear to Darwin that the denizens of the Galapagos were very similar to (although different from) the denizens of the mainland.

Something significant was at issue, but still Darwin hesitated to hypothesize. The big conceptual move was made in the spring of 1837. Darwin was back home looking at, and trying to make sense of, his collections. He realized that the only sensible answer to the island differences was that original animals had come from the mainland, and once on the Galapagos had changed and evolved after they moved from island to island. Charles Darwin moved across the divide, never again to think that species are fixed, for ever to think that life is in flux. Yet, at the same time, he knew that such a belief would not be viewed with favor by the older members of his group. Hence, Darwin kept very quiet about his thinking, even as he now opened the notebooks in which he began to speculate.

Being a graduate of Cambridge University was a significant factor at this point. Isaac Newton was the university's most famous scientist, and he was a model for all who followed. Most particularly, he was a model for those who aimed to be honored in the halls of science. Newton showed the way. His great achievement was to provide a causal solution to the new physics: his force of gravitational

attraction tied together the cosmological speculations of Copernicus and Kepler with the terrestrial mechanics of Galileo. All was now seen to be part of the same system. An ambitious young scientist who wanted to do the same in the life sciences – to be the "Newton of the blade of grass" as Kant had called him (1790; Kant 1928), while denying that such a person could ever exist – had to come up with a causal solution to the problem of organic origins, had to put a Newtonian force behind evolution.

This was Charles Darwin's project until the end of September 1838, when finally he came to the solution. Early on, thanks to his agricultural connections (Shrewsbury lies right in the heart of farming Britain), Darwin realized that the key to changing the forms of animals and plants is systematic selection. The breeder takes his best stock and uses these, and only these, as the parents of the next generation. Rapidly, one gets shaggier sheep and beefier cows and redder and bigger strawberries. What Darwin could not see was how something like this could ever occur in nature. Then – and it is this sort of thing that bears out what I said about Darwin using the ideas that were fed to him – he read a rather conservative socio-political tract by the Anglican clergyman Thomas Robert Malthus. In his *Essay on a Principle of Population* (6th edition, 1826), the first version of which had appeared at the end of the eighteenth century, Malthus was concerned to oppose what he thought were prevalent and unsupported views about the onward progress of humans and their civilizations. Malthus's was a much darker view of life, at the same time one trying see how God had arranged it that we humans do anything at all. Why do we not just sit around doing nothing? The answer came in a famous deduction. Space and food supplies can at best be increased arithmetically (1, 2, 3, 4, . . .), whereas, unchecked, population increases geometrically (1, 2, 4, 8, . . .). There will be inevitable clashes – what Malthus called "struggles for existence"; and grand schemes to alleviate poverty and so forth are bound to end in failure – if anything, they will only make things worse for the next generation. In later versions of his *Essay*, Malthus allowed that such struggles might be avoided if we exercise what he primly called "prudential restraint." I am not sure that he ever truly believed this to be possible in real life. Although his name today tends to be linked to the need for contraception, Malthus himself recoiled in horror at such a disgusting practice.

Darwin seized on the Malthusian ratios, and had there, in his hand, the force behind a natural form of selection. More organisms are born than can survive and reproduce. There is natural variation in populations in the wild. The successful in the struggle (what came to be known as the "fit") will be different from the unsuccessful, and on average and in general the success will be a function of the different characteristics: the successful will be a bit better camouflaged than the unsuccessful, or a bit stronger, or able to go with less food and water, or whatever. Over time this will lead to full-blown change; change, moreover, of a particular kind, namely that which makes for "adaptations" to organs like the hand and the eye that help their possessors in the struggle to survive and reproduce. So we have the biological equivalent to Newtonian gravitation – natural selection or (as it later was called) the survival of the fittest.

The Origin of Species

The private Darwin worked on these ideas for the next five or six years, in 1842 writing up a 35-page sketch of his thinking and in 1844 a 230-page essay (Darwin and Wallace 1958). These remained hidden from view. The public Darwin was now becoming known as a very good young scientist, and also as a travel writer. Darwin's journal from the *Beagle* voyage was published, and quickly made him a known figure in the young Victorian era. (Queen Victoria came to the throne in 1837, and remained there until 1901.) For reasons that are still not fully understood, Darwin started now to show symptoms of an illness that reduced him from the vibrant young adventurer of his youth to the invalid that he was to become and remain for the rest of his life – indigestion, headaches, boils, bad breath, and flatulence, among others. Perhaps it was something physical, possibly a disease picked up in South America; perhaps it was psychological, the stress of his work and his ideas; perhaps it was a consequence of the many appalling potions with which the Victorians dosed themselves, the mildest of which were drugs that today would earn you a long prison sentence. Whatever it was, Darwin became the victim of his ailments. Early in 1839 he married his first cousin, Emma Wedgwood, and with the large settlements that they both received he bought a house in Kent not far from London, where he and Emma set about having and

raising a large family. There were ten children, seven of whom lived to maturity.

Darwin became a near recluse, though, as his biographers, often note, a recluse who used his illnesses as an excuse to avoid burdensome meetings and other duties. Over the years, as it suited him, he kept in touch with the scientific community, and indeed made new friends among the younger members. Lyell (older than Darwin) persisted as a friend, as did Henslow. Joseph Hooker, a botanist and son of Sir William Hooker, the superintendent in charge of the Royal Botanic Gardens at Kew, became a good friend, and then somewhat later, in the 1850s, the young morphologist Thomas Henry Huxley joined the circle. It is clear that people did truly love Darwin, for in person he was warm and friendly and no doubt genuinely so. However, he used his friends and many, many correspondents as his eyes and ears, to do much of the groundwork of science for him, particularly information collecting, as he turned into a truly obsessive worker, laboring without a break, save only for periods of inactivity brought on by illness.

For reasons that are still not quite clear, Darwin repeatedly postponed the publication of his thinking about evolution. A major factor undoubtedly was that in 1844 an anonymous author – we now know him to have been Robert Chambers, a Scottish publisher – published an evolutionary tome, *Vestiges of the Natural History of Creation*. Crude on science, bold on speculation, it caught the public imagination and drew the excoriation of the Cambridge scientific community, especially Sedgwick and Whewell. Their brightest student was not about to stir up that pot publicly. So, Darwin finished writing books on the geology of the *Beagle* voyage and then in the mid-1840s turned to what was to become an eight-year obsession with barnacle classification – an obsession pursued by dissecting the rather smelly invertebrates sent to him from all over the world, and which led to the publication of massive works on the living species and more tomes on the fossil representatives.

Finally, in the 1850s Darwin turned back to the question of organic change, and began writing a huge work on evolution. This was interrupted in the summer of 1858 by the arrival of an essay from a young collector and naturalist, then in the East Indies. Alfred Russel Wallace had hit upon virtually the same ideas as Charles Darwin had found some twenty years before. Quickly, Lyell and Hooker

arranged for the publication, by the Linnean Society of London, of Wallace's essay together with selected pieces from earlier (hitherto private) writings by Darwin. Then Darwin sat down and in fifteen months wrote up what was published towards the end of 1859 as his definitive statement on the subject: *On the Origin of Species by Means of Natural Selection, or, The Preservation of Favoured Races in the Struggle for Life*. After a long, long delay, Darwin's theory of evolution was there for all to see. An oft-noted but not terribly important point is that Darwin never used the word "evolution" in the *Origin*. "Evolution" was a term only then coming into use to denote the change of species through time, and its use was confined mainly to the change of the individual embryo as it developed. Many used the term "transformation" to mean what we now mean by "evolution." Darwin generally wrote of "descent with modification," although as it happens the last word of the book is "evolved."

Reception

We all know that there was a huge row after the *Origin* was published. But, truly, how successful or unsuccessful was Darwin? This much can be said with near certainty. Very quickly, respectable opinion in Britain and elsewhere in the world (Europe and much of the northern USA, as well as the British Empire) came to accept the evolutionary theory that all organisms, living and dead, are the end results of a long, slow process of law-bound change. This even applies to humans, although most commentators jumped in to argue that souls or spirits require interventions from above. It also seems true that evolution was accepted by most segments of society. Benjamin Disraeli, soon to become the conservative prime minister of Britain, jokingly protested that he was on the side of the angels against evolutionists, but the middle classes and the thinking members of the working class (and in those days there were many such people) embraced organic change. Moreover, although religious people tended more to caution on these matters, in that quarter also there was considerable acceptance of evolution.

It is always hard to justify generalizations of this kind and there have been many exceptions (especially in the American South), but scholars have done very extensive surveys of the literature and

especially of the popular journals, newspapers, and magazines (Ellegård 1958). It seems well borne out that acceptance of evolution came quickly. Charles Darwin was a high-profile, well-respected man: his *Beagle* book was a Victorian standard, his barnacle work had turned him almost into a parody of the scientist who spends much time learning more and more about less and less, and his position as a man of solid status (large family, faithful wife, devoted servants, friend of the clergy and squires of the neighborhood, magistrate who judged poachers and other transgressors), who struggles on despite crippling illness, had earned him the affection of his countrymen. It was easy, it was comfortable, to agree with Darwin. He represented all of the things his generation thought praiseworthy. Like the little boy who cried out "But the emperor has no clothes," as soon as Darwin cried out "But evolution is true," within ten years or so almost everyone agreed. And those who disagreed took care to moderate their objections. My favorite piece of confirmatory evidence is the speed with which the examinations at English universities changed from demanding discussion about evolution as such to discussion about the causes.

For here indeed there was continuing controversy (Hull 1973). Most people agreed that natural selection could cause some change. Very few agreed that natural selection could cause all change. There were some serious scientific issues at stake here. In the first place, and most troubling, Darwin had no decent theory of heredity – what we today would call genetics. He needed two things for selection to work properly: a constant source of new variation and a way in which such variation can be transferred from one generation to the next. From detailed study of populations in the wild, not the least of which were his barnacle species, Darwin was convinced that such variation does occur, but he had no real theory to account for why it occurs. Moreover he had no real theory of how such variation gets passed on. A real stumbling block seemed to be that in each generation variations tend to get blended and watered down – a black man and a white woman have a brown child – and it seems that in but a few generations any new feature, however valuable in the struggle for existence, is swamped and wiped out. Darwin certainly knew of features that were not blended and wiped out – sexual features, most obviously. In the mid-1860s he proposed a theory of heredity, "pangenesis," showing how physical features could be preserved,

proposing that little gemmules are given off all over the body and collect in the sex cells. Moreover, in later editions of the *Origin* Darwin stepped up the inheritance of acquired characteristics (so-called Lamarckism) as a source of new variation. But ultimately he never really got on top of this problem.

Darwin's other major scientific problem concerned the age of the earth (Burchfield 1974). Darwin never truly specified just how old he thought the earth must be, although in the first edition of the *Origin* he did try his hand at making estimates about the time it had taken for erosion to occur in the part of England where he lived. What he and everyone knew was that a great deal of time had been needed for so slow a mechanism as natural selection to be effective. And this the physicists of his day refused to allow. By working from such factors as the radiation from the sun and the saltiness of the sea, the popular estimate of the earth's age was around a hundred million years, dating from the very beginning of time, when everything was molten and hence far too hot to sustain life. Darwin wriggled as best he could on this question, but here too he recognized that there was a major problem – as, of course, we now know that there was, though it was not Darwin's. The physicists were ignorant of radioactive decay and its warming effect. Now it is thought that the earth is 4.5 (American) billion years old, and that for about 3.75 billion years it has been sustaining life – quite long enough for even a slow process like natural selection.

What did people suggest instead of selection? They were all over the place. Some went one better than Darwin and made the inheritance of acquired characteristics the main driving force behind change. Some, like Thomas Henry Huxley, supposed that occasionally there is a big jump from one form to another, with no intermediates. (This is known as "saltationism," from the Latin *saltus*, "a jump.") Yet others thought that perhaps there is a kind of inner momentum to evolution and that, rather as in embryology, once a species gets going it develops its own internal forces that drive it into new directions and forms. There was one drawback that many of these rival proposals had in common: if you were an active scientist looking for a tool of research, they were not awfully useful. Natural selection was significantly different, for all that most did not take it up: one could apply selection to actual problems, trying to crack them. One man in fact did just this. Henry Walter Bates (1862; Bates 1977), a traveling

companion of Wallace, became fascinated with animal mimicry, particularly the way that Amazonian butterflies that were not poisonous would mimic those that were. He argued that selection was responsible, and performed simple but effective experiments to show this. But, with the possible exception of Lamarckism (the theory of inheritance of acquired characteristics), other suggestions simply did not lend themselves much to experiment or test. Major jumps might have happened, but when and how and why and what? Momentum might be important, but what was it and how did it function and was it always in the direction of adaptation?

Evolution as secular religion

The plain fact is that, after Darwin, there simply was not a great deal of interest in causal questions. A lot of people were keen on uncovering the history of life. Although by the time of the *Origin* the main outlines of the fossil record had been established, it was in the decades after the *Origin* that the record was really opened up, especially in America, which poured forth hosts of beasts from the past – Amphicoelous, Allosaurus, Ceratosaurus, Camarasaurus, Diplodocus, Camptosorus, Brontosaurus, and many, many others. More than this. There were many speculations about past histories, drawn by analogy from embryological development. As goes the individual, so apparently goes the group. The German evolutionist Ernst Haeckel (1866) popularized this kind of reasoning with his so-called "biogenetic" law: ontogeny (the development of the individual) recapitulates phylogeny (the development of the group). But when it came to causes, especially causes as the basis for an ongoing evolutionary research program, interest dropped right through the bottom.

The truth is that even Darwin's greatest supporters – in fact, especially Darwin's greatest supporters, if you think of Huxley – did not want to use evolutionary ideas as the foundation of a professional, university-based, area of research and inquiry (Ruse 2005). They wanted to use some parts of biology in this way, for this was the very time when (in Britain and then somewhat later in America) the whole profession of science was being organized and made into a career opportunity for a bright young scholar. This was tied in with more

general changes in the ways that the countries were run – toward a world where merit and education rather than simply inherited wealth and status would be the deciding factors in a person's success. These organizers knew full well that if they were to achieve their aims, then they had to show their fellow citizens that what they had to offer were goods that were generally desirable. Organization and reform had to point to future benefits and payoffs. Huxley and friends were very successful at this. Physiology they sold to the medical profession, offering to produce well-grounded biologists who could then go on to medical training, furnished with a solid background in basic science. Anatomy they sold to the teaching profession, arguing that hands-on experience of cutting up fish and rabbits would be better training for real life than rote learning of Latin and Greek. Huxley himself offered summer schools for teachers. His most famous pupil was the novelist H. G. Wells.

Evolution did not make these sorts of promises. It did not cure a pain in the belly and it seemed too risqué for straight, schoolroom teaching. However, there was one use to which it could be put, namely as a kind of ideology – secular religion, if you like – that could substitute in the minds of the new men and women for the old superstitions (otherwise known as Christianity) of the past. Rightly, Huxley saw the Church of England as allied with all of the conservative forces in Britain against which he and other reformers were battling, and evolution fit the role of a kind of popular science or world picture that could replace it. Like Christianity, evolution told of origins, it told of humankind and (in the opinion of Huxley and friends) it put us not only last-appearing but at the top, and for many it offered a kind of up-to-date version of the Sermon on the Mount. We will learn more later about "social Darwinism," but in essence it directed people to do whatever will best further the survival and continued success of the human species, most particularly that fragment of the human species to which this kind of evolutionary enthusiast belonged. In short, far from being a vigorous new branch of science – which had surely been Darwin's aim when he wrote the *Origin of Species* – evolutionary theorizing became a part of the social fabric of forward-looking Britain (and America and elsewhere). It was popular, but with hindsight not necessarily for the right reasons or for the right purposes.

Darwin on humans

What of Darwin himself after the *Origin*? For the two decades left to him, he kept working hard. He wrote books on a variety of topics, from orchids to climbing plants, from agriculture to earthworms. His main work, however, was on our own species, *Homo sapiens*. Darwin had never doubted that we humans are part of the world of life. We must have evolved and for essentially the same reasons as other animals. HMS *Beagle* carried, and returned to the tip of South America (Tierra del Fuego), three natives, who had been taken on a previous voyage and educated in England. Within a very short time, these three, who had apparently acquired a solid veneer of British culture, reverted to their original state of complete savagery – at least as judged by the young ship's naturalist. Darwin learnt a lesson that he never forgot. The line dividing the most refined of humans and the most degraded of brutes is very fine indeed. It is remarkable how, at a time when everyone else was jumping around and arguing over the question of the status of humans – going against his own philosophy, Lyell could never quite bring himself to think that human origins were entirely natural – Darwin was entirely cold-blooded on the matter. We are animals. End of argument. Most significantly, the very first (private notebook) jottings that we have dealing unambiguously with natural selection, from late in 1838, apply the mechanism to humans – and to their mental abilities, into the bargain.

In the *Origin*, wanting first to get his basic theory on the table as it were, Darwin merely made very brief reference to humankind, so that no one could think he was dodging the issue. "In the distant future I see open fields for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation. Light will be thrown on the origin of man and his history" (Darwin 1859, 488). That was it. For the time being at least. Towards the end of the 1860s, Darwin returned to the issue of humankind, and wrote a book where the focus was essentially on our species (followed by another, almost a supplement, on the emotions). Picking it up and looking at it today, the "human" book, *The Descent of Man* (1871), is rather odd. It may be essentially on humans. It is not primarily on humans. From the beginning, Darwin had always believed that, along with natural selection, there is a secondary form of selection, which he called

"sexual selection," meaning the selection that comes from competition for mates. He divided it into two kinds. First there is sexual selection through male combat, as when two stags fight for the female and in successive generations the stags' antlers get bigger and bigger. Second there is sexual selection through female choice, as when females choose between males with which to mate – for instance, a peahen deciding between two displaying peacocks. Undoubtedly these two kinds come from the world of breeders: natural selection is like choosing bigger and fleshier cattle, sexual selection through male combat is like two fighting cocks going at each other, and sexual selection through female choice is like choosing the dog that most closely fits the standards that one favors. However, although sexual selection was no mere add-on, but something that came right from the heart of Darwin's thinking, for much of his life he made little of it.

Then when he turned full time to humans, Darwin began to think that sexual selection might be an important mechanism in its own right. Wallace had gone somewhat off the track. By the late 1860s, he had embraced spiritualism and, thinking that unseen forces must have been responsible for human evolution, he was denying that natural selection could account for human intelligence (Wallace 1905). He argued that many human features, not just intelligence but things like the lack of hair, are beyond causes as we know them. Fighting something of a rearguard action, Darwin decided that Wallace was right about natural selection as such, but wrong about selection generally. Sexual selection could pick up the slack. In particular, in humans, males compete for females and females choose the males they like. This leads to all sorts of racial and sexual differences in their offspring, as well as to such things as improved intelligence and so forth. To make this case, Darwin went off in the middle of *The Descent of Man* into a long digression about sexual selection in the animal world generally, and only towards the end did he return to our species to draw his conclusions – conclusions that left him where he had come in almost forty years before: humans are animals and as such we have evolved like every other living thing. No exceptions.

Work to be done

We draw to the end of the story of Charles Darwin the person. From the viewpoint of evolutionary theory, there was yet a long way to go. Scientifically, at the beginning of the twentieth century, the age-of-the-earth question cleared itself up quickly when it was realized that radioactive decay and the warmth it generates makes for a much longer earth history. Heredity, building on the insights of Gregor Mendel (of whom more later), took much more work and time. Even when its study started to pick up pace, there were barriers to be overcome. Early geneticists, to use the name given to those who study variation, tended naturally to work with major variations, and hence thought that these must be the key to significant evolutionary change. It took some time for this kind of saltationism to subside and for selection and genetics to work together rather than apart.

Indeed, it was not until the 1930s that the real synthesis came – appropriately the Darwin–Mendel conjunction was known (in Britain) as "neo-Darwinism" or (in America) as the "synthetic theory of evolution" – and from then evolution had its working theory (Mayr and Provine 1980; Ruse 1996). At the same time, thanks to its now professional practitioners, it began to distance itself from its role as something purely at the level of popular science or secular religion. With selection backed by Mendelism (that is, genetics) now in place, it was possible for full-time scientists to work on evolutionary problems, experimenting, observing, and hypothesizing, just like scientists in other fields. We shall talk more on these matters in later chapters. Now is our time to take leave of the individual. Darwin grew old, loved by his family and friends, greatly respected by his countrymen and by many in other lands. When he died, there was little debate about what absolutely had to happen. He must be placed in that Valhalla of English heroes, Westminster Abbey. And there he still lies, right next to Isaac Newton, who led the way, doing in physics what Darwin was to do in biology.