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Charles Darwin's paradigm shift

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ABSTRACT

The publication of Darwin's *On the Origin of Species* in 1859 created a paradigm shift from creation to evolution. Darwin showed that humans are part of nature, not above it, and that all animal life, including human, is related by descent from a common ancestor. His mechanism of evolution via natural selection is a powerful creative force that provided an explanation for the diversity of life. This dramatic change in world view from supernaturalism to methodological naturalism has allowed staggering scientific advances in the past 150 years that transcend science and impact on the human psyche.

KEYWORDS: Charles Darwin, evolution, natural selection, naturalism, paradigm shift.

INTRODUCTION

Charles Darwin (1809-1882) was an extraordinary man by any standard. The theory of evolution by natural selection as elaborated in his book *On the origin of species* (1859) is considered by historians and philosophers of science to be one of the most important ideas ever had by the human mind (Dennett 1995). Before exploring this grandiose statement, a brief review of Darwin's life and scientific accomplishments is in order. Then I will address the implications of his very useful insight that extended beyond science and profoundly impacted on the human mind.

An outline of Darwin's Life

Charles Darwin was born into a wealthy English family on 12 February 1809. His father, Robert Waring Darwin (1766–1848), was a prominent physician as was his grandfather Erasmus Darwin (1731–1802). His mother was Susannah Wedgwood (1764–1817), the daughter of Josiah Wedgwood (1730–1795), the pottery manufacturer and entrepreneur, who was a close friend of Erasmus Darwin.

Darwin's father sent Charles to medical school at Edinburgh University in 1825 and removed him in 1827 when it became obvious that Charles was not interested in a medical career. Robert Darwin then decided that Charles should study to be a clergyman in the Church of England, and sent him to Cambridge University in 1828. Charles graduated 10th in his class in 1831 and then received an invitation orchestrated by his professor, John Stevens Henslow (1796-1861), to be an unpaid naturalist-companion to Captain Robert FitzRoy (1805-1865) on a surveying voyage around the world on H.M.S. *Beagle* (1831-1836). Darwin later described this opportunity as "the first real training or education of my mind".

Upon return from the nearly five-year *Beagle* voyage, Darwin found that he was accepted as a serious scientist, and he had no desire to become a clergyman. He began working on the specimens collected on the voyage. He married his first cousin, Emma Wedgwood (1808–1896), and they eventually moved from London to Down House in Kent (Fig. 1). They had 10 children, seven of whom survived to adulthood. After the voyage, he was often ill, but nevertheless, highly productive. He entered his ideas about how species form in a series of notebooks This included a

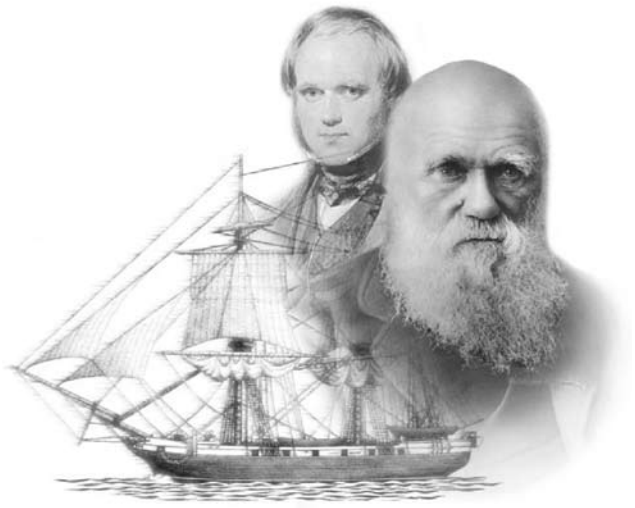

Fig. 1. At rear of montage, wedding portrait of Charles Darwin (watercolour) in 1840 at age 30 by George Richmond. **At centre**, HMS Beagle drawing by American artist Samuel L. Margolies (1897-1974) from Dibner (1960) in the Burndy Collection at the Huntington Library, San Marino, CA. Used with permission of the Huntington Library. **In foreground**, one of the last photographs of Charles Darwin, by Elliot and Fry.

branching, tree-like diagram that reflected the common origin and relatedness of organisms. This first evolutionary tree showed that classification should be genealogical. However, he kept his revolutionary ideas private for 20 years except for his closest scientific colleagues: geologist Charles Lyell (1797–1875), botanist Joseph Dalton Hooker (1817–1911), zoologist Thomas Henry Huxley (1825–1895), and his American botanist correspondent at Harvard University, Asa Gray (1810-1888). In 1858 Darwin received of a letter from naturalist Alfred Russel Wallace (1823–1913), who, like Darwin, was inspired by the writings of Thomas Malthus (1766–1834). Wallace outlined ideas nearly identical to Darwin's. This letter and urging from Lyell and Hooker prompted him to complete and publish *On the Origin of Species* in 1859. Darwin continued to do experiments and publish on a variety of topics right up to the time of his death. He died of heart disease on 19 April 1882 and was laid to rest with pomp and ceremony in Westminster Abby a few feet from Isaac Newton. Further details can be pursued in three of the most comprehensive biographies of Darwin (Desmond and Moore 1991; Browne 1995, 2002), a concise biography (Berra 2009), and, of course, Darwin's autobiography (Barlow 1958).

SYNOPSIS OF DARWIN'S SCIENTIFIC ACHIEVEMENTS

The educated citizen is generally aware of *The origin* and Darwin's account of his voyage around the world in H.M.S. *Beagle* through his book now universally known as *The voyage of the Beagle*. These two books have never been out of print.

Most people are surprised to learn that Darwin also made many other major contributions to geology, zoology, and botany through his observations, experiments and writings. His books have been chronicled (Berra 2009), so I will just briefly outline the breadth of his influence. Darwin explained how coral reefs form (1842) and contributed to geological observations on earth movements (1844) and deformation theory of metamorphic rock (1846). In a pioneering four-volume work that took eight years to complete, he described all known barnacle species, fossil and living (1851–1854). Darwin explained how orchids are fertilized by insects (1862), how plants climb (1865), and catalogued the bewildering amount of variation in domestic plants and animals (1868). He explained human origins and sexual selection in ways never before articulated (1870–71), and discussed human and animal emotions in similar terms (1872). The latter work was one of the first books to use photographs to illustrate a point.

Darwin showed how insectivorous plants on impoverished soils utilise nitrogen-rich insects (1875), and demonstrated that the offspring of cross-fertilised plants were more numerous and vigorous than self-fertilised ones (1876, 1877). His observations of climbing plants laid the foundation for the field of plant growth hormones (1880), and his work on earthworms (1881) is a classic study in ecology. Any one of these achievements could constitute a life's work for most scientists.

DARWIN'S LEGACY

Darwin was born and educated at a time when special creation was the prevailing scientific view. That is, God created the universe and all species a few thousand years ago, and they were unchangeable. "Revelation", not research, provided this view. Darwin began the *Beagle* voyage with this belief. During his lifetime the age of the earth was increasingly recognised as ancient as suggested by Georges Cuvier (1769–1832) and Charles Lyell (Bowler 1984; Larson 2004). Observations made during the voyage made him question the Genesis creation myth and immutability of species. He found marine fossils thousands of feet above sea level and reasoned that the land had been elevated by earth movements, not inundated in a great biblical flood. The fossil mammals he uncovered in South America resembled living mammals from the same area. He wondered why this should be if each species were specially created. Extinction was hardly recognised in those days. Why did the animals on islands off continental areas resemble those of the nearest land mass if each species were created in place? Why were there so many species in an island group that looked very similar but with slight differences from island to island? It is as if "one species had been taken and modified for different ends", he wrote in *Voyage of the Beagle*. None of these things made sense from a creationist perspective. In 1844 he wrote to Hooker that "I am almost convinced (quite contrary to the opinion I started with) that species are not (it is like confessing a murder) immutable."

The elegant simplicity of Darwin's reasoning can be distilled as follows. There is variation in nature, many more offspring are generated than can survive, therefore there is a struggle for life in which favorable variations are preserved and unfavorable variations are removed. This leads to evolution which he defined as "descent with modification" and to the formation of new species. Nature is doing the selecting for the forms best adapted to a particular environment so he called the process natural selection as opposed to artificial selection that breeders impose. We now know that mutation, chromosomal rearrangements, sexual reproduction, etc. are the sources of genetic variation, but Darwin had no knowledge of such topics. Today we can speak of "descent with modification" as "a change in gene frequency", and natural selection is simply "differential reproduction", that is, one genetic variant leaves more offspring than another (Berra 1990). Darwin borrowed the expression "survival of the fittest" from economist Herbert Spencer (1820–1903). Evolutionary fitness means reproductive fitness. In modern terms, the fittest is the one who gets the most genes into

Fig. 2. Cartoon of Charles Darwin as a monkey, from *Fun*, 16 November 1872, just after *The expression of the emotions in man and animals* was published. Many other similar personal attacks were published during his lifetime.

the next generation, not necessarily the biggest or strongest individual.

By the time of Darwin's death in 1882, most scientists of the world had accepted the concept of common descent, but some were still skeptical of natural selection as a creative mechanism (Bowler 1984). The public was less accepting (Fig. 2).

The publication of *On the origin of species* on 24 November 1859 precipitated one of those rare events in the history of science, a paradigm shift. Philosopher Thomas Kuhn used this term to refer to the replacement of one world view by another (Kuhn 1962). Examples of a paradigm shift in science include the replacement of the earth-centered Ptolemaic system by the sun-centered Copernican system and the replacement of Newtonian physics by relativity and quantum physics.

Darwin's work neatly dove-tailed into the wider pattern of scientific advances that were occurring during his life. Lyell and others had provided the necessary geological time for evolution to operate. The writings of Malthus, Spencer, Wallace, and many others help set the evolutionary stage. By 1859 evolution by natural selection was an idea whose time had come. Darwin and the publication of *The origin* closed the deal. Darwin changed the way humans view their place in nature. He showed that humans were not above nature, but part of it. He supplied the explanation for the great diversity of life and showed that all life, including human, is related by descent from a common ancestor. His explanation of evolution via natural selection is the basis of all of biology and its applied subdisciplines of medicine, agriculture, and biotechnology. No other biologist in the history of our species has had an impact of this magnitude. In the words of the eminent geneticist Theodosius Dobzhansky, "Nothing in biology makes sense except in the light of evolution" (Dobzhansky 1973).

The paradigm shift from creation to evolution has moved intellectual endeavors from untestable belief to rational understanding that flows from the scientific method. This, in turn, has allowed a vast array of advances in knowledge.

DARWINIAN IMPLICATIONS

One of the attributes of a powerful scientific theory is that it enables future research and understanding. Darwinian or evolutionary medicine as formulated by Nesse and Williams (1996) explains how some disease symptoms, such as fever, may be a response favored by natural selection as a defense against pathogens. Some genetic diseases such as sickle cell anaemia may allow differential survival of its victims in malarial zones, a phenomenon called a balanced polymorphism (Berra 1990). Evolutionary thinking explains the arms race waged by pathogens and hosts that prevents either from being completely eliminated. The development of antibiotic resistant bacteria through the flagrant overuse of antibiotics is easily explained by Darwinian reasoning. A drug kills the susceptible bacteria leaving bacteria with a pre-existing resistant mutation to build up the next generation. Then when you actually need the antibiotic for a bacterial infection, you find that the drug is ineffective. This is evolution, pure and simple.

A similar process occurs in agriculture with the over application of pesticides and the formation of pesticide resistant pathogens, insects, and noxious plants. Australians are very familiar with the myxomatosis versus rabbit "arms race" whereby the virus initially killed 99 percent of the rabbits, but given enough time the surviving rabbits returned in force as the virus evolved in the direction of less virulence and the rabbits were selected for more resistance to the virus (Berra 1998).

Evolutionary psychology and evolutionary ethics, as explored by Barkow *et al*. (1992) and popularised by Wright (1994) help explain the origin of morality. Peacemaking among non-human primates by the calming effect of mutual grooming to diffuse aggression may be seen as the precursor of what became morality in humans (de Waal 1989). Modern religions are recent human inventions – a mere few thousand years old. The antecedents of morality, on the other hand, clearly evolved before humanity as reflected in the empathy exhibited by bonobos (*Pan paniscus*) and the reciprocity of chimpanzees (*P. troglodytes*) (de Waal 2005). Kin selection, whereby an individual sacrifices for a close genetic relative, makes sense in an evolutionary context

because some of the same genes of the individual making the sacrifice will be passed on by the kin who survives. This is referred to as inclusive fitness by Hamilton (1972). Realisation that humans share kinship with all animal life has helped to raise consciousness of how we treat other animals (Singer 1977).

The ancestry of the AIDS virus, HIV-1 (human immunodeficiency virus-1) has been traced to SIVcpz (simian immunodeficiency virus) carried by our closest living relative, the chimpanzees, *Pan troglodytes* (Bailes *et al*. 2003). This is not surprising from an evolutionary perspective. Somewhere in high school today there is a student who may contribute to the control of the AIDS epidemic. What chance of that would there be if creationism were taught as science in high school?

Even religion is now being explained as having an evolutionary origin as a natural phenomenon once the brain evolved a critical mass and complexity (Dennett 2006). Bloch (2008) suggested that the evolution of imagination was a requisite for the emergence of religion which he considered a logical extension of human sociality. This occurred about the time of the Upper Palaeolithic "revolution" as manifested by an explosion of image-making and cultural transformations (White 2003). Acceptance of authority necessary for group cohesion and survival enforced by tool use and language combined with confusion of cause and effect and coincidences can result in the establishment of a belief that becomes dominate in a culture (Wolpert 2007).

Those whose religion requires a literal interpretation of the Bible fear that the paradigm shift from supernaturalism to methodological naturalism threatens their beliefs. The 1925 Scopes trial, nicknamed "monkey trial" and "trial of the century" in Dayton, Tennessee, has come to symbolise the struggle of religion against science in popular culture that later inspired the play and film *Inherit the wind* (Larson 1977). Such creationists are particularly vocal in America which has a long standing tradition of anti-intellectualism (Numbers 1992; Pigliucci 2002). This has resulted in a series of creationist legal challenges to evolution which have been decided in favor of evolution (Berra 1990). The most recent of these was the Intelligent Design creationist challenge of the Dover, Pennsylvania, School Board. The Intelligent Design creationist philosophy that life is too complex to have arisen by natural means and therefore had a supernatural origin has been critiqued in Pennock (2001) and exposed as a threat to science education by Forrest and Gross (2004). In the conclusion of his decision Judge John E. Jones III determined that the school board's policy of teaching Intelligent Design violated the Establishment Clause of the First Amendment [separation of church and state] of the U.S. Constitution, and he wrote, "…in making this determination, we have addressed the seminal question whether Intelligent Design is science (Jones 2005). We have concluded that it is not, and moreover that Intelligent Design cannot uncouple itself from its creationist, and thus religious, antecedents." He further wrote, "The breathtaking inanity of the board's decision is evident when considered against the factual backdrop which has now been fully revealed through this trial." Padian (2007) reviewed three books based on the Dover trial.

Biotechnology, whether in the form of genetically modified crops, designer drugs, gene therapy, or the human genome project all derive from Darwin's profound insight. Darwin had no knowledge of genes, chromosomes, or how inheritance worked. This required additional input from the understanding of Gregor Mendel's (1822–1884) genetic work.

The modern evolutionary synthesis grew from Darwin's explanation of natural selection and Mendel's demonstration of inheritance augmented by the research of mathematically oriented population geneticists such as J.B.S. Haldane, Ronald Fisher, Sewall Wright, Thomas Hunt Morgan, Theodosius Dobzhansky, palaeontologist George Gaylord Simpson, botanist G. Ledyard Stebbins, Jr., biologist Julian Huxley (T.H. Huxley's grandson), and the most important evolutionary biologist since Darwin, Ernst Mayr. This fusion of knowledge moved evolutionary science forward to the middle of the 20th century (Larson 2004). James D. Watson's and Francis Crick's 1953 demonstration that the molecular structure of DNA allowed for genetic coding was a huge breakthrough that ultimately made it possible to sequence the three billion chemical base pairs that compose the human genome and identify the approximately 20,000-25,000 genes in human DNA (Lander *et al.* 2001; Venter *et al*. 2001).

Recent discoveries in evolutionary developmental biology, known as evo-devo, have shown that very similar genes are present in very dissimilar animals. These body-shaping genes are controlled by DNA switches called enhancers that turn them on or off at various times in development. Such enhancers are a major factor in the evolution of anatomy (Carroll 2005). The above examples are just a sample of the benefits to society that flow directly from the creative power of Charles Darwin's theory of evolution by means of natural selection.

The paradigm shift instigated by Darwin has made obvious the superiority of the scientific method as a means of understanding the world around us. It is ironic that the legacy of a man once destined for the church has been to replace supernaturalism with methodological naturalism.

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REFERENCES

Bailes, E., Gao, F., Bibollet-Ruche, F., Courgnaud, V., Peeters, M., Marx, P., Han, B.H. and Sharp, P.M. 2003. Hybrid origin of SIV in chimpanzees. *Science* **300**: 1713.

Barkow, J.H., Cosmides, L. and Tooby, J. (eds). 1992. *The adapted mind*. Oxford University Press: Oxford.

Barlow, N. (ed.) 1958. *The autobiography of Charles Darwin 1809-1882: with original omissions restored*. W.W. Norton and Company: New York.

Berra, T.M. 1990. *Evolution and the myth of creationism*. Stanford University Press: Stanford.

Berra, T.M. 1998. *A natural history of Australia*. University of New South Wales Press/Academic Press: Sydney/San Diego.

Berra, T.. 2009. *Charles Darwin: the concise story of an extraordinary man*. Johns Hopkins University Press: Baltimore.

Bloch, M. 2008. Why religion is nothing special but is central. *Philosophical Transactions of the Royal Society B* **363**: 2055–2061.

Bowler, P.J. 1984. *Evolution: the history of an idea*. University of California Press: Berkeley.

Browne, J. 1995. *Charles Darwin voyaging. volume I of a biography*. Princeton University Press: Princeton.

Browne, J. 2002. *Charles Darwin: the power of place. volume II of a biography*. Knopf: New York.

Carroll, S.B. 2005. *Endless forms most beautiful: the new science of evo devo and the making of the animal kingdom*. W.W. Norton: New York.

Darwin, C. 1859. *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. John Murray: London.

de Waal, F. 1989. *Peacemaking among primates*. Harvard University Press: Cambridge.

de Waal, F. 2005. *Our inner ape*. Riverhead Books: New York.

Dennett, D.C. 1995. *Darwin's dangerous idea*. Touchstone: New York.

Dennett, D.C. 2006. *Breaking the spell: religion as a natural phenomenon*. Viking: New York.

Desmond, A. and Moore, J. 1991. *Darwin: the life of a tormented evolutionist*. Warner Books: New York.

Dibner, B. 1960. *Darwin of the Beagle*. Burndy Library: Norwalk.

Dobzhansky, T. 1973. Nothing in biology makes sense except in the light of evolution. *American Biology Teacher* **35**: 125–129.

Forrest, B. and Gross, P.R. 2004. *Creationism's trojan horse: the wedge of intelligent design*. Oxford University Press: Oxford.

Jones, J.E. III. 2005. Memorandum Opinion. In the United States District Court for the Middle District of Pennsylvania. Tammy Kitzmiller, *et al*. Plaintiffs vs Dover Area School Board Defendants. Case No. 04cv2688. 1–139 p.

Hamilton, W.D. 1972. Altruism and related phenomena, mainly in the social insects. *Annual Review of Ecology and Systematics* **3**: 193-232.

Kuhn, T.S. 1962. *The structure of scientific revolutions*. University of Chicago Press: Chicago.

Lander, E.S., and 19 coauthors 2001. Initial sequencing and analysis of the Human genome. *Nature* **409**: 860–921.

Larson, E.J. 1997. *Summer for the gods: the Scopes trial and America's continuing debate over science and religion*. Basic Books: New York.

Larson, E.J. 2004. *Evolution*: *the remarkable history of a scientific theory*. The Modern Library: New York.

Nesse, R.M. and Williams, G.C. 1996. *Why we get sick*. Vantage Books: New York.

Numbers, R.L. 1992. *The creationists: the evolution of scientific creationism*. Alfred A. Knopf: New York.

Padian, K. 2007. The case of creation. *Nature* **448**: 253–4.

Pennock, R.T. 2001. *Intelligent design creationism and its critics: philosophical, theological, and scientific perspectives*. Massachussetts Institute of Technology Press: Cambridge.

Pigliucci, M. 2002. *Denying evolution: creationism, scientism, and the nature of science*. Sinauer Associates: Sunderland.

Singer, P. 1977. *Animal liberation: towards an end to man's inhumanity to animals*. Granada Publishing: London.

Venter, J.C., and 273 coauthors 2001. The sequence of the human genome. *Science* **291**: 1304–1351.

White, R. 2003. *Prehistoric art: the symbolic journey of humankind*. H.N. Abrams, Inc.: New York.

Wolpert, L. 2007. *Six impossible things before breakfast: The evolutionary origin of belief*. W.W. Norton and Co.: New York.

Wright, R. 1994. *The moral animal*. Pantheon Books: New York.

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