(Dis)Entangling Darwin: Cross-disciplinary Reflections on the Man and His Legacy

Edited by

Sara Graça da Silva, Fátima Vieira and Jorge Bastos da Silva

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INTRODUCTION: DARWIN OUR CONTEMPORARY

SARA GRAÇA DA SILVA, FÁTIMA VIEIRA AND JORGE BASTOS DA SILVA

2009 marked the bicentenary of Charles Darwin's birth (12 February 1809) and the 150th anniversary of the publication of his groundbreaking *On the Origin of Species* (24 November 1859). The global celebrations of his life and work, with conferences, exhibitions and performances being held to honour Darwin's enduring legacy, and publications ensuing in many parts of the world, provided ample opportunity for examining how his ideas remain central to contemporary research, within and beyond the biological sciences. Indeed, the recent revival of his theories opened a Pandora's box of different theoretical studies and, more than ever, scholars are particularly receptive to exploring new and exciting angles of research.

Darwin's curiosity had a remarkable childlike enthusiasm driven by an almost compulsive appetite for a constant process of discovery, which he never satiated despite his many voyages: he would puzzle about the smallest things, from the wonders of barnacles to the different shapes, colours and textures of the beetles which he obsessively collected, from flowers and stems to birds, music and language, and would dedicate years to understanding the potential significance of everything he saw. His findings and theories relied heavily on that same curiosity, on seeking and answering questions, however long these would take to clarify. His son Francis Darwin often recalls how "he would ask himself 'now what *do* you want to say' & his answer written down would often disentangle the confusion" (Darwin, F., 1887: 173). In fact, "disentangling confusions" seems to have been the driving force behind Darwin's scientific pursuits, as he was struck with bewilderment when contemplating the luxuriousness of life. His remarks in the concluding paragraphs of *The Origin of Species* bear testimony to this feeling of intellectual rapture:

> 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. (...)
>
> 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, whilst 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: 508)

Darwin's descriptions rely on the formulation of incredibly complex and visual pictures, often portrayed in a series of "imaginary illustrations" which combine colourful arrangements of both facts and suppositions (Darwin, 1859: 75). The reader is constantly involved in a visual perceptual chaos of entanglements and webbed relationships, performances and theatricalities, exhibiting the way in which the human, animal and natural worlds are mutually imbricated.

Allied to Darwin's curiosity was a powerful penchant for imagination. Indeed, he has many wonderful passages in his autobiography and letters where he explains this uncontrollable urge for inventing stories, which was apparent from a very early age:

> I can well remember often and often inventing day dreams of old letters between distinguished Romans, and manuscripts being discovered at Pompeii or elsewhere. I scarcely went out without saying I had seen a pheasant or some strange bird – these lies, when not detected I presume, excited my attention. (Darwin, F, 1887: 326)

Despite this realization, Darwin knew that his reputation as a man of science depended on the production of verifiable observations and that he could not rely overly on speculation, although he is frequently criticised by his ambiguous explanations. Nevertheless, his narratorial style is still clearly evident in his various writings. Acknowledging the complexity of Darwin's methods, thought processes and explanatory style amounts to perceiving to what extent he can be counted our contemporary. The assessment of his impact is both daunting and exhilarating, and remains a challenge to many scholars in the most diverse fields, where interdisciplinarity is in high demand and long overdue.

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The present volume comprises fourteen essays which address Darwin's impact across the disciplines, and intends to contribute to the ongoing disentanglement of his legacy. It is organised into two main sections: "Darwin in the History of Science" and "Evolution, Literature and the Arts".

John Van Wyhe provides a compelling and intimate voyage through Charles Darwin's life, from his birth on 12 February 1808, and early family life in Shrewsbury, to his death on 19 April 1882, in Downe, Kent. His incursion into Darwin's life and work constitutes an appropriate prologue to this volume. Through captivating descriptions that debunk some of the myths surrounding the famous English naturalist, Wyhe covers important landmarks and recalls Darwin's early penchant and devotion for experimentation. It is with increasing appetite that one jumps from one episode to another, as if going through a family photo album. We hear of his years in Edinburgh; of his failed career as a clergyman; of his enrolment at Christ's College, Cambridge, "where he became close friends with his elder cousin William Darwin Fox", who, as Wyhe notes, "may have introduced Darwin to the latest craze of collecting beetles"; of the life-changing letter from Henslow which gave him the opportunity to embark on the *HMS Beagle* and experience the most important voyage of his life; of the writing, publication and reception of his most seminal works; of the fascination with plants as his health declined. With such a rich and accomplished life, it is no surprise that Darwin remains a milestone in the history of science.

Part I of the volume – Darwin in the History of Science – opens with an essay authored by Tinneke Beeckman, who equates the "philosophical naturalism" of Spinoza, as expressed namely in his *Ethics*, with Darwin's thought. Without claiming that Darwin actually knew the work of the seventeenth-century philosopher, Beeckman nevertheless points out that "in terms of a profound philosophical reflection, Spinoza's theory counts as a coherent, comprehensive and even visionary formulation of naturalism, before fundamental scientific research led to the discovery of evolutionary mechanisms". She accordingly makes a case for considering Spinoza an important non-essentialist thinker in the background of the evolutionary thought that came to maturity in the nineteenth century. By stressing the importance of the concept of causality (as opposed to finality) in both Spinoza's and Darwin's views on nature, Beeckman notes that both thinkers trod paths which were decidedly unconventional as compared to the traditional, Judeo-Christian worldview.

James T. Costa guides the volume into a perspective on the profound influence four traveller-naturalists – Alexander von Humboldt, John Herschel, Charles Lyell and John Stevens Henslow – had on Darwin. In fact, Darwin suffered the joint influence of personal acquaintanceship (in some cases) and the reading of their works. Costa emphasizes "the collaborative nature of voyages of discovery" whereby the operations of travelling and observation – either actually performed by the researcher or experienced vicariously – effectively involved a community of scientists. Darwin's methods, which involved both the voyage aboard the *Beagle* and later a process of gathering information from an impressively large number of international correspondents, point to this double aspect of scientific work. Costa's contribution to the present volume gives evidence of the fact that scientific travelling fostered the development of the idea of species "transmutation" in Darwin's mind.

João Cabral, on the other hand, provides an interesting and thorough reflection on Darwin's "unbound curiosity, robust methods and independent thinking" by analysing his botanical work. Darwin's tremendous botanical contribution, irrefutably meritorious, is nevertheless, as Cabral reminds us, largely indebted to his established network of correspondents and collectors. Incidentally, the significance of this arrangement is also explored by James T. Costa in the preceding paper. Supporting his study on correspondence exchanged between Darwin and other renowned botanists at the time, including Joseph Dalton Hooker, Daniel Oliver, Asa Gray and John Scott, Cabral praises the "honesty and sincerity of Darwin's report and speech", whilst calling attention to his devotion for experimentation and rigorous methods. The naturalist's impressive tenacity and endurance are also discussed, with some works spanning over a decade. Darwin started his botanical incursions with insectivorous plants, such as *Drosera rotundifolia,* in 1860, having made some exciting discoveries. He observed, for instance, as Cabral notes, that "in many insectivorous plants, leaves captured insects and responded promptly to organic and inorganic nitrogenous substances" as well as to mechanical stimulation. Other interesting incursions in the botanical realm considered in Cabral's paper include Darwin's work on orchids, especially regarding fertilization.

Not unlike Beeckman, André Levy's approach to Darwin stresses the fact that his work entails a resistance to anthropocentrism in that both his interest in the problems of evolution and his insights into the expression of emotions bear witness to his fundamental conviction about the inter-related processes that virtually connect all forms of life. Looking into the context in which such works as *The Descent of Man* and *The Expression of the Emotions in Man and Animals* came to be developed, Levy considers Darwin's work as a direct response to the thought of the nineteenth-century physician and natural theologian Charles Bell, and pinpoints the connection between Darwin's study of human expressions and the work of photographer O. G. Rejlander and neurologist G.-B. Duchenne de Boulogne. Finally, Levy assesses the significance of the research conducted by the behaviorist psychologist Paul Ekman in reviving Darwin's thoughts in the late twentieth century through a series of cross-cultural studies.

J. Edgar Bauer presents a refreshing view on the influence of Darwin's evolution theory on the non-essentialist world vision which is at the base of feminist and queer theories. This reading, which may be surprising at first (since, as Bauer explains, both Darwin's sexual "prejudices" and his antifeminism are well known), departs from an analysis of the influence Darwin had on the thesis of two of the most prominent sexologists of the first decades of the twentieth century: the Spanish endocrinologist and psychologist Gregorio Marañón, and the German-Jewish physician Magnus Hirschfeld. In his essay, Bauer shows how Darwin's challenge of the binary understanding of sexuality led the two theorists into different directions. Marañón used Darwin's dismantlement of sexual "binarity" as the basis for a teleological hierarchization which puts women at an intermediate stage of sexual evolution and men at a terminal one. Hirschfeld, on the other hand, took the Darwinian principle of androgynous variability to its last consequences: by evincing that all human beings have a bisexual primary disposition, Hirschfeld elaborated a theory of bio-psychological intermediariness which excludes male / female hierarchizations. Bauer suggests that Gender and Queer Studies have failed to recognize the importance of Darwin's anti-essentialist naturalism, as they have neglected a systematic study of Hirschfeld's sexual theories. In fact, seen through Hirschfeld's eyes, Darwin's thought appears modern.

The impact of Darwin's theories is explored from a different angle by Pedro Fonseca, who presents an important contribution to the study of the reception of Darwin's theories in Portugal by examining the handwritten degree thesis Luís Wittnich Carrisso presented to the University of Coimbra in 1910. Offering a critical reading of *Hereditariedade (Heredity*), Fonseca examines Carrisso's view on both Darwin's theories and the evolutionary debates of the beginning of the twentieth century; he further assesses the way Carrisso's thesis reflected the ideas of his time, a period known as "the eclipse of Darwinism" in the history of evolutionary theory. Fonseca invites the reader to look at *Heredity* with a degree of salutary caution, as it was presented as an academic text, i.e., subject to subsequent evaluation; thus, Carrisso was not thus completely free to openly stand for mutationism as his preferred evolutionary theory. Fonseca shows how Carrisso was influenced by Dutch botanist and mutation's grand theorizer Hugo de Vries, as well as French zoologist Lucien Cuénot. He then proceeds to demonstrate how Carrisso strived to inscribe mutationism (and particularly Cuénot's theory of pre-adaption) in the Darwinian tradition, overly emphasizing Darwin's concept of abrupt variation. Fonseca's essay includes an informed interpretation of Carrisso's perspective with regard to other evolutionary theories popular at the time.

The following essay, by Iolanda Ramos, offers a solid reflection on the influence of nineteenth-century scientific and utopian views on the emergence of the "white negro" phenomenon. Focusing on "Victorian commodity culture", namely through the expansion of advertising and trade, Ramos analyses how the illusion of negrowashing "helped to maintain the notion of British white middle-class superiority both in the metropolis and the Empire". Focusing on the disconcerting image of the "Tree of Man Family", the author sets out to explain how the ranking of societies along an evolutionary scale from barbarism to civilization coincided with the imperial project, and helped disseminate "'scientific' racism with the idea of *racial* progress". The author then proceeds to make a case about how popular culture assimilated this racial prejudice through the spread of portable commodities such as soap and bleach, which represented "the obvious and most effective way to cleanse and purify" – both physically and morally. Examining how the Victorian need to perpetuate racial difference and emphasise hybridity ultimately resulted in what she calls "an imperial utopia of 'white negroes'", Ramos finally embarks on an appealing discussion over the Irish, regarded as an inferior, degenerate race by the English and Americans, seen as wild, barbarous, poor, ignorant, dirty and rebellious – themselves a kind of "white negroes". Ultimately, as Ramos acknowledges, the construction of white negroes represented an attempt to "transform 'the Other' so as to make him/her similar to 'us'".

Finally, Álvaro Fonseca provides a humbling contemplation of humanity as an evolving part of a wonderful whole, giving continuity to the tree metaphor introduced by Ramos earlier, yet, offering a more optimistic message. By focusing on the metaphor of the tree, Fonseca explains how "the idea that all life on Earth shares a common evolutionary history is one of Darwin's outstanding contributions to modern biology". This bridge is continuously and knowingly built throughout the essay. Although acknowledging that the tree metaphor precedes Darwin, Fonseca notes that these earlier dwellings were merely "based on morphological, physiological and paleontological observations", and lacked the evolutionary notions of "common descent", "shared ancestry" and homology, so instrumental in Darwin's theory and in modern molecular biology. Fonseca explains that Darwin was not familiar with the central concepts of contemporary biology, namely "the nature of genetic information and its transmission, the mechanisms of biological variation and the full extent of biological diversity", nor could he have dreamt of the major breakthrough that the "unveiling of the cell's genetic make-up (i.e. DNA)" represented. Hence, Fonseca sets out to explain some of the mechanics behind modern molecular biology, as well as some of the difficulties encountered when drawing phylogenetic trees. He also describes the arduous quest for the universal tree of life, whose final steps were taken by Carl Woese's work with bacteria. While discussing the arguments for and against Woese's approach, and the dangers of a certain anthropocentrism within the field, Fonseca recognises that the crucial role of bacteria and microbes in the tree of life was a surprise to many, and would certainly have been to Darwin himself.

Part II of this volume – Evolution, Literature and the Arts – opens with Sara Graça da Silva's essay on the intersections between Charles Darwin's theory of sexual selection and Edward Bulwer Lytton's satirical depiction of gender in *The Coming Race* (1871). Her reading of the interplay between literary and scientific discourses attests to the Victorian fascination, both popular and scientific, with the psychic phenomena and theories of evolution, whilst exposing nineteenth-century widespread stereotypes regarding gender. After a brief, yet important contextualisation of Darwin's theory, Da Silva engages in an original and thorough analysis of the novel from an evolutionary perspective, demonstrating how Lytton plays with "complex perceptions of the self and the other" by "unearthing a subterranean race which, contrary to a fossilized remain of our distant past, acts as an omen of prophetic traces of future developments". Her elaboration on the contrasting versions of evolution proposed by Darwin and Lytton is particularly enthralling. In many respects, she notes, among the objects of Lytton's satire there seems to be the theory of evolution itself. She draws special attention to the novel's concern with the future of humankind, and the possibility of the extinction of species (including the human species) due to the achievement of what Peter W. Sinnema describes as "the terminal point of genetic perfection". Da Silva shows that what begins as a utopian description of the Vril-ya society ends with a rather dystopian vision of the same. Ultimately, the narrator of *The Coming Race* increasingly disapproves of the deceiving perfection and inflexibility of the Vril-ya people, whilst "longing for humanity's imperfect harmony".

The following contributions focus on the same period in British social and intellectual history. Paula Guimarães elaborates on the relationship between poetry and science, showing how Romantic and Victorian poets were familiar with evolutionary theories. She focuses particularly on Mathilde Blind's *The Ascent of Man* (1889), a poetic epic which, by summarizing Darwin's evolutionary theory, allows Blind to reflect on social issues, namely on gender relations. In fact, right from the beginning of her lengthy poem, Blind's emphasis on the relevance of women's role is very clear. In the first section of the poem – on the beginning of the world – Blind provides us with what Paula Guimarães describes as a rather feminine account of the progress of humanity, and compares the earth to a maternal body giving birth. The second and third sections of the poem address a pessimistic view of human pilgrimage, and depict, respectively, the banishment of sympathy and love for the sake of pleasure and wealth, and the prevalence of suffering and sorrow. This situation is presented by Blind as resulting from the brutality of institutionalized religion and from political oppression. In Blind's account, it is Art – not God – that brings hope to humanity and grants man eternal life. In that last stage, eventually made possible by the agency of a feminine soul sensible to thought and beauty in Art, all boundaries are to be removed – namely those of gender.

Darwin's profound impact on Victorian literature, and on Victorian novelists in particular, is also addressed by Chengping Zhang, who provides a compelling reading of Thomas Hardy's *Tess of the D'Urbervilles* (1891). Demonstrating how the theme of evolution suits the author's concern particularly well, Zhang goes on to "speculate on the relations between mankind and nature, and on the nature of morality" in the novel. Negotiating scientific and philosophical discussions is a recurrent preoccupation in Zhang's study, as is the analysis of the relationship between evolution and ethics. Throughout the essay, Thomas Huxley's "Evolution and Ethics" (1893) is dutifully explored, namely his belief, as Zhang puts it, that "the ruling principle in human society is ethics, which is antagonistic to natural law, for it requires man to suppress his natural instinct, desire and self-assertive propensities and replace them with sympathy, mutual aid, altruism and self-restraint." Zhang's reading is particularly attracted to Hardy's critique of the rigid Victorian moral conventions. She embarks on a lengthy description of the novel's central character's "position on the ladder of evolution", elaborating on the "cosmic irony" which consists of the irreconcilable discrepancy between natural and social worlds.

Moving forward in time and crossing the Atlantic, Brian Railsback's study of the influence of Darwin on the American writer John Steinbeck offers another example of the ways in which Darwin remains our contemporary. Identifying connections which are at once literary, personal and intellectual, Railsback notes the presence of Darwinian themes in both

Steinbeck's fiction and his non-fiction, most significantly in his journal *Sea of Cortez*, derived from a trip which is claimed to be in some way the equivalent of Darwin's voyage aboard the *Beagle*. Steinbeck, Railsback points out, examines Depression-era issues from a perspective that owes much to a reading of Darwin, and that has ultimately made him capable of "formulating a political/environmental stance before any other writer in the United States". He was, indeed, the country's "first eco-novelist, the first important literary voice to call a halt to our foolish experiments with the environment", and therefore a significant, if relatively unacknowledged, figure for ecocriticism. Steinbeck's concerns over the environment go hand in hand with a holistic view of reality, against the temptation of reductive, excessively man-centred thinking.

The final contribution to this volume belongs to Teresa Botelho who offers an interesting analysis of a selection of twentieth-century science plays which deal with evolutionary theory, examining the way they seek to integrate scientific ideas into the dramatic discourse. Botelho distinguishes four different types of plays, according to their main topic and their author's intentions. The first type includes plays which have Darwin as a character, and depict both his scientific achievements and his personality. Such is the case of *Trumpery*, by Peter Parnell, a play centered on the ethical challenge that Darwin had to face when he discovered that Alfred Russel Wallace had also arrived at the basis of the theory of evolution, and of *Re-Design*, a play "crafted" by Craig Baxter, where the friendship and intellectual complicity between Darwin and the American botanist Asa Gray is portrayed. *Inherit the Wind*, by Jerome Lawrence and Robert E. Lee, is a good example of the second type of science plays. It examines the social and political implications of the theory of evolution by describing the trial, held in 1925, of a Biology school teacher who was prosecuted for teaching evolution in his classes. The third type includes plays that problematize the reception of evolutionism, such as the hilarious *Darwin in Malibu*, by Crispin Whittell, which depicts the very pleasant afterlife of Darwin and his contemporaries, *Darwin's Flood*, by Soo Wilson, where a dead Darwin meets characters from different layers of the past, and *After Darwin*, by Timberlake Wertenbaker, a play which, as Botelho shows, asks questions more than it provides answers about the ethics implied in the theory of evolution. *The Rap Guide to Evolution,* which is an instance of the fourth type of science plays, is in fact a performance by Canadian rapper Baba Brinkman, with clear didactic purposes. In Botelho's view, the considerable success of all these plays attests to the profound impact of science on contemporary societies.

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Despite the enormous bulk of commentary and research on Charles Darwin produced over the last century and a half, either polemical, revisionist or fundamentally appreciative in tone, there are still many missing links and inherent contradictions that continue to attract growing inter- and transdisciplinary attention to Darwin's work from a wide range of specialisms. All in all, the re-drawing of physical and psychological frontiers demanded by evolutionary theory in an attempt to define what is meant by human nature is still very much in progress, validating at the same time extraordinary opportunities for further research. The true implications of Darwin's legacy remain as controversial to the critics of our time as they were to Darwin and his contemporaries.

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PROLOGUE: CHARLES DARWIN'S LIFE AND WORK 200 YEARS ON

JOHN VAN WYHE

Charles Robert Darwin was born on 12 February 1809, the fifth of six children, into a wealthy gentry family in Shrewsbury, Shropshire, in the middle of Georgian England. The family home, The Mount, was a large comfortable house with many servants. Darwin's father, the hugely portly physician and financier Robert Darwin, was the respected son of the philosopher-poet Erasmus Darwin. Darwin's mother, Susannah Wedgwood, was the daughter of the Wedgwood pottery family. In later years, he could only just remember the death of his mother when he was eight. No evidence has been presented for the frequently repeated view that her death had a profound psychological effect on him. His recollections give equal attention to his mother's "curiously constructed work-table" (Barlow, 1958: 22). He was tended by maidservants so that the death of his mother was not the same sort of deprivation as for a modern child. His three elder sisters oversaw the upbringing of Darwin and his younger sister Catherine. Darwin was tutored at home by his sister Caroline before going to a day-school in Shrewsbury run by the minister of the Unitarian Chapel, which his mother attended along with the children. Nevertheless, Charles was baptized and meant to belong to the Church of England. This was crucial in qualifying him to later attend an English University.

In 1818, Darwin went to the grammar school in Shrewsbury as a boarder, about a mile from The Mount, where he stayed for the next seven years, until 1825, when he was sixteen years old. Darwin was not an impressive student and he felt his time at school was wasted learning Greek and Latin classics. He studied chemistry in a home "laboratory" set up in a garden shed with his elder brother Erasmus (1804-1881). Together, they investigated the composition of various domestic substances, mixing, boiling, separating and crystalizing. Through these activities, and the careful studying of chemistry books, Darwin learned first-hand the basic principles of scientific experimentation.

Erasmus went up to Cambridge in 1822 to study medicine. In 1825, he went to Edinburgh University to continue his medical studies. Darwin's father thought it was a good opportunity for young Charles to make a start towards the medical profession. In 1825, Darwin went to Edinburgh and a whole new world of possibilities lay before him. Darwin greatly disliked his studies and was horrified at the sight of blood or operations which were then still performed without anaesthetic.

Darwin was inspired to collect and investigate marine creatures in tidal pools with Dr Robert Grant. These Darwin investigated and dissected under a "wretched microscope" (Darwin, 1958: 50):

> I made one interesting little discovery, and read about the beginning of the year 1826 [actually 1827], a short paper on the subject before the Plinian Soc[iet]y. This was that the so-called ova of Flustra had the power of independent movement by means of cilia, and were in fact larvæ. (Barlow 1958: 50)

Darwin at first hurried to inform Grant of the discovery but was surprised when Grant told him that this was his area of research and that it would be unfair of Darwin to publish it. Thus Darwin was introduced almost simultaneously to the thrill of discovery and the scientific jealousy that often accompanies it. Afterwards Darwin was less keen to be close to Grant.

Darwin gathered that his father would leave him enough property to live in comfort, thus dispelling any real sense of urgency in learning the details of medicine necessary to become a physician. After two years, it became clear to his father that Darwin did not want to be a physician so it was proposed he become a clergyman instead. Although not particularly religious, Darwin did not doubt the truth of the Bible. Becoming a clergyman would mean he could pursue natural history like the famous parson naturalist Gilbert White. And so, Darwin would have to attend an English university to pursue a BA degree as the prerequisite to entering holy orders in the Church of England.

Darwin was admitted to Christ's College, Cambridge, where he became close friends with his elder cousin William Darwin Fox. Fox may have introduced Darwin to the latest craze of collecting beetles. Darwin soon discovered several novel ways of procuring rare and unusual specimens. He sent records of his captures to the well-known entomologist James Stephens who published records of British entomology. These were Darwin's first words in print (see van Wyhe, 2009: 1-2).

Darwin's interests in science became a permanent lifelong devotion, though he continued to have a passionate devotion to shooting. He avidly read the scientific travel accounts of Alexander von Humboldt and dreamed of travelling to the Canaries on a scientific tour of his own. Another influential work for Darwin was by the astronomer John Herschel. His *Preliminary Discourse* (1831) was the role model for correct methods of scientific investigation.

Darwin became the devoted pupil of John Stevens Henslow, professor of botany, from whom he learned a great deal about scientific method. Darwin also studied other branches of natural science in his own time, as the university then offered little instruction in science, eventually learning the basics of a wide range of current fields. In 1831, he successfully completed his exam to gain the B.A. degree. He would later need to take special divinity training to become a clergyman.

In 1831, Darwin was fresh from university and budding with scientific talent. Henslow could see this and encouraged him to study geology, which Darwin took up with enthusiasm. Later, he accompanied Adam Sedgwick on a geological tour of North Wales. Darwin arrived home on 29 August to find a letter from Henslow awaiting him. It contained an offer which would change his life.

A twenty-six year old naval officer, Robert FitzRoy, was given command of HMS *Beagle* for a second surveying voyage to South American waters. He was determined to take along a naturalist capable of studying the little-known lands the ship would visit. He appealed to the Hydrographer of the Navy, Captain Francis Beaufort, to find such a person. FitzRoy wanted someone scientifically qualified, but it went almost without saying that he must also be a gentleman. Henslow then recommended his favourite pupil Darwin. The *Beagle* was to survey the Southern portions of South America, the Galapagos islands and to carry a chain of chronometric measurements around the world. The little ship set sail from Devonport on 27 December 1831.

Darwin and FitzRoy are often portrayed as antagonists during the voyage of the *Beagle*. But FitzRoy became an evangelical Christian only after the voyage. It was FitzRoy who gave Darwin his copy of the first volume of Lyell's *Principles of Geology* (1830). And Darwin was not inherently sceptical of the Bible. His greatest misfortune in the early months at sea and indeed throughout the voyage was terrible sea sickness which often left him incapacitated in his hammock.

The *Beagle*'s first stop was the Cape Verde islands 385 miles off the west coast of Africa. It arrived in Brazil where she was stationed for 19 days at Bahia [Salvador] where, for the first time, at the end of February 1832, Darwin experienced the breathtaking abundance of the tropics. The exotic fauna and flora, and the astonishing variety of natural sights and sounds all around him was one of the most exhilarating experiences of his life. But he was soon hard at work. His pocket field notebook shows he was soon writing torrents of calculations, geological sections, measurements of angles, temperatures, barometer readings, compass bearings, diagrams and sketches (see Chancellor and van Wyhe, 2009). Over the next two years, the *Beagle* proceeded to Rio de Janeiro, Monte Video, Bahia Blanca, Patagonia, and the Falkland islands all the while surveying the coasts and measuring the depth of the seas.

One of the great facts that impressed Darwin in South America, and which later led him to discover evolution, was the change of species as one moved southwards down the continent. The range of one species would finish and another, very similar species, would commence. An example is the rhea. Throughout the pampas, Darwin was familiar with the common rhea. But the gauchos told him of a smaller rarer sort which they called the Avestruz Petise. This kind was seldom seen on the plains bordering the Rio Negro. When camping near Port Desire, one of Darwin's companions shot a small rhea which they ate for dinner. Darwin at first assumed the bird was an immature juvenile of the common sort. Only after dinner did he remember the rare Petise. He later learned that further south this kind took the place of the northern species. Why this should be he could not imagine, but it was a very curious fact that he continued to contemplate over the next few years.

In the southern reaches of Patagonia Darwin discovered the fossilized bones of giant extinct mammals. He spent many hours digging them out of river banks assisted by his servant Syms Covington. There were bones, teeth and mysterious bony armour plates. Several species later proved to be new to science. Darwin could see immediately that some of the fossils resembled the unique present inhabitants of South America such as armadillos and sloths. This was not unlike Australia where extinct fossil marsupial animals had been discovered. The obvious question for Darwin was, why had these creatures become extinct? The pampas were now so tranquil. One possibility was that a great catastrophic flood had torn across the entire region, sweeping away these monstrous beasts.

On another occasion, Darwin experienced a tremendous earthquake which destroyed scores of towns and villages in Chile as well as destructive tidal waves. In the days and weeks after the earthquake, FitzRoy and Darwin pieced together what had happened. The earthquake had affected an area of four hundred miles. Repeated aftershocks came roughly from the east, sometimes leaving long north-to-south cracks in the ground. The shoreline, as could be seen from previously submerged rocks now exposed and high-water lines of mussels, was elevated eight feet above its previous level. Darwin began to search for inland beds of marine shells as evidence of previous earthquakes. He found what he expected to find, and continued to find them 230 feet above the sea. The local people did not believe the shells were marine because they were located in the mountains.

Applying his Lyellian geological training, Darwin found that the western coast of South America was slowly and gradually being uplifted and that so comparatively small an event as the earthquake he had experienced, if reiterated over a long enough period of time, was sufficient to explain the mighty mountain chain of the Andes. The certainty of the continued elevation and subsidence of parts of the Earth's crust brought Darwin surprisingly close to modern plate tectonics. What eluded him was any sense of the crust also drifting horizontally. The principle of elevation and subsidence over vast areas also enabled Darwin to come up with one of his first great theories – the formation of coral reefs and atolls.

No part of the *Beagle* voyage is today more famous or more shrouded in legend than the Galapagos islands. The *Beagle* was in the Galapagos for five weeks, from 15 September to 20 October 1835, and made a series of charts which were still in use in the 1940s. Darwin spent about nineteen days ashore, on Chatham, Charles, Albemarle and James islands. Historians now know that Darwin did not discover evolution while in the islands.

When the *Beagle* left the west coast of South America for the last time, Darwin was interested in studying the geology of the Galapagos. When the *Beagle* arrived, Darwin was not impressed with the largely barren and rocky islands. He soon learned, however, that the islands were of comparatively recent volcanic origin. The *Beagle*'s soundings revealed that the ocean was extremely deep around and between the islands, which seemed to indicate that they were very tall volcanic mountains and not a visible extension of the continent of South America. This made the islands' inhabitants all the more curious for Darwin. He could see that the islands had erupted as molten lava from the bottom of the sea. In some deposits, he found fossilised sea shells. When the islands first appeared, they were devoid of life. While on the islands, Darwin still believed in a version of Lyell's views that species were created in a particular centre and could radiate outwards from there.

The birds were obviously like those in South America. Darwin could not help noticing that the mocking birds on three different islands were distinct, and he noted this fact on his specimens. It did not occur to him at the time that many of the land birds would differ on different islands since many of the islands were in sight of one another. Darwin did not even know, for example, that all of the kinds of what since 1935 have been called "Darwin's finches" were finches at all. Until he had his specimens checked by an expert ornithologist with a world-wide collection, Darwin could not determine if his specimens were distinct species or only local varieties. It was also unknown at the time that the tortoises were indigenous to the islands. It was possible that they had been brought by man to populate the islands with a food source. Darwin dissected some of the marine iguanas, unique in the world. He found that they were vegetarians. Even though Darwin was not stirred to evolutionary speculation on the Galapagos, they were later to influence his thinking profoundly, and would provide one of the three main inspirations for Darwin's theory of evolution.

Darwin's collections and papers proved to the scientific elite that he was a naturalist of the highest calibre. Living on a generous allowance from his father he was, in every sense, a gentleman of science. After returning home in 1836, Darwin began adapting his ship-board diary into a book. Much of the text remained unchanged though Darwin added condensed descriptions of some of his more interesting scientific findings. While working on this book, Darwin first began to think systematically about species origins, but little of his dawning speculations made it into the almost completed book.

Darwin convinced five distinguished experts to classify, name and describe his zoological specimens, to what would later become known as *The Zoology of the Voyage of H.M.S. Beagle* (1838-43). There would be five parts. Richard Owen, professor of anatomy, wrote *Fossil mammalian*. In this work, Darwin's fossil giants like the Macrauchenia from South America were named and described, and Darwin added a geographical introduction. Owen found that the specimens were not only very large but all herbivores, curiously similar in type to those still found in South America.

George Robert Waterhouse, curator of the Zoological Society, wrote *Mammalia,* which described the living mammals collected by Darwin and "their habits, ranges, and places of habitation" with a geographical introduction by Darwin.

The ornithologist John Gould wrote *Birds*. There were fifty magnificent hand-coloured plates which Gould sketched himself. His wife engraved them on stone. All but six were natural size. Gould classified Darwin's Galapagos finches not as varieties but thirteen distinct species. Before the volume was finished, Gould left for an expedition to Australia. Darwin completed the work with the help of George Robert Gray, the ornithological assistant in the Zoological department of the British Museum.

The cleric and naturalist Leonard Jenyns wrote *Fish.* Because Darwin's fish were preserved in alcohol, their colours were faded. Darwin, knowing this when he collected them, recorded their colours using the standard colour names in Werner's *Nomenclature of Colours*, by Patrick Syme.

The dental surgeon and naturalist Thomas Bell wrote the final part, *Reptiles*. Unfortunately, Bell delayed completion of the whole set by almost two years through procrastination and ill-health.

Perhaps his favourite group of living creatures, the marine invertebrates, remained unpublished. At first, Darwin planned to spend a couple years publishing descriptions of the most interesting specimens as articles in scientific journals. In his London lodgings, with his specimens and books and animated conversations with scientific experts, Darwin took on a tangle of puzzles. The anatomist Richard Owen confirmed Darwin's suspicions about the South American fossil bones. They belonged to the same kind of creatures that live uniquely in South America today, such as armadillos and sloths. The ornithologist John Gould told Darwin that his collection of Galapagos gross beaks, finches and wrens were in fact all finches. Many were island specific. The mocking-thrushes which Darwin had observed at the time to be distinct on different islands turned out to be separate species, not just varieties. The same was true for the South American rheas.

Darwin's speculations went through many stops and starts and dead ends. The fact that in all the world the species most similar to those on the Galapagos were on the South American mainland 600 miles to the east was inescapable. That must be their origin. It was inexplicable on any other view – the climate, temperature the very bedrock of the Galapagos is different from South America. All of this evidence converged on the general conclusion that species had to be changeable.

Charles Lyell argued that species in the fossil record had naturally gone extinct as the world changed until it no longer suited them. New species were somehow created to suit the new environment. From a centre of creation, they would have migrated outwards. But if, as Darwin then believed, his finches all fed together in flocks, how could the same environment bring about different species? He started at the most basic level – reproduction; why do organisms reproduce? Why do they have such short life spans and not live forever? There were two kinds of reproduction, splitting or budding which resulted in identical copies, and sexual reproduction which resulted in mixed and therefore altered offspring.

Given that the world changed radically over time as geology proved, reproduction, which resulted in more variable offspring, would allow them to adapt to a changing world. If species were descended from earlier species, just as an individual is descended from parents, then different species in a genus would be related by common descent, as cousins share the same grandparents. He sketched a tiny tree diagram in his notebook to demonstrate how lineages of species would thus be related.

It was not until September 1838 that he read Thomas Malthus's *Essay on the Principle of Population*. Malthus argued that human population growth, unless somehow checked, would necessarily outstrip food production. Population growth, according to Malthus, should be geometrical. For example, two parents might have four children, each of whom could have four children, whose children could also have four children and so forth. The focus of this argument inspired Darwin. He realised that an enormous proportion of living things produced are always destroyed before they can themselves reproduce. This must be true because every species would otherwise breed enough to cover the Earth. Instead, populations remain roughly stable year after year. The only way this can be so is that most offspring (from pollen, to seeds and eggs) do not survive long enough to reproduce. Darwin, already concentrating on how new varieties of life might be formed, suddenly realised that the key was whatever made a difference between those that survive to reproduce and those that do not. He later came to call this open-ended collection of causes "natural selection" because it was analogous to breeders choosing which individuals to breed from and thus changing a breed markedly over time.

Darwin imagined the world of living things – all reproducing at an incredible rate, and almost all being destroyed – devoured, starved or lost. The bursting outward force of reproduction was checked by the carnage of ingestion and death. These two opposing processes were like a war of nature that never ended. Yet, those with the right stuff to slip through the gauntlet and survive would pass on their characteristics to offspring. The result would be the change of species over time and most crucially the way by which they could become adapted to particular environments.

Every part of every organism varies. Hence, every feature was varying hither and yon constantly. There was an endless and spontaneous supply of variations. If circumstances were such that one of these happened to benefit its possessor, then it would get through the filtering process of natural selection and be passed on. In this simple and natural manner, every change from the unknown ancestor of Glyptodon to a modern armadillo could be effected.

In late 1846, Darwin had almost completed his decade-long programme of publishing his experiences, theories and collections from the *Beagle* voyage. All that remained were some marine invertebrates. The government grant which covered *Zoology* had been exhausted so the plan to write a final volume in that series was dropped. Instead, Darwin planned to spend a couple of years writing up some scientific papers describing his final specimens. After that, he would turn full-time to his species theory. First, he wrote some scientific papers on flat worms and arrow worms.

One of his marine invertebrates was a curious tiny parasitical barnacle that bored into the shells of molluscs. It was so different from all other barnacles that Darwin had to name a new sub-order to classify it. Before long he had made a number of exciting discoveries including a possible insight into the origin of sexual reproduction from hermaphroditic forebears. In order to understand where his barnacles fit into the vast group of these creatures, he investigated some other genera. Soon, he was encouraged by colleagues to describe the entire sub-class of barnacles. He thought this might put off his species work for a couple of years, but he was enchanted with his new discoveries. It was also a pleasure to work with his hands again after only writing books for the past ten years.

Unfortunately, the barnacle work dragged on, and on. Many writers have claimed that Darwin worked at barnacles so long to avoid publishing on evolution or because he felt he needed to bolster his skills or professional reputation. Yet, not only is there no evidence for these claims but the masses of notes and letters which survive show that Darwin was at first deeply interested and enthusiastic about the barnacle research in its own right. The simple fact of the matter is, as so many harmless drudges have experienced before and since, sometimes a big project can take a lot longer than originally anticipated. In the end, the barnacle work took eight years to complete. In the end, his work was highly admired by his fellow naturalists. On 9 September 1854, he packed up and returned the last of his borrowed barnacle specimens. On the very same day, he began working on his species theory.

For almost two years, Darwin worked on his species theory on a vast scale. In May 1856, Lyell warned him that other naturalists were drawing closer to Darwin's views. He should condense his materials and bring out a book more quickly. Darwin followed this advice. From mid-1856, he worked steadily on one chapter after another. There was one on geographical distribution, variation in nature, the struggle for existence, natural selection, hybridism, divergence, instinct and so forth.

By the summer of 1858, Darwin was about half way through this "big book" on species which he planned to call "Natural Selection". One fateful morning, however, a packet arrived from an English naturalist and collector in Indonesia, with whom Darwin had been corresponding, named

Alfred Russel Wallace. Darwin was surprised to see that, in an enclosed essay, Wallace proposed a theory for the origin of species strikingly like his own! Darwin forwarded the essay to Lyell as Wallace had requested. Rather than see their friend lose his priority of twenty years, Lyell, in consultation with J. D. Hooker, arranged to have papers by both Wallace and Darwin read together at a meeting of the Linnean Society of London in July 1858. When later printed, it was the first publication of the theory of evolution by natural selection.

Darwin was urged to publish a summary or abstract of his large unfinished work. He spent the next thirteen months drafting it. It became *On the Origin of Species by Means of Natural Selection* (1859). The book had fourteen chapters plus an introduction and conclusion. Darwin began by explaining how he came to doubt the stability of species and how long he had worked on the subject. The brute facts of the similarities of different species, the similarities during embryological development of members of the same genus, geographical distribution, the progressive succession of fossil forms and so forth could indeed convince a naturalist that species change. But this would still be incomplete. One would need a theory to explain how they changed and, most importantly of all, how they came to be so wonderfully adapted to their environments and their immensely complex relationships with one another. His theory of natural selection explained how adaptation could occur, over many generations, given the commonly accepted, but often overlooked, properties of living things.

The *Origin of Species* sparked off a world-wide debate. There were hundreds of book reviews and countless works written in opposition or in support. Darwin was not particularly interested in the reception of his theory by the general public. He was mostly concerned with the views of scientists with relevant knowledge needed to assess his work. At first the views were mixed. Nevertheless, Darwin, as a prominent and respected name in science, had to be taken seriously. Different kinds of people reacted differently to different components and implications of his theory. Many scientists, especially younger ones, soon accepted that evolution was true. Some did not accept Darwin's stress on natural selection. Very many writers focused on the implication that humans must be descended from earlier species. For many, especially religious and non-scientific readers, this was considered unacceptable and Darwin was sometimes harshly criticized.

More and more scientists found that Darwin's explanation made sense of their particular areas of expertise. Articles and books began to appear praising Darwin's ideas. By around 1869, ten years later, most scientists had accepted that Darwin was right. By the 1870s, Darwin was widely regarded as a scientific revolutionary who had transformed the study of the natural world.

Darwin did not abandon his original intention of writing his large work on evolution. The first two chapters of his unpublished manuscript became *Variation of Animals and Plants under Domestication*, published in 1868. It is his longest book. At that time, he envisioned writing two more works of equal scope, but he never did. The book examined many examples of domesticated plants and animals, especially pigeons which Darwin had kept himself, as well as rabbits, fowls and ducks. He demonstrated the degree and nature of changes that domesticated species had undergone while under the control of humans. He argued that breeds of the same species such as dogs and pigeons were probably descended from a single wild ancestral species rather than many separate wild species. One of the main points of the book was to demonstrate that "no part of the organisation escapes the tendency to vary" (Darwin 1868, vol. 2: 408). As far as could be determined, organisms were highly malleable. For example, he showed that "In certain pigeons the shape of the lower jaw, the relative length of the tongue, the size of the nostrils and eyelids, the number and shape of the ribs, the form and size of the œsophagus, have all varied" (*ibidem*). These small naturally occurring differences or variations were artificially selected by humans to improve their breeds in a desired direction. Darwin made the point that pigeon breeders, for example, could not cause a bird to have a slightly larger tail. Instead, they selectively breed from individuals with the longest tails, excluding those with shorter tails. By continuing this process over generations extremely different breeds had been produced, so different that a naturalist seeing one in nature would classify it as a different species. Darwin used this point to show that since:

> We have abundant evidence of the constant occurrence under nature of slight individual differences of the most diversified kinds (...) we are led to conclude that species have generally originated by the natural selection, not of abrupt modifications, but of extremely slight differences. (Darwin 1868, vol. 2: 414)

As his health declined, Darwin worked more and more on plants because he could study them at home when he could manage only and hour or two of work per day. He became fascinated by the movement of plant tendrils and soon took up the study of many kinds. Eventually, he studied over a hundred species of climbing plants including twining plants, leaf-climbers, and tendril-bearers. His work on them stressed some familiar Darwinian themes – to make the invisible, visible and to explain the apparently inexplicable by revealing how tiny changes could build up to achieve great results.

Because plants move so slowly, many mysteries were involved with how they moved such as whether light, gravity or touch affected their growth and motion. He set to experimenting to find answers. Darwin used several ingenious methods to reveal the motions of climbing plants. For example, he covered the plant to be studied with a glass dome or bell-glass. He then traced the motion of the part of the plant he was observing onto the glass at regular intervals. Eventually, he had a series of lines, which could be transferred to paper, revealing how the plant had moved.

Darwin could show that many types of climbing plants had probably descended from earlier, simpler forms of climbing such as wrapping the entire stem around an object rather than specialized tendrils. He showed, for example, that "tendrils consist of various organs in a modified state, namely, leaves, flower-peduncles, branches, and perhaps stipules" (Darwin, 1875: 193). He concluded his work with the observation:

> It has often been vaguely asserted that plants are distinguished from animals by not having the power of movement. It should rather be said that plants acquire and display this power only when it is of some advantage to them; this being of comparatively rare occurrence, as they are affixed to the ground, and food is brought to them by the air and rain. (*Idem*: 206)

Darwin collected notes on the origins of humans from the 1830s. It seemed to him sufficient to state at the end of *Origin of Species* "Light will be thrown on the origin of man and his history" (Darwin, 1859: 488). After the *Origin* a few other authors, notably T. H. Huxley with his 1862 *Man's Place in Nature*, wrote about the evolutionary implications to mankind. Darwin thought it was time to give his own view and his work was published in 1871 as *The Descent of Man, and Selection in Relation to Sex*. An apparently odd feature of the book is that much of it is about sexual selection in other species like insects, fish, lizards, primates and especially birds. This was Darwin's second kind of mechanism for explaining evolutionary change though now regarded as a sub-type of natural selection. He explained sexual differences such as male antlers, spurs on cocks or the peacock's tail as the result of differential success in males either competing against other males or being chosen by females and therefore leaving more offspring. This makes *Descent* practically two books. Darwin explained why sexual selection occupied so much of the work:

> During many years it has seemed to me highly probable that sexual selection has played an important part in differentiating the races of man (...) When I came to apply this view to man, I found it indispensable to treat the whole subject in full detail. Consequently the second part of the present work, treating of sexual selection, has extended to an inordinate length, compared with the first part; but this could not be avoided. (Darwin, 1871, vol. 1: 4)

The first part demonstrates what humans are and what we come from. Darwin grouped the evidence into three kinds: similarities between man and other animals such as in the same bones in our skeletons, muscles, organs etc. “On any other view the similarity of pattern between the hand of a man or monkey, the foot of a horse, the flipper of a seal, the wing of a bat, &c., is utterly inexplicable” (*idem*: 31). He showed that humans are more similar to apes than apes are to any other living animals. Darwin also stressed the similarities in embryological development. Human embryos do not start out as very small mini adult humans which just get bigger. Instead, they go through a long developmental process where they closely resemble the embryos of other animals. And finally vestigial parts which no longer have a function but are a remnant from ancestral forms such as our rudimentary tail bones. Darwin speculated that humans originally evolved in Africa.

Darwin originally intended to discuss human expressions in *Descent*, but the book became too long so he published a second work in 1872, *The Expression of the Emotions in Man and Animals*. He was originally stirred to write on this subject by the assertion of an earlier writer who claimed that man is provided with special muscles just for expressing emotions. Darwin showed instead that human emotions and their expression were present to some degree in other animals. He also showed that the main expressions were universal in all human races, which was additional evidence that all are descended from “a single parent-stock”.

Darwin’s last book was on earthworms, published in 1881, the year before his death. Like so many of his other words, it was published decades after he first began speculating on the subject. And he once again discovered that small apparently trivial natural processes, ever present but unnoticed beneath our feet, completely change the surface of the land “Worms have played a more important part in the history of the world than most persons would at first suppose” (Darwin, 1881: 305).

Darwin died on 19 April 1882. Since the early 20th century a few legends have arisen, especially in America, claiming that Darwin recanted of evolution or converted to Christianity on his deathbed. His family forcibly refuted these when they first appeared but to this day they continue to circulate, generally amongst people who wish them to be true. Although Darwin intended to be buried in St Mary's churchyard in Downe, many senior figures in British science and the Church of England felt that their distinguished countryman should be interred in Westminster Abbey. It was soon arranged and Darwin was buried after a state funeral on 26 April 1882.

In the century and more since Darwin's death, an amount of knowledge about the workings of living things and the history of the Earth has been uncovered which is without parallel in human history. No wonder it is daunting for beginners. Yet all of this work has confirmed and corroborated Darwin's essential points to a degree he could never have imagined. Further discoveries in the fossil record, the discovery of genetics and DNA and a host of other findings have made Darwin's theory as solid today as the theory of gravity. Darwin's theory makes sense of the natural world.

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