PERSPECTIVES

Where is Darwin 200 years later?

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Abstract

The theory of evolution is perceived by many people, particularly but not only in the United States, as a controversial theory not yet fully demonstrated. Yet, that living organisms, including humans, have evolved from ancestors who were very different from them is beyond reasonable doubt, confirmed by at least as much evidence as any other widely accepted scientific theory. I argue that Darwin's contribution to science goes much beyond the theory of evolution in itself. The theory of natural selection explains the adaptations of organisms, their 'design'. The 'Copernican Revolution' brought the phenomena of the physical universe into the realm of science: explanations by natural causes that can be tested by observation and experiment. However, the scientific revolution that occurred in the 16th and 17th centuries had left the living world out of scientific explanations, because organisms seemingly show that they are 'designed,' and thus call for an intentional designer. It was Darwin's greatest contribution to science, to demonstrate that the adaptations of organisms, their apparent 'design', can be explained by natural processes governed by natural laws. At that point, science came into maturity, because all natural phenomena in the universe, living as well as nonliving, could be investigated scientifically, and explained as matter in motion governed by natural laws.

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Isaac Newton was born in 1642. Newton's *Philosophiae naturalis principia mathematica* (The mathematical principles of natural philosophy), a book that had remained unpublished for years, appeared in 1687, establishing Newton as the greatest of all physical scientists. His three "laws of motion" soon became the basis of all future work in physics. By 1842, 200 years after Newton's birth and 155 years after the publication of his *Principia Mathematica*, the inverse-square law of attraction and other fundamental tenets of Newton's mechanics were universally taught in the schools and generally accepted (even if not necessarily in their mathematical formulation) by the public at large.

Albert Einstein was born in 1879. Einstein published his special theory of relativity in 1905 and the general theory of relativity in 1916. The theory of relativity is too abstruse to be taught in detail to elementary school children, but its physical implications concerning mass and energy are part of the curriculum in higher school grades, and are held without objection or contempt by the general public. By the time of his death in 1955 and beyond, Einstein was revered as the greatest physicist of the times and as a model, almost saintly scientist.

Charles Darwin was born in 1809, 70 years before Einstein, and published *The origin of species* in 1859, nearly 50 years before the theory of special relativity. The year 2009 marks the 200th anniversary of Darwin's birth and the sesquicentennial of the *Origin*'s publication. Scientists, universities, natural history museums and other sorts of people, and institutions throughout the world are celebrating these anniversaries with scientific lectures, symposia, exhibitions, and otherwise. Yet, in the United States, the theory of evolution is not taught in some schools, and only begrudgingly in others. The general public has heard of evolution and of the claim that humans have evolved from nonhuman ancestors. However, a large number of people, perhaps a majority, do not consider that the claims of biological evolution have been demonstrated, or simply reject them as false.

Consider the following: according to a Gallup poll of 1016 US adults, taken in November 2004, 45% of those surveyed favoured the statement that 'God created human beings in their present form within the last 10,000 years' (38%

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favoured that 'man developed over millions of years, but God guided the process,' and 13% that 'man developed over millions of years from less advanced life forms'). The public attitude about the teaching of the theory of evolution is no less scary. In a CNN/*USA Today* Gallup poll of 1001 adults conducted in March 2005, 76% would not 'be upset if public schools in (their) community taught creationism,' but only 63% would not 'be upset if the schools taught evolution.' Only 22% would be upset if creationism would be taught, while 34% would be upset if evolution would be taught. Other polls yield similar statistics. There can be no doubt that a crucial link is missing in the US educational system. Moreover, the press, television, and other mass communication media are failing in any role one might want to allocate to them in informing and educating the citizenry. Many newspapers dedicate a much larger amount of print copy to the horoscope than to science.

Darwin and the history of ideas

Darwin occupies an exalted place in the history of western thought, deservedly receiving credit for the theory of evolution. In *The origin of species*, published in 1859, he laid out the evidence demonstrating the evolution of organisms. Darwin did not use the term 'evolution', which did not then have its current meaning, but referred to the evolution of organisms by the phrase 'common descent with modification' and similar expressions. However, Darwin accomplished something much more important for intellectual history than demonstrating evolution. Indeed, accumulating evidence for common descent with diversification may very well have been a subsidiary objective of Darwin's masterpiece. Darwin's *Origin of species* is, first and foremost, a sustained effort to solve the problem of how to account scientifically for the adaptations or 'design' of organisms. Darwin sought to explain the design of organisms, their complexity, diversity, and marvelous contrivances as a result of natural processes. Darwin brought about the evidence for evolution, because evolution was a necessary consequence of his theory of design.

There is a priggish version of the history of the ideas that sees a parallel between Copernicus' and Darwin's monumental intellectual contributions, which are said to have eventuated two revolutions. According to this version, the Copernican Revolution consisted in displacing the earth from its previously accepted locus as the centre of the universe, moving it to a subordinate place as one more planet revolving around the sun. In congruous manner, this version affirms, the Darwinian Revolution consisted in displacing humans from their position as the centre of life on earth, with all the other species created for the purpose of humankind, and placing humans instead as one species among many in the living world, so that humans are related to chimpanzees, gorillas, and other species by shared common ancestry. Copernicus had accomplished his revolution with the heliocentric theory of the solar system; Darwin's achievement emerged from his theory of organic evolution.

I propose that this version of the two revolutions is inadequate: what it says is true, but it misses what is most important about these two intellectual revolutions, namely that they ushered in the beginning of science in the modern sense of the word. These two revolutions may jointly be seen as the one scientific revolution, with two stages, the Copernican and the Darwinian. Darwin is deservedly given credit for the theory of biological evolution, because he accumulated evidence demonstrating that organisms evolve and discovered the process, natural selection, by which they evolve their functional organization. But *The origin of species* is most important because it completed the Copernican Revolution, initiated three centuries earlier, and thereby radically changed our conception of the universe and the place of mankind in it.

The Copernican Revolution was launched with the publication in 1543, the year of Nicolaus Copernicus' death, of his *De revolutionibus orbium celestium* (On the revolutions of the celestial spheres), and bloomed with the publication in 1687 of Isaac Newton's *Philosophiae naturalis principia mathematica*. The discoveries of Copernicus, Kepler, Galileo, Newton, and others, in the 16th and 17th centuries, had gradually ushered in a conception of the universe as matter in motion governed by natural laws. It was shown that the earth is not the centre of the universe, but a small planet rotating around an average star; that the universe is immense in space and in time; and that the motions of the planets around the sun can be explained by the same simple laws that account for the motion of physical objects on our planet (laws such as $f = m \times a$, force = mass × acceleration, or the inverse-square law of attraction, $f = g(m_1, m_2)/r^2$). These and other discoveries greatly expanded human knowledge, but the conceptual revolution they brought about was more fundamental yet: a commitment to the postulate that the universe obeys immanent laws that account for natural phenomena. The workings of the universe were brought into the realm of science: explanation through natural laws. Physical phenomena could be accounted for whenever the causes were adequately known.

Darwin completed the Copernican Revolution by drawing out for biology the ultimate conclusion of the notion of nature as a lawful system of matter in motion. The adaptations and diversity of organisms, the origin of novel and highly organized forms, the origin of mankind itself, could now be explained by an orderly process of change governed by natural laws.

From natural theology to natural selection

The advances of physical science had driven mankind's conception of the universe to a sort of intellectual schizophrenia, which persisted well into the mid 19th century. Scientific

explanations, derived from natural laws, dominated the world of nonliving matter, on the earth as well as in the heavens. However, supernatural explanations, depending on the unfathomable deeds of the Creator, were accepted in order to account for the origin and configuration of living creatures—the most diversified, complex, and interesting realities of the world. It was Darwin's genius that resolved this intellectual inconsistency. Darwin completed the Copernican Revolution by drawing out for biology the notion of nature as a lawful system of matter in motion, which human reason can explain without recourse to extranatural agencies.

The conundrum faced by Darwin can hardly be overestimated. The strength of the 'argument from design' to demonstrate the role of the Creator had been forcefully set forth by the English clergyman and author William Paley in his *Natural theology*; or, *Evidences of the existence and attributes of the deity*, published in 1802, a book that had greatly impressed Darwin, while he was a student at Cambridge University. *Natural theology* is a sustained argument-from-design claiming that the living world provides compelling evidence of being designed by an omniscient and omnipotent Creator. Paley's keystone claim is that, "There cannot be design without a designer; contrivance, without a contriver; order, without choice; means suitable to an end, and executing their office in accomplishing that end, without the end ever having been contemplated" (pp. 15–16).

The argument-from-design to demonstrate the existence of God had been put forward by theologians and other authors over the centuries. But Paley elaborated the argument-from-design with greater cogency and more extensive knowledge of biological detail than has ever been done by any other author, before or since. Paley brings in all sorts of biological knowledge, from the geographic distribution of species to the interactions between predators and their prey, the interactions between the sexes, the camel's stomach and the woodpecker's tongue, the compound eyes of insects and the spider's web. *Natural theology* has chapters dedicated to the complex design of the human eye; to the human frame, which displays a precise mechanical arrangement of bones, cartilage, and joints; to the circulation of the blood and the disposition of blood vessels; to the comparative anatomy of humans and animals; to the digestive system, kidneys, urethras, and bladder; to the wings of birds and the fins of fish; and much more.

For 352 pages, *Natural theology* conveys Paley's expertise: extensive and accurate biological knowledge, as detailed and precise as it was available in the year 1800. After detailing the precise organization and exquisite functionality of each biological object or process, Paley draws again and again the same conclusion, that only an omniscient and omnipotent deity could account for these marvels of mechanical perfection, purpose, and functionality, and for the enormous diversity of inventions that they entail.

Darwin's greatest accomplishment, and his main contribution to the history of ideas, was to show that the complex organization and functionality of living beings can be explained as the result of a natural process, natural selection, without any need to resort to a Creator or other external agent. The origin and adaptation of organisms in their profusion and wondrous variations were thus brought into the realm of science.

In his autobiography, Darwin wrote, "The old argument of design in nature, as given by Paley, which formerly seemed to me so conclusive, falls, now that the law of natural selection has been discovered. We can no longer argue that, for instance, the beautiful hinge of a bivalve shell must have been made by an intelligent being, like the hinge of a door by a man" (Barlow 1958). Authors, such as William Paley, argued that the complex design of organisms could not have come about by chance, or by the mechanical laws of physics, chemistry, and astronomy, but was rather accomplished by an intelligent designer, just as the complexity of a watch, designed to tell time, was accomplished by an intelligent watchmaker.

Darwin accepted that organisms are 'designed' for certain purposes, i.e. they are functionally organized. Organisms are adapted to certain ways of life and their parts are adapted to perform certain functions. Fish are adapted to live in water, kidneys are designed to regulate the composition of blood, the human hand is made for grasping. But Darwin went on to provide a natural explanation of the design. The seemingly purposeful aspects of living beings could now be explained, like the phenomena of the inanimate world, by the methods of science, as the result of natural laws manifested in natural processes.

Darwin's theory: natural selection versus evolution

Important as the evidence for evolution was, Darwin considered the discovery of natural selection to be his most important scientific achievement, as becomes apparent from consideration of his life and works. In his diaries and correspondence, Darwin referred to natural selection as 'my theory,' a designation he never used when referring to the evolution of organisms. The discovery of natural selection, Darwin's awareness that it was a greatly significant discovery because it was science's answer to Paley's argument from design, and Darwin's designation of natural selection as 'my theory,' can be traced in Darwin's 'Red Notebook' and 'Transmutation Notebooks B to E,' which he started in March 1837, not long after returning (on 2 October 1836) from his five-year voyage on the *Beagle*, and completed in late 1839 (see Eldredge 2005, pp. 71–138).

The evolution of organisms was commonly accepted by naturalists in the middle decades of the 19th century. The distribution of exotic species in South America, in the Galápagos Islands, and elsewhere, and the discovery of fossil remains of long-extinguished animals, confirmed the reality of evolution in Darwin's mind. The intellectual chal-

lenge was to explain the origin of distinct species of organisms, how new ones are adapted to their environments, that 'mystery of mysteries,' as it had been labelled by Darwin's older contemporary, the prominent scientist and philosopher Sir John Herschel (1792–1871).

Early in the Notebooks of 1837 to 1839, Darwin registers his discovery of natural selection and repeatedly refers to it as "my theory". From then until his death in 1882, Darwin's life would be dedicated to substantiating natural selection and its companion postulates, mainly the pervasiveness of hereditary variation and the enormous fertility of organisms, which much surpassed the capacity of available resources. Natural selection became for Darwin 'a theory by which to work.' He relentlessly pursued observations and performed experiments in order to test the theory and resolve presumptive objections.

As I read it, Darwin's focus in *The origin of species* was the explanation of design, with evolution playing the subsidiary role of supporting evidence. The introduction and chapters I through VIII of *The origin of species* explain how natural selection accounts for the adaptations and behaviours of organisms, their 'design'. The extended argument starts in chapter I, where Darwin describes the successful selection of domestic plants and animals and, with considerable detail, the success of pigeon fanciers seeking exotic 'sports'. The success of plant and animal breeders manifests how much selection can accomplish by taking advantage of spontaneous variations that occur in organisms but happen to fit the breeders' objectives. A sport (mutation) that first appears in an individual can be multiplied by selective breeding, so that after a few generations that sport becomes fixed in a breed, or race. The familiar breeds of dogs, cattle, chickens, and food plants have been obtained by this process of selection practiced by people with particular objectives.

The ensuing chapters (II–VIII) of *The origin of species* extend the argument to variations propagated by natural selection for the benefit of the organisms themselves, rather than by artificial selection of traits desired by humans. As a consequence of natural selection, organisms exhibit design, i.e., exhibit adaptive organs and functions. The design of organisms as they exist in nature, however, is not 'intelligent design' imposed by God as a 'Supreme Engineer' or by humans; rather, it is the result of a natural process of selection, promoting the adaptation of organisms to their environments. This is how natural selection works: individuals that have beneficial variations, i.e., variations that improve their probability of survival and reproduction, leave more descendants than individuals of the same species that have less beneficial variations. The beneficial variations will consequently increase in frequency over the generations; less beneficial or harmful variations will be eliminated from the species. Eventually, all or most individuals of the species will have the beneficial features; new features will arise over eons of time.

Organisms exhibit complex design, but it is not, in current language, 'irreducible complexity,' emerging all of a sudden in full bloom. Rather, according to Darwin's theory of natural selection, the design has arisen gradually and cumulatively, step-by-step, promoted by the reproductive success of individuals with incrementally more adaptive elaborations.

It follows from Darwin's explanation of adaptation that evolution must necessarily occur as a consequence of organisms becoming adapted to different environments in different localities, and to the ever-changing conditions of the environment over time, and as hereditary variations become available at a particular time that improve, in that place and at that time, the organisms' chances of survival and reproduction. *The origin of species*' evidence for biological evolution is central to Darwin's explanation of design, because this explanation implies that biological evolution occurs, which Darwin therefore seeks to demonstrate in most of the remainder of the book (Darwin 1859, chapters IX–XIII).

In the concluding chapter XIV of *The origin*, Darwin returns to the dominant theme of adaptation and design. In an eloquent final paragraph, Darwin asserts the 'grandeur' of his vision: 'It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us... Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, while this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning-endless forms most beautiful and most wonderful have been, and are being, evolved' (Darwin 1859, pp. 489–490).

Coda

Two-hundred years without Darwin and 150 years without *The origin of species* are enough. It is about time that public schools teach the theory of evolution by natural selection for what it is: one of the greatest intellectual achievements of all times. It completed the Copernican Revolution and brought to mankind the scientific revolution, the methodological commitment to explain all of nature, inanimate as well as living, as matter in motion governed by natural laws. And it is about time that the mass media of communication take up their mission of educating, as well as informing, the general public about science in general and about human origins and the theory of evolution.

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