MAY 1982 - 5 French francs

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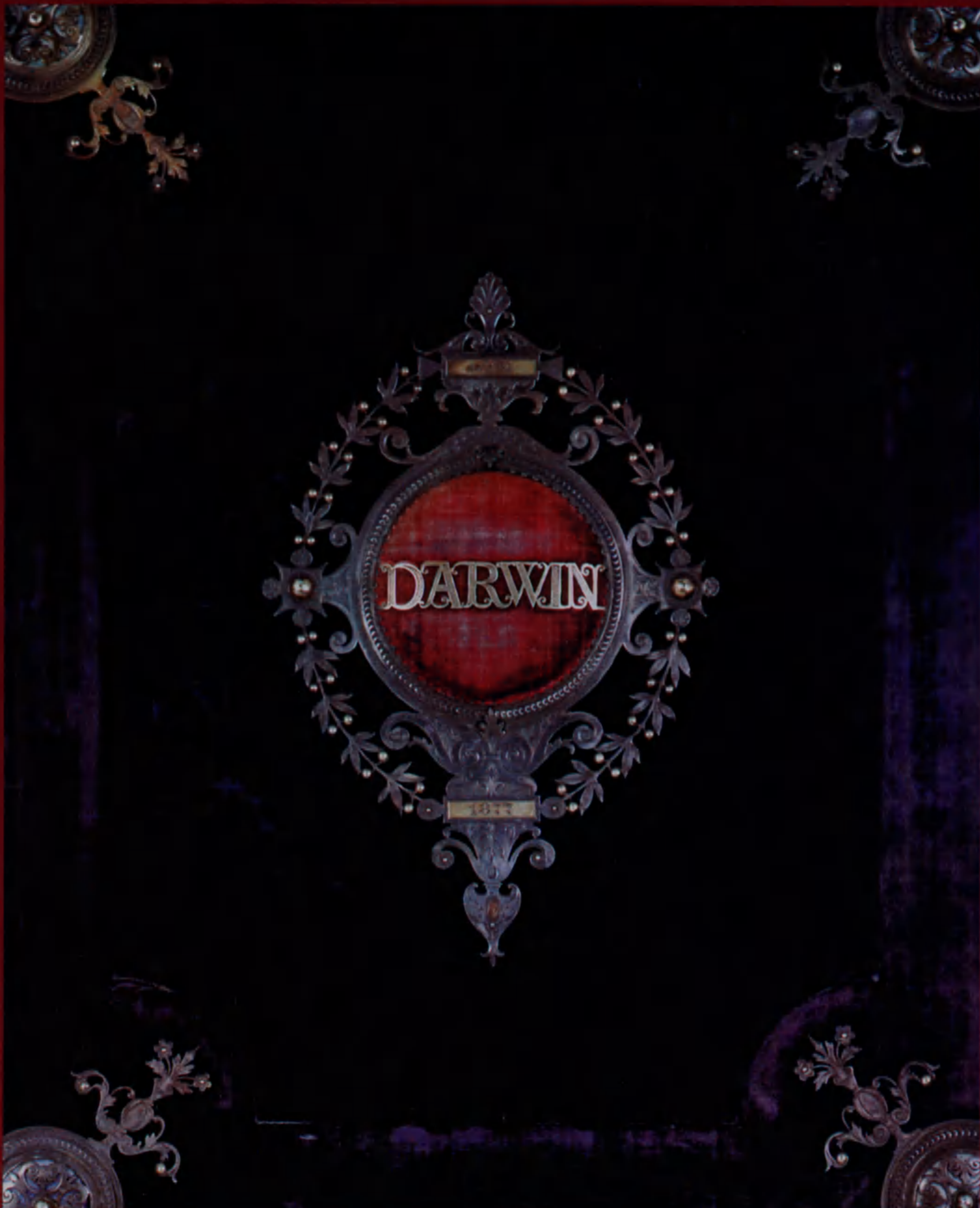

by

Asimov ☆ Thuillier ☆ Wickramasinghe

A time to live...

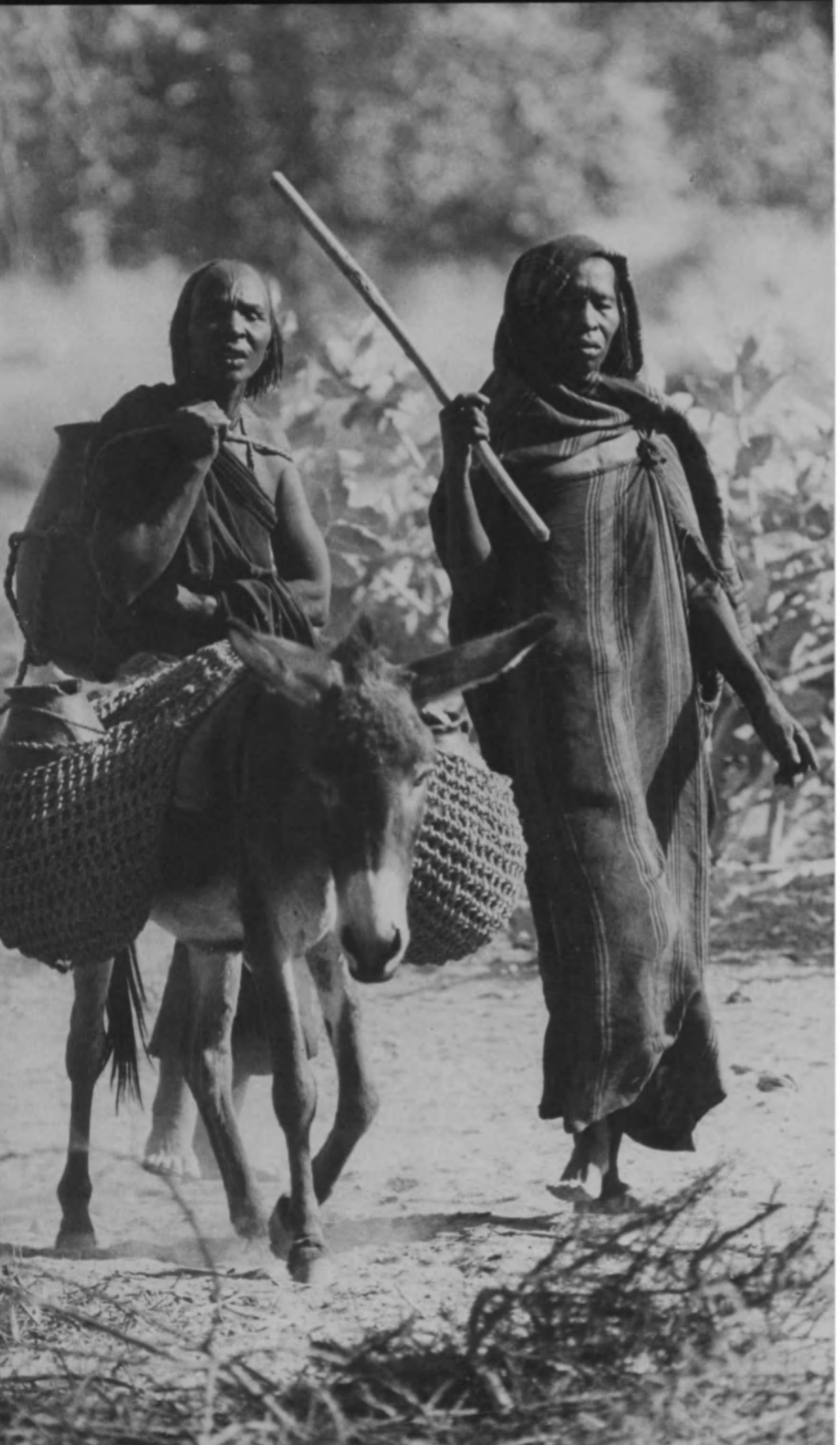

Photo © Léon Herschtritt, Paris

❷ CHAD

The water-bearers

"Water. Where I get it? Oh, I walk two hours every time, and two hours back. I do this twice a day..." A young Sudanese girl describes in these words a fact of everyday life for many of the world's population. According to figures for 1980 approximately *three out of five* persons in developing countries do not have easy access to safe drinking water, so that rural women and children, who usually fetch and carry water, often trek up to ten kilometres a day just to obtain enough to satisfy their families' minimum requirements. The consequences of this situation for health and development are devastating. In 1981 the General Assembly of the United Nations launched the International Drinking Water Supply and Sanitation Decade, a worldwide co-operative effort to provide "clean water and adequate sanitation for all by the year 1990." Photo shows two village women near Lake Chad.

The Unesco Courier

A window open on the world

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page

Editorial

THIS year marks the centenary of the death of Charles Darwin, the man whose theory of evolution by natural selection was unquestionably the most important single scientific innovation of the nineteenth century. Our purpose in this issue of the Unesco Courier *is to pay homage to this great scientist whose work laid the foundations of modern biology; we leave to others the task of assessing the moral and religious repercussions of a theory that one modern philosopher has described as a "metaphysical research programme".*

In contrast to traditional creationist theory, which maintained that all forms of life had existed virtually unmodified since they were created at the beginning of biological time, Darwin's theory of evolution held that existing species, including man, had evolved over billions of years from a single primitive form of life.

Yet when The Origin of Species *was published in 1859, evolutionary theory already had a long history; Darwin himself, in the* Historical Sketch *with which he prefaced later editions of* The Origin, *listed over thirty predecessors. Why then is Darwin honoured above all others as the symbol and the primary force behind the greatest transformation ever in the biological sciences?*

The answer is that whereas earlier evolutionary theories had been speculative in character, Darwin, in The Origin, *marshalled an overwhelming array of evidence to support his claim that evolution could be seen to have occurred and that natural selection was its driving mechanism. On reading this evidence Thomas Huxley, who was to become Darwin's most able champion, remarked admiringly: "How stupid not to have thought of that!"*

Publication of The Origin of Species, *however, sparked off a revolution not only in the biological sciences but also in western man's philosophical, moral and religious conception of himself. Although Darwin declared that he could "see no good reason why the views given in this volume should shock the religious feelings of anyone", his message threatened the whole edifice of rational Christian thought as represented by Natural Theology, since it denied the notion of inherent progress and purposiveness in evolution and introduced the spectre of randomness.*

Samuel Wilberforce, bishop of Oxford, denounced "the degrading notion of the brute origin of him who was created in the image of God". Less extreme, but reflecting the general sense of shock at this assault on the genteel standards of Victorian English society, was the comment of the wife of the bishop of Worcester: "Descended from the apes! My dear, let us hope that it is not true, but if it is, let us pray that it will not become generally known."

Comparison with the Copernican revolution is inescapable. In the words of Sigmund Freud: "Humanity has in the course of time had to endure from the hands of science two great outrages upon its naive self-love. The first was when it was realized that our earth was not the centre of the universe, but only a speck in a world system of a magnitude hardly conceivable... The second was when biological science robbed man of his particular privilege of having been specially created and relegated him to a descent from the animal world."

Cover photo shows detail of the cover of an album presented to Darwin by men of science in Germany on his birthday in 1877.

CHARLES DARWIN

1809-1882

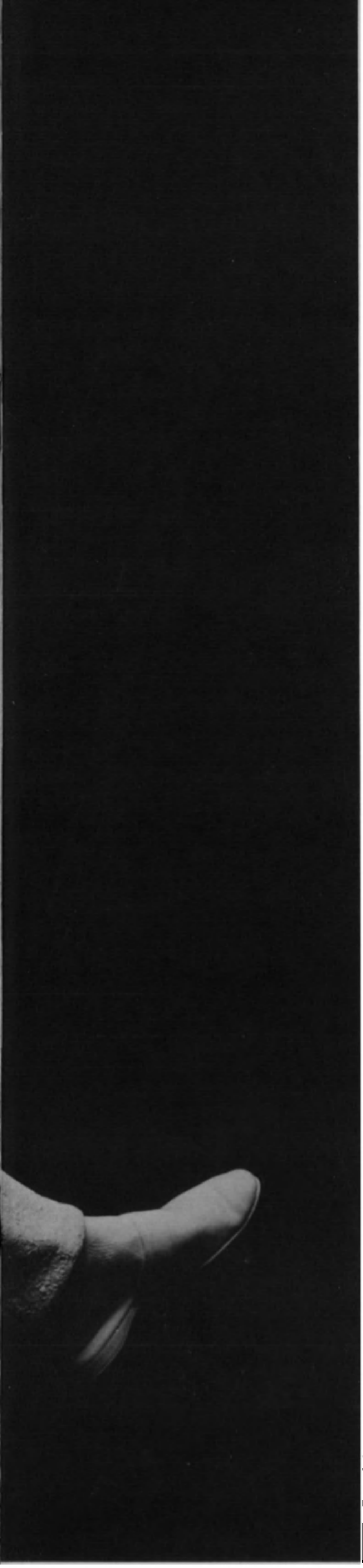


Photo (c) Courtesy of the Natural History Museum, London

THE EVOLUTION OF A GENIUS

by Magnus Pyke

BY the time Charles Darwin was twenty-seven years old, he already had in his possession, that is to say, in his notebooks and in his head, all the information on plants and animals on which, later on, he constructed the theory of evolution and based his ideas about the origin of species. This theory and these ideas upset the world. It thus came about that all those who lived after him knew that the universe was a different place from what those who lived before had believed it to be.

As Darwin's life strikingly demonstrates, social and ethical consequences may often surprisingly arise from the work of people whose activities seem to be most unpromising and even uninteresting. Darwin as a young man showed little promise. Nor were his interests such as would have suggested a potential for great scientific attainment.

In 1876, when he was sixty-seven years old, he wrote a charming essay for his children, without any thought that it would ever be published. This he entitled *Recollections of the development of my mind and character*. In it he described how, as a little boy at his first day-school, he was much slower to learn than his younger sister Catherine and was, as he believed, in many ways a naughty child.

At the same time, he always had a taste for collecting. Even in those early days, he collected all sorts of things, not only plants, birds' eggs, shells and minerals, but coins and seals as well. He also made an effort to learn the names of plants. Whether his love of fishing can be taken as part of his interest in collecting or not, it undoubtedly led to his spending long hours on the bank of a river or a pond watching the float and thus provided time for quiet contemplation.

In that period of his life, no one had any thought of his becoming a scientist. In 1818, when he was nine years old, he was sent to "Dr Butler's great school at Shrewsbury", where he remained for seven years until the summer of 1825. This school taught him nothing of value to his later life. The teaching was confined to Latin, Greek and ancient geography and history.

He left school neither high nor low in comparison with his fellows and was considered in general a very ordinary boy. His father, though fond of him, once had occasion to say to him "You care for nothing but shooting, dogs and rat catching, and you will be a disgrace to yourself and all your family".

Perhaps this was a very harsh judgment. When he was taught the geometry of Euclid by a private tutor, he experienced intense pleasure at the clear and rational proofs. He felt similar delight when his uncle explained to him the principle of the vernier of a barometer. But his main enthusiasm at sixteen, an enthusiasm which he retained for many years, was shooting.

It was, perhaps, a sign of some stirring of scientific curiosity that impelled him to volunteer to serve as an assistant to his brother who was studying chemistry and who had set up something of a laboratory in the garden tool-shed of their house. The two boys often worked here half the night, immersed in their experiments. When Charles' schoolmaster, the formidable Dr Butler, heard what he was doing, he delivered a public rebuke, accusing him of "wasting his time on such useless subjects".

In October 1825, his father, seeing that he was doing no good at school, sent him to Edinburgh University with the idea of his becoming a doctor. The notion of his taking up medicine as a career was not proposed as a means for him to develop such scientific bent as he might possess. Rather, medicine was considered to be a useful, honourable and gentlemanly occupation.

But although Charles Darwin gained little or no benefit from the official course of instruction in medicine, his interest in science was awakening through his association with a number of bright young men who were fond of natural science.

An indication of Darwin's growing attachment to biological science was his friendship with a Dr Grant, his senior by several years, who subsequently became professor of zoology in University College. Stimulated by these men, he took part in expeditions to collect animals in tidal pools by the sea-shore. These activities had nothing to do with his medical curriculum. Nevertheless, they illustrate a fundamental factor in the development of the thinking of a young man destined to make one of the major scientific discoveries of his century.

It is interesting to note that in 1826, when he had only attended Edinburgh University for a year, Charles Darwin published two short papers on conclusions arising from the ▶

MAGNUS PYKE, *British scientist and popularizer of science, was Secretary of the British Association for the Advancement of Science and Chairman of its Council from 1973 to 1977. He is the author of many popular works on science and society including* Butter Side Up: Delights of Science *(John Murray, 1976) and* Our Future: Dr. Magnus Pyke Predicts *(Hamlyn 1980) as well as specialized studies such as* Food Science and Technology *(John Murray, 1970). This article is adapted from a chapter contributed by Dr. Pyke to a book being published this month by Unesco and the Mendelianum of the Moravian Museum, Czechoslovakia:* From Biology to Biotechnology, *edited by Colette Kinnon, Alexander Kholodilin and Vitezslav Orel.*

▶ observations he had made when collecting sea creatures from tidal pools around Newhaven. Thus, simply and while still a student, and in spite of the discouragement of his schoolmaster and the tedium of his official teachers at the university, his life as a scientist can be seen to have begun.

After Charles Darwin had spent two sessions at Edinburgh University, his father formed the opinion, partly from his own observations and partly from what Charles' sister had told him, that he did not like the idea of becoming a doctor. Since he was strongly averse to his son turning into an idle sporting man, he proposed to Charles that he should become a clergyman.

The young man considered his father's proposition very carefully. He liked the idea of becoming a country parson. He believed at that time in the literal truth of every word in the Bible, it never having entered his head to do otherwise. After having read one or two books on theology, he found no difficulty in accepting the dogma of the Church of England and, therefore, in agreeing to his father's suggestion. In view of some of the implications of the deductions which arose from his subsequent theory of the origin of species, his willingness at the age of nineteen to take Holy Orders is strangely paradoxical.

In order to become an Anglican clergyman in 1828, it was necessary to take a degree at one of the two English universities of Oxford or Cambridge. And so once more we find Charles Darwin at a university, ostensibly studying a subject in which he had no interest. On the other hand, casually attending a public lecture by John Henslow on botany, he found himself enchanted by its clarity and by the admirable drawings with which it was illustrated. More than this, he enjoyed the field excursions which Henslow used to organize, on foot, in coaches, or in a barge down the river. But there was no pursuit at Cambridge which he enjoyed so much as collecting beetles.

None of this, of course, had anything to do with becoming a clergyman. On the other hand, his invention of two new methods of collecting beetles (by employing a labourer to scrape the moss off old trees during the winter, and by collecting the rubbish at the bottom of the barges used to transport rushes) was an indication of what was to come. And again, as when he was a student in Edinburgh, so now when he was an undergraduate at Cambridge, his name appeared in the scientific literature, this time as the magic words, "captured by C. Darwin", in Stephen's *Illustrations of British Insects.*

Undoubtedly, there was already something about this idle theological student that attracted the attention of people such as Professor Henslow and distinguished him from the ordinary run of students. Professor Henslow kept open house once a week when he invited older members of the university who were interested in one or other of the branches of science. He invited young Darwin and obviously took to him. They soon dropped into the habit of taking long walks together when the conversation ranged over botany, entomology, chemistry, mineralogy, geology and—yes, this was included too—religion.

Darwin appreciated Henslow's wide knowledge and his habit of long-continued observation from which he drew his conclusions. It is interesting to note that in a later account of Henslow he described him as one whose "judgment was excellent, and his whole mind well balanced; but I do not suppose that any one would say he possessed much original genius". The *Encyclopedia Britannica,* after noting that he was, with Sedgwick, responsible for founding the Cambridge Philosophical Society, lists as his claim to celebrity that "to him Darwin largely owed his attachment to natural history and his introduction to Captain Fitzroy of H.M.S. Beagle".

Collapsible microscope and the pistol, powder horn and bullet mould Darwin took with him on H.M.S. Beagle.

His three years at Cambridge he later described as among the happiest in his life. He enjoyed his shooting and hunting. He got into a sporting set who dined, drank and played cards together. He also associated with a musical set of jolly young men. His summer vacations were given up to his hobby of collecting beetles. In the autumn he devoted himself to shooting.

How easily might he have slipped into the life of a conventional middle-class gentleman. How easily could he have become a country clergyman whose side interest was entomology. But while he was still at Cambridge, two incidents changed the whole pattern of his career.

Because of his incompetence in the classics, Darwin had not been able to begin his studies in Cambridge on the appropriate date. The university authorities, therefore, required that he stay at his college for two extra terms. To fill in his time usefully, Professor Henslow arranged for him to accompany his colleague Sedgwick on a geological expedition which the latter was undertaking in North Wales. Charles Darwin jumped at the opportunity and it was while he was collecting geological specimens on this trip that he came to realize that such a collection was not of scientific interest for its own sake but was rather of value for the way in which it contributed to a coherent hypothesis capable of explaining how it was that rocks of a particular type got where they were.

The second incident came hard on the heels of the first. On returning home after his geological tour with Sedgwick, Darwin found a letter from Henslow awaiting him. In this letter Henslow mentioned that a Captain Fitzroy, who had been commissioned by the Government to undertake a round-the-world survey, had formed the idea of taking with him a naturalist to survey the plants and animals encountered during the voyage. The job was unpaid but would clearly be of interest to someone with an appropriate bent. Darwin was attracted by the idea and was anxious to accept the invitation. Having obtained his father's permission, Darwin set off for Cambridge to see Henslow and, briefed by him, travelled on to London to be interviewed by Captain Fitzroy, the leader of the expedition and captain of the ship.

How nearly Darwin was rejected he only learned later on. At the time, Captain Fitzroy was an ardent disciple of the Swiss divine and mystic, Johann Kaspar Lavater. Lavater was famous for his work on physiognomy, a so-called science which purported to enable its adherents to read a man's character from the shape of his features. Fitzroy believed in this system and was convinced that he could judge the ability of each candidate who came before him by the shape of his nose. Looking carefully at Darwin, he was filled with doubt whether anyone with a nose like his could possess sufficient energy and determination for the voyage. Luckily, Fitzroy overcame his doubts and came later to accept that Darwin's nose had spoken falsely.

Thus, almost by chance, as it would seem, Darwin set sail as a biologist to collect the information from which he came to draw the conclusions which changed the understanding of future generations. "The voyage of the Beagle", he wrote later, "has been by far the most important event in my life and has determined my whole career". It kept him away from home for five years, from December 1831 to October 1836. He was twenty-two when he left and twenty-seven when he returned.

The ship sailed from England to the Cape Verde Islands and other islands in the Atlantic, then on to the east coast of South America, to Tierra del Fuego, the west coast of South America, calling at the Galapagos Islands in the Pacific. These constitute an archipelago of twelve large and several hundred small islands, six hundred miles from the nearest land, in Ecuador. They were discovered by the Spaniards early in the sixteenth century and owe their name to the presence in them of large numbers of characteristic giant tortoises. *Galápago* is the Spanish word for a tortoise. These and other creatures peculiar to the islands were important to Darwin's thesis because they had lived undisturbed by outside influences and, primarily, the influence of man.

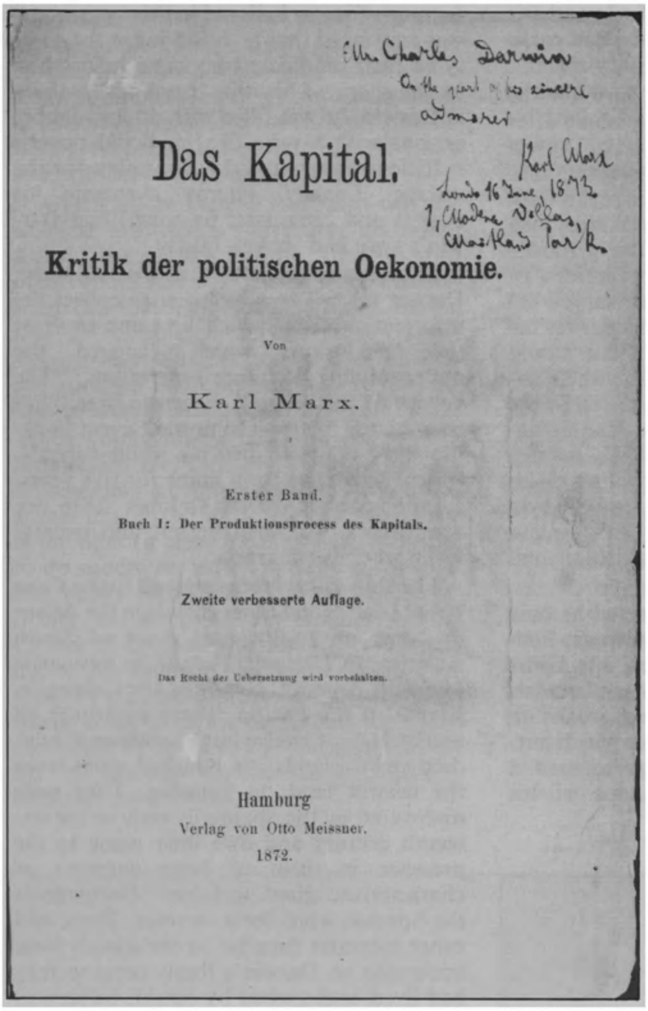
Sailing further west, the *Beagle* visited Tahiti on the way to New Zealand, Australia and Tasmania, then on to Keeling Island, the Maldives in the Indian Ocean, Mauritius, St. Helena, Ascension Island and Brazil. Leaving Brazil, they sailed back to the Verdes and on to the Azores in mid-Atlantic on their way home.

Whatever reputation Charles Darwin had acquired as a schoolboy and an undergraduate—for sports, idleness or diligence—he showed himself during this five-year expedition to be enormously industrious. Not only did he keep a detailed diary of every item of scientific interest in the geology, botany and zoology of each region, but he also set down with delighted curiosity particulars of the people living in each place and the incidents that befell himself and his fellow travellers.

Charles Darwin came home from his voyage in October 1836. During the period from then until September 1842, a period of six years, he lived first in Cambridge and then in London. These years were devoted to the codifying and organizing of the mass of information which he had collected. In 1839, he published a narrative of the surveying voyages of the *Beagle's* round-the-world cruise. In 1840, he published two sections of ▶

Photo © Courtesy of the Syndics of the Cambridge University Library, Cambridge

Engraving by the ornithologist and artist John Gould of the *Rhea Darwinii*, a rare species of flightless, ostrich-like bird from southern Patagonia, identified by Darwin in 1834 during an expedition near Port Desire.


Mr. Charles Darwin
On the part of his sincere
admirer
Karl Marx
London 16 June, 1873
1, Modena Villas,
Maitland Park

Das Kapital.

Kritik der politischen Oekonomie.

Von

Karl Marx.

Erster Band.

Buch I: Der Produktionsprocess des Kapitals.

Zweite verbesserte Auflage.

Das Recht der Uebersetzung wird vorbehalten.

Hamburg

Verlag von Otto Meissner.

1872.

The title page of a copy of *Das Kapital,* presented to Darwin by Karl Marx. The handwritten inscription reads: "Mr. Charles Darwin, on the part of his sincere admirer Karl Marx, London 16 June 1873".

▶ a work on *The Zoology of the Voyage of the Beagle.* More came out in 1841, 1842 and 1843. Indeed he went on writing and publishing for much of the rest of his life. He undoubtedly worked hard and thought deeply. Nevertheless, his ideas developed slowly. Furthermore, he was hampered by ill health.

Before setting sail on the great voyage, when he was troubled by the thought of leaving his family and friends, he believed he had a heart disease and complained of "palpitation and pain about the heart". Now, during his time in London, and after having married his cousin, Emma Wedgwood, in 1839, he suffered from "frequently recurring unwellness, and to one long and serious illness". He was then thirty (he lived to the age of seventy-three). In September 1842, he bought a house in the country, at Downe in the county of Kent, where he lived for the rest of his life, seeing few people and taking little or no part in social life. Throughout this period, he complained of ill health. Dinner parties, which "always put me into high spirits", he avoided because, he found, "my health almost always suffered from the excitement, violent shivering and vomiting attacks being thus brought on."

In 1842, the year in which Darwin installed himself at Downe and six years after the completion of his collections in the *Beagle,* he allowed himself to write down—only in pencil—an outline of a theory to explain the origin of new species of creatures from their predecessors. In fact he had already had this notion in his head for four years. "In Oc-

Emma Darwin

In January 1839, some two years after the Beagle returned to England, Charles Darwin married his cousin Emma Wedgwood, seen here at the age of 32 in a portrait by Charles Richmond. The marriage was a happy one. A gay, attractive, intelligent woman, Emma took a keen interest in music and was devoutly religious. She nursed Darwin through his long bouts of illness and never wavered in her support for him as a man of integrity, even though she suffered greatly to see him gradually losing his religious faith. This moving letter to Darwin was found among her papers after her death. On it Darwin had written "When I am dead, know that many times I have kissed and cried over this. C.D."

"...The state of mind that I wish to preserve with respect to you is to feel that while you are acting conscientiously and sincerely wishing and trying to learn the truth, you cannot be wrong, but there are some reasons that force themselves upon me, and prevent me from being always able to give myself this comfort. I dare say you have often thought of them before, but I will write down what has been in my head, knowing that my own dearest will indulge me. Your mind and time are full of the most interesting subjects and thoughts of the most absorbing kind, viz. following up your own discoveries—but which make it very difficult for you to avoid casting out as interruptions other sorts of thoughts which have no relation to what you are pursuing, or to be able to give your whole attention to both sides of the question... May not the habit in scientific pursuits of believing nothing till it is proved, influence your mind too much in other things which cannot be proved in the same way, and which if true are likely to be above our comprehension?... I do not wish for any answer to all this —it is a satisfaction to write it, and when I talk to you about it I cannot say exactly what I wish to say, and I know you will have patience with your own dear wife. Don't think that it is not my affair and that it does not signify much to me. Everything that concerns you concerns me, and I should be most unhappy if I thought we did not belong to each other forever...".

Here perhaps lies the true answer to the much discussed riddle as to why Darwin delayed so long in publishing *The Origin of Species,* a delay (see caption opposite page) which nearly cost him very dear—he could not bring himself to affront the deeply-held religious beliefs of his beloved Emma.

tober 1838", he wrote, "that is fifteen months after I had begun my systematic enquiry, I happened to read for amusement Malthus on 'Population', and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species. Here, then, I had at least got a theory by which to work; but I was so anxious to avoid prejudice, that I determined not for some time to write even the briefest sketch of it."

And so he ruminated as the years went by and gradually refined and improved his ideas about evolution and the origin of species. His early conception provided no explanation of why biological species descended from the same stock should diverge in character as they became modified. His conclusion was that "the modified offspring of all dominant and increasing forms tend to become adapted to many highly diversified places in the economy of nature." In describing how he reached this hypothesis, he wrote, "I can remember the very spot on the road, whilst in my carriage, when to my joy the solution occurred to me." This sentence reveals something about the nature of scientific discovery—that ideas can come to the prepared mind; that they may strike as a sudden flash of intuition, and that, when they do, they engender a feeling of delight.

The process of reflection and thought, the consideration and reconsideration of evidence drawn from his own observations and from those of others, went on for twenty years until early in 1856 Sir Charles Lyell, the leading geologist of the day, advised Darwin to publish his ideas. Darwin at once began to prepare an extensive exposition. Even so, by the summer of 1858 he was only about half finished. Then one day through the post came a letter from a Mr Alfred Wallace. This man was a surveyor and architect with a strong taste for natural history who was at that time exploring in Malaya. He enclosed with his letter a paper entitled *On the tendency of varieties to depart indefinitely from the original type*. Darwin was thunderstruck to find that Wallace's essay contained exactly the same theory about the origin of species as his own.

Here then we find a characteristic of scientific discovery that repeatedly occurs. The great men and women who make outstanding discoveries are undoubtedly ahead of their times, but often by not very much. Knowledge grows and it may then happen that discoveries come to be made, but only when the time is ripe for making them. Although there had been some questioning here and there, up to the time of Darwin it was generally assumed that species were separate and always had been so. Furthermore, most of the great religions recounted as revealed truth how different animals had been created different from the beginning at the creation of the world. But although there had been changes in the understanding of geologists who directed their attention to the fossils of animals embedded in the rocks (the palaeontologists), it was only in Darwin's own time that it became apparent that the length of time needed for the formation of the diverse ▶

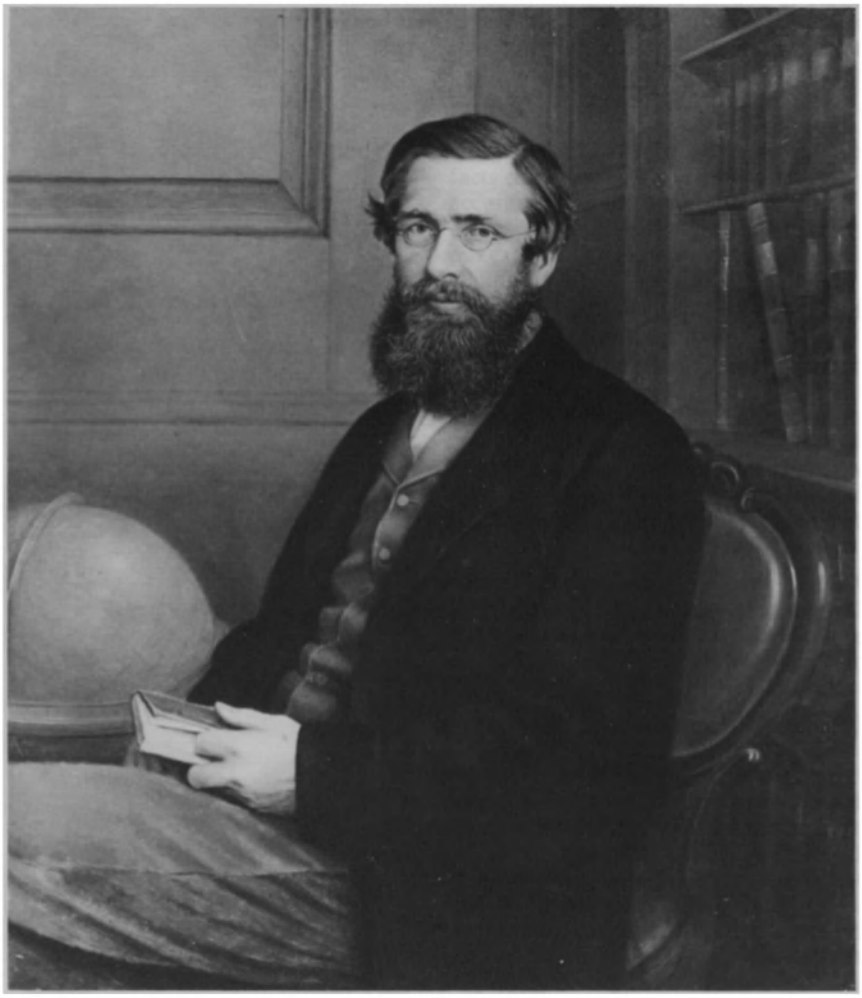
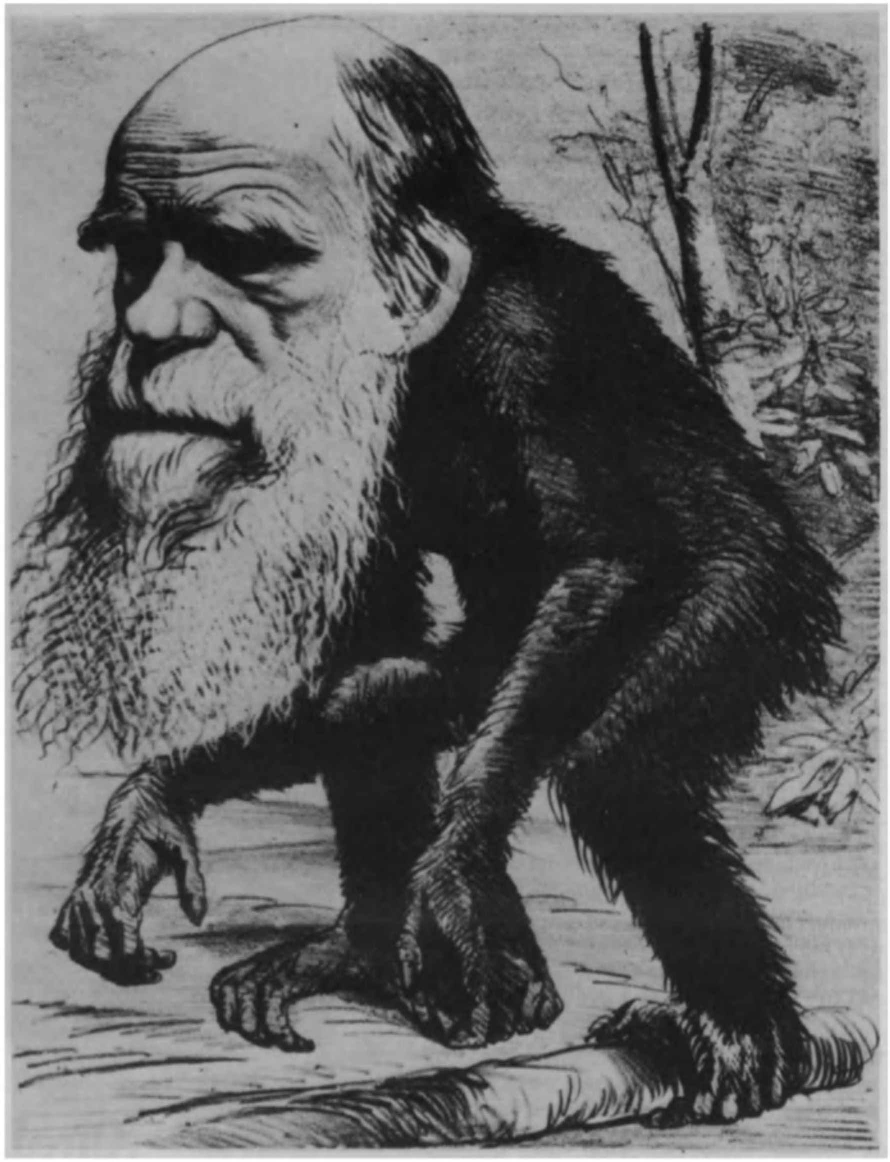


Photo © National Portrait Gallery, London

Alfred Russel Wallace

This portrait of the naturalist Alfred Russel Wallace was painted over a photograph by Thomas Sims and is now in the National Portrait Gallery, London. In 1858, Wallace independently discovered the principle of natural selection and sent Darwin a short essay, On the Tendency of Varieties to Depart Indefinitely from the Original Type, *in which the principle of natural selection was expounded. In a brief accompanying note Wallace wrote that he was hopeful that it "would supply the missing factor to explain the origin of species" and asked Darwin, if he found it "sufficiently important", to forward it to the geologist Charles Lyell. The manuscript came as a bombshell to Darwin. For some years Lyell had been urging him to publish his theory, but suddenly it seemed that Wallace had effectively pre-empted his life work. "Your words have come true with a vengeance—that I should be forestalled", he wrote to Lyell; and he added, "I never saw a more striking coincidence. If Wallace had my manuscript written out in 1842, he could not have made a better short abstract! Even his terms now stand as heads of my chapters". Charles Lyell and the botanist Joseph Hooker found an elegant solution that was fair to both men. They arranged for a joint Darwin-Wallace memoir on natural selection to be read at a meeting of the Linnean Society in July 1858. Both Darwin and Wallace were honourable men. "I would far rather", Darwin told Lyell, "burn my whole book than that he [Wallace] or any other man should think that I had behaved in a paltry spirit". And to the end of his life Wallace accorded priority to Darwin. In an address to a meeting of the Linnean Society held in 1908 to commemorate the fiftieth anniversary of the Darwin-Wallace memoir, Wallace declared: "I should have had no cause for complaint if the respective share of Darwin and myself... had been... estimated as being roughly proportional to the time we had each bestowed upon it... as twenty years is to one week. If he had published his theory after ten years, fifteen years, or even eighteen years elaboration of it, I should have had no part in it whatever..."*



Cartoon of Darwin from *The Hornet,* 22 March 1871. Contrary to popular belief, Darwin never claimed that man was descended from the ape, but only that both shared a common ancestor.

▶rocks of which the earth is composed and the animals whose fossils are found in them was much longer than holy writ allowed. In short, although it needed talented men to perceive the meaning of the evidence, the time was ripe for that perception to come about. And so it came to *two* biologists: to Darwin, sitting contemplating his specimens in his country house in England, and to Wallace in Malaya.

Wallace's essay together with an abstract of Darwin's conclusions were read conjointly at a meeting of the Linnean Society in London in 1858 and published together the following year.

Darwin had received a jolt. However, on the advice of his scientific friends and spurred by his own ambition, he got to work and, delayed as ever by bouts of ill health, completed the chief work of his life, the writing of his book *On the Origin of Species,* in thirteen months. It was published in November 1859. The whole of the first edition was sold on the day of publication. Darwin himself explained its immediate and continuing success as being to some degree due to the fact that, in spite of his having allowed twenty-three years to elapse between his return home with the data on which his hypothesis was based and the publication of his conclusions as a coherent narrative, this time could not be taken as entirely wasted. In fact, it gave the members of the community, both scientific and lay, some opportunity to familiarize themselves with the conception of evolution.

We now come to the time when the new discovery—this fresh approach to biology and the origin of species—having been made public, began to exert its social influence on the community. Its impact was profound. Looking back after the lapse of more than a century, the fundamental nature of the disturbance which the Darwin-Wallace theory exerted on people's preconceived ideas about the world and the creatures in it is difficult to understand. Today, the theory seems to us to be self-evident. The first principle of the theory of evolution is, as Wallace put it in his essay, that "the life of wild animals is a struggle for existence". The second principle is that variations that take place in the typical form of a species (neither Darwin nor Wallace specified what it was that caused such variations to occur) will have an effect, for good or ill, on the capacity of that species to survive. This principle is summarized in the phrase "the survival of the fittest". By this means do species originate and change by a process of evolution. As Wallace wrote: "the giraffe [did not] acquire its long neck by desiring to reach the foliage of the more lofty shrubs and constantly stretching its neck for the purpose, but because any variations which occurred among its antitypes with a longer neck than normal at once secured a fresh range of pasture over the same ground as their short-necked companions, and on the first scarcity of food were thereby enabled to outlive them."

This theory exerted the powerful social effect it did for three main reasons. First, it ran counter to the word of holy writ in which people believed unquestioningly as describing the different animals and plants having been created so. Secondly, it was deeply disturbing for its implication that, just as each species of animal and plant evolved from a less successful predecessor, so also had man—that paragon of animals, as Shakespeare put it, but an animal nevertheless—evolved from a lower form. Thirdly, it took yet one further step along the road implying that the value-free rationality of science was the primary means by which a person views the environment, rather than the exaltation of revelation.

On the Origin of Species was published in 1859. The following year, the British Association for the Advancement of Science held its annual meeting in Oxford. At that meeting, Thomas Henry Huxley, one of the foremost lecturers of his time, a Professor at the Royal College of Surgeons who later was appointed to a chair at the Royal Institution and became President of the Royal Society, was speaking about the implications of Darwin's work. In the discussion that followed, Samuel Wilberforce, Bishop of Oxford, violently attacked Darwin's entire hypothesis and rounded furiously upon Huxley to ask him whether it was upon his grandfather's or his grandmother's side that he was descended from a venerable ape This confrontation made a deep impression. Huxley, standing his ground, replied to the bishop that if he were asked to claim parentage from a man, great in the affairs of Church and State, who mocked the earnest seeker after truth, or with a monkey, grovelling and chattering in its cage yet representing the mystery and wonder of nature, he would have difficulty in deciding which to choose. A lady on the platform, who had never heard an Anglican bishop thus rebuffed in his own see, fainted.

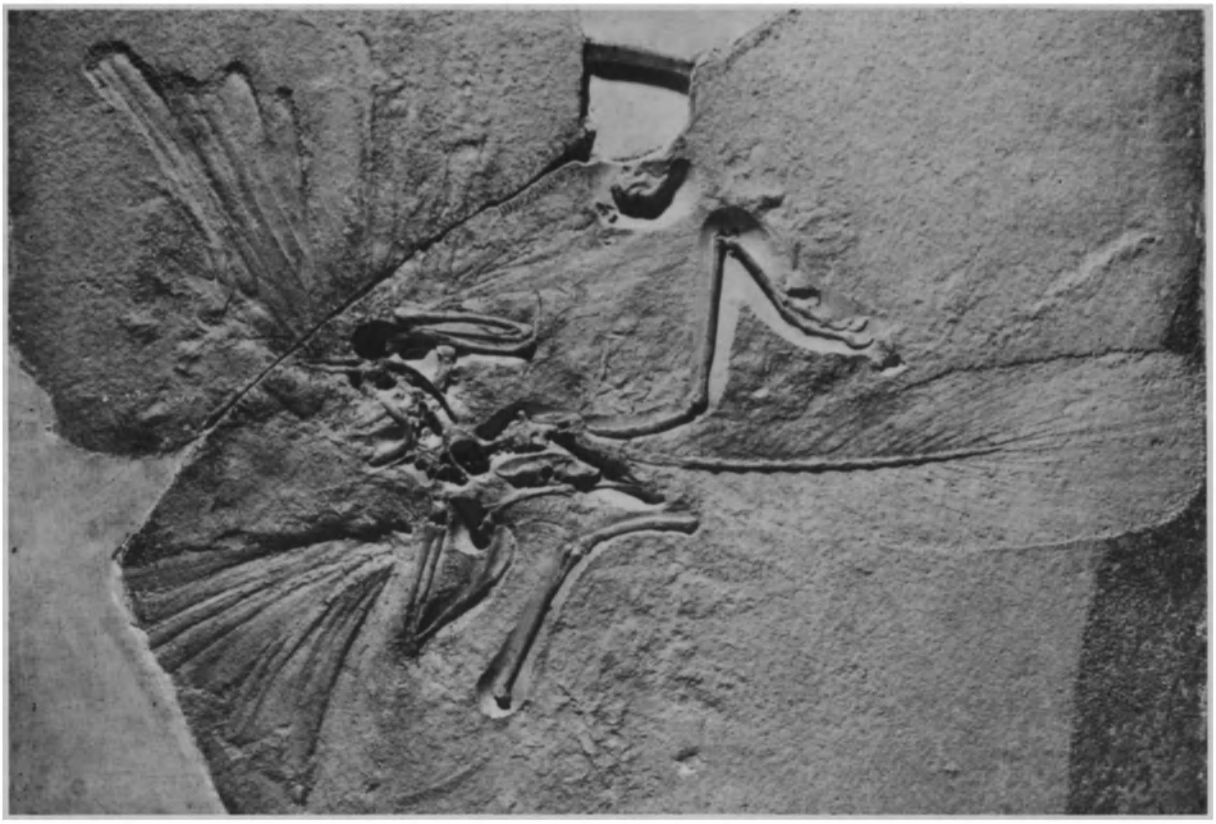
The idea of evolution, supported on the one hand by observations made by Darwin of variations in the creatures found in the Galapagos Islands and by Wallace from parallel observations in the islands of the Malay Archipelago, was a potent one. Nor was Bishop Wilberforce the only leader to believe that "the principle of natural selection is absolutely incompatible with the work of God." Cardinal Manning described it as a "brutal philosophy—to wit, there is no God and the ape is our Adam". Monseigneur Ségur in France wrote: "These infamous doctrines have for their only support the most abject passions. Their father is pride, their mother impurity, their offspring revolutions." In a bitter book called *Science and the Bible,* Dr Perry, Bishop of Melbourne, declared that the object of Darwin and Huxley was not so much to advance truth and understanding as to "produce in their readers a disbelief in the Bible".

In 1859, when *On the Origin of Species* was published, science was bringing changes in many directions. The achievements were welcomed with pride as indications of human progress. The theory of evolution, however, was disturbing. Its discoverers, and the members of the communities to which they belonged, could, on the one hand, take pride in the extension of their understanding of the biological principles by which species originated. At the same time, it came to many people as a shock to have to accept that they themselves, like all other species of biological life, had evolved too from lower forms, less than human. The acrimonious debate, of which the clash of Wilberforce and Huxley was the beginning, was long drawn out. Echoes continue here and there to this very day. For the most part, however, the basic principles of the theory of evolution conceived by Darwin and Wallace have been accepted as true. If there are those who feel that belief in biological evolution involves loss or the weakening of formerly held religious beliefs, there are others who see gain in a deeper perception of man's relationship with the other species of creatures with whom the human species must share the earth.

Wallace, the man who was the first to put together coherent evidence to support the theory of evolution, wrote long afterwards in 1870, with a generosity not always found in a scientist, of the way in which Darwin's thinking, particularly as written in his great book, changed the world.

"I have felt all my life, and I still feel, the most sincere satisfaction that Mr Darwin had been at work long before me, and that it was not left for me to write *On the Origin of Species*. I have long since measured my own strength, and know well that it would be quite unequal to that task. Far abler men than myself may confess that they have not that untiring patience in accumulating and that wonderful skill in using large masses of facts of the most varied kind, that wide and accurate physiological knowledge, that acuteness in devising and skill in carrying out experiments, and that admirable style of composition, at once clear, persuasive, and judicial—qualities which in their harmonious combination mark out Mr Darwin as the man, perhaps of all men now living, best fitted for the great work he has undertaken and accomplished".

■ Magnus Pyke



Many of Darwin's critics objected that no fossil remains had been found of intermediate or transitional forms which, according to his theory, must have linked up the species. The finding, in 1861, of the Archaeopteryx fossil did much to silence these criticisms. Archaeopteryx had bird-like characteristics such as wings and feathers, but like the reptiles it had claws at the end of its forelimbs, teeth and a long bony tail.

THE PROBLEM DARWIN SOLVED

by Isaac Asimov

THE notion of biological evolution is quite old. It began when biologists tried to classify living things. The Greek philosopher, Aristotle, was among the first to do so, back in the fourth century BC.

Eventually, in 1737, the Swedish botanist, Carolus Linnaeus, worked out a system in which living things could be arranged into different kinds (species), similar species could be gathered into groups, and these into groups of similar groups, and so on. It became possible to draw a diagram separating all of life into a few chief branches, each of these into smaller branches, and each of these into still smaller branches, until one finally ended with individual-species, rather like the individual leaves of a tree.

Imagine that through some magic, all we could see of a real tree were its individual leaves distributed in space. Would we suppose that somehow those leaves had just sprung into existence where they were? Surely not! We would suppose they were part of a tree which had grown from a simple shoot, developing branches and sub-branches from which the leaves grew.

In the same way, scientists began to wonder if there might not be a "tree of life" that grew something like an ordinary tree; if present-day species might not have developed from simpler species; and those from simpler species still; until originally all had developed from one original form of very simple life. This process is called "biological evolution".

Through the 1800s, scientists discovered and studied objects in the rocks that were called "fossils". They had the shapes of bones, teeth, shells and other objects that had once been alive, but they must have been trapped in rock for millions of years until they had slowly turned into rock themselves.

These fossils were forms of life that were not quite like living species, but were related to them. The fossils filled in earlier branches

CONTINUED PAGE 16

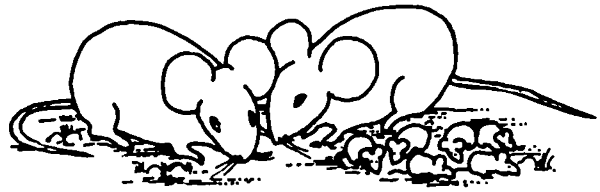
ISAAC ASIMOV, *of the USA, is internationally known as a popularizer of science and a science fiction writer. His huge output of published works reflects the variety of his interests which include: literary criticism, psychology, mathematics, mystery, poetry and humour. In 1979 he published his 200th book, assigning the same number to two works:* Opus 200 *(Houghton Mifflin), an Asimov anthology, and* In Memory Yet Green *(Doubleday), the first volume of his autobiography.*

Of mice and moths

Darwin's theory of natural selection was based on four ideas about species. It is easy to follow the steps in Darwin's argument if we apply these four ideas to a living population...

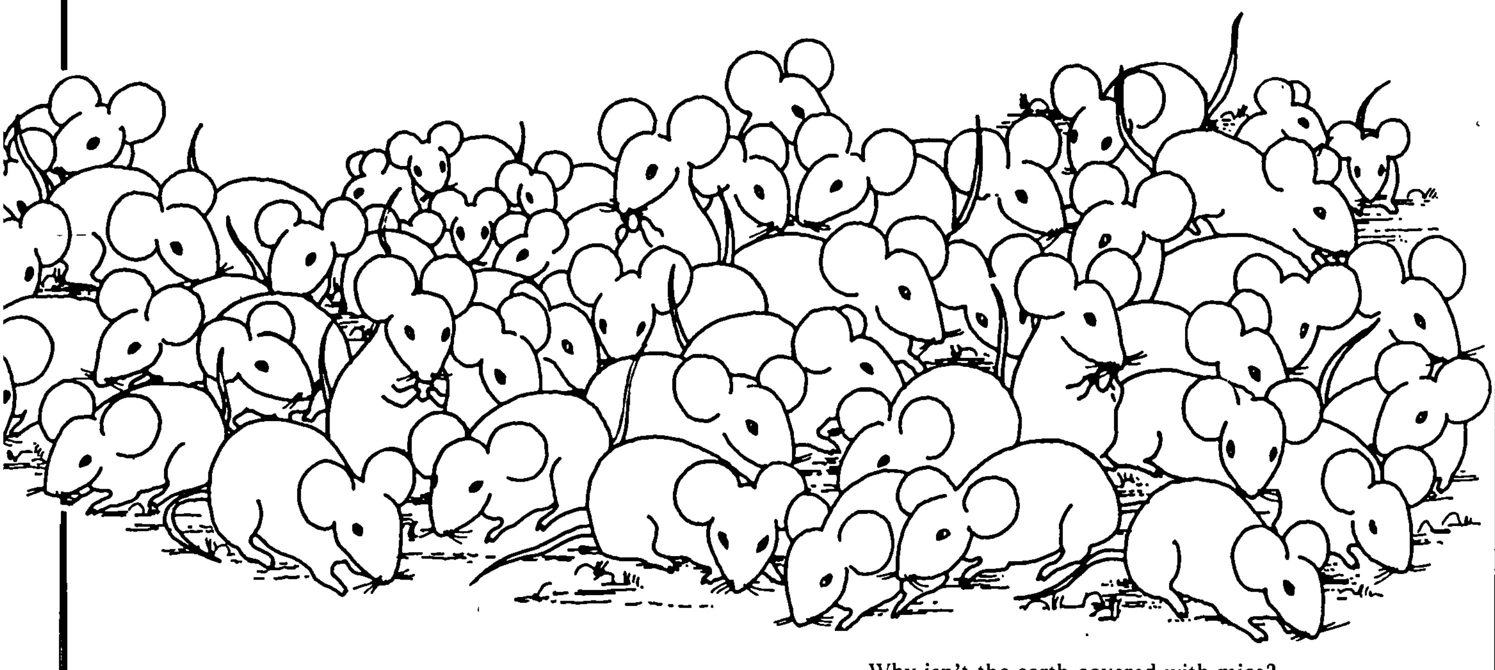
1. More than enough offspring

All species are capable of producing more than enough offspring to replace themselves.



One pair of *mice* can produce a litter of about six offspring as many as six times a year. Within six weeks, these offspring could produce litters of their own.

If all these mice survived and continued to breed, just imagine how many mice there could be...

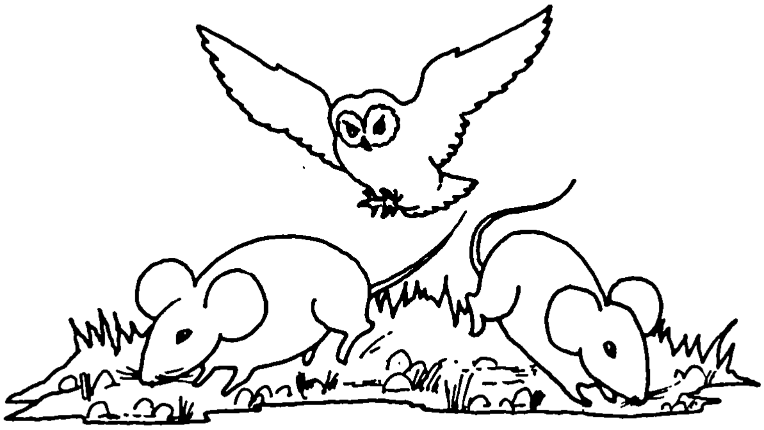


Why isn't the earth covered with mice? Although a pair of mice can produce far more than enough offspring to replace themselves, the numbers in any population tend to remain more or less the same, because not all the offspring survive to reproduce.

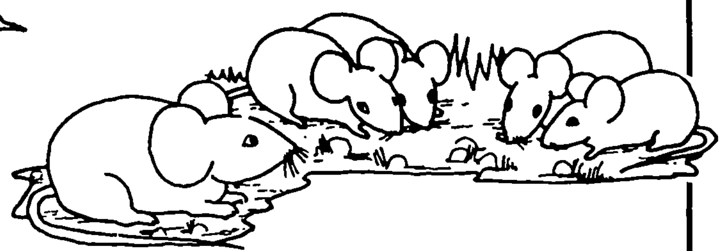
2. The struggle to survive

The environment may affect an individual's chances of survival.

All living things interact with their environment. The environment provides food, space and suitable surroundings to live in, but it also includes competitors and predators. So, in any population, not all individuals survive to reproduce...

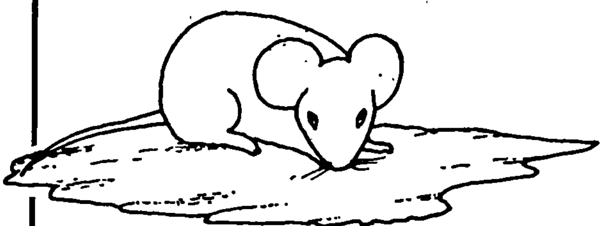


A mouse might be eaten by a predator.



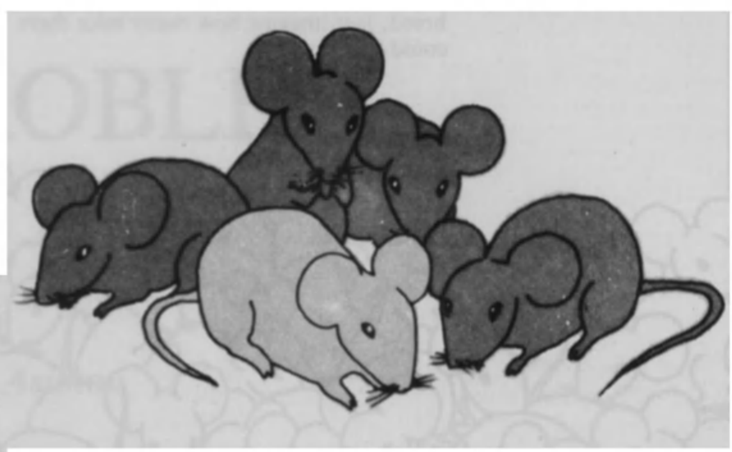
Or it might not find a mate.

Or it might not be able to get enough food.



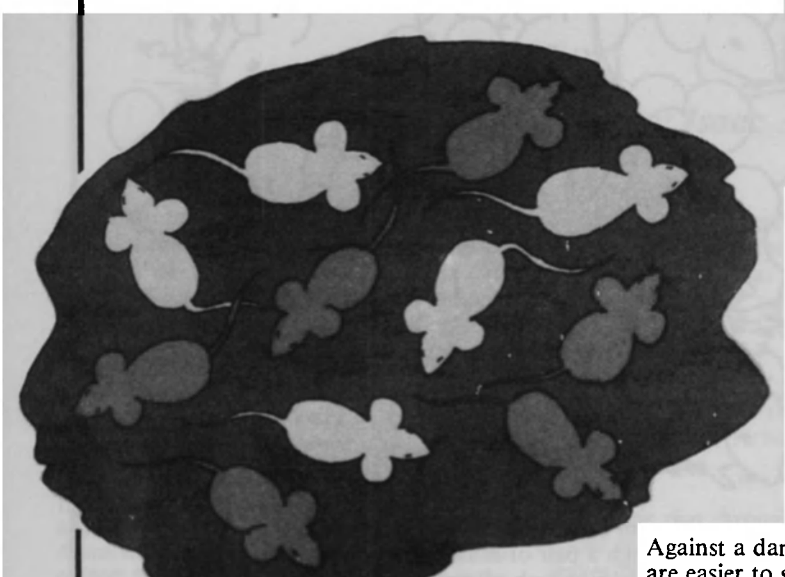
3. Some important differences

Because individuals are not all identical, some are more likely to survive than others.



No two mice are exactly alike, and some of the variations between them may affect their chances of survival.

Not all mice are the same colour—some are darker than others.



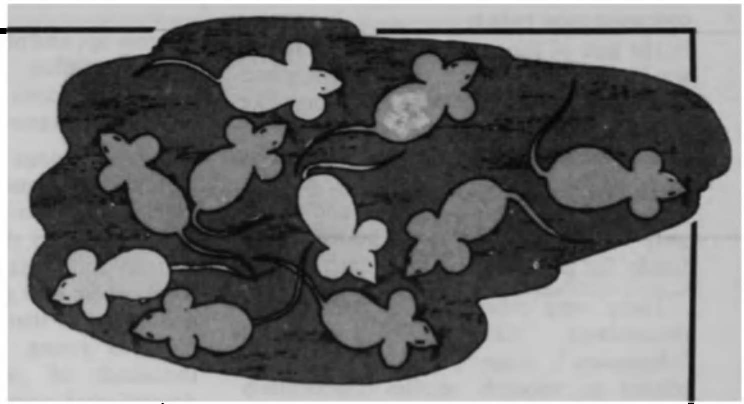
Against a dark background, the pale mice are easier to see, so they are the ones more likely to be eaten by owls. The dark mice are *better adapted* to this environment, and are more likely to survive and produce offspring.

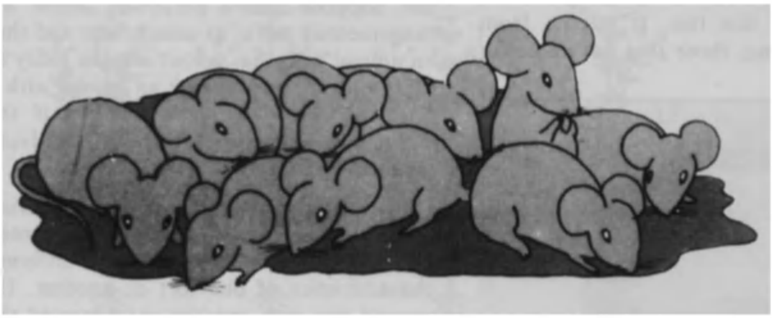
4. A question of inheritance

Some characteristics are passed on to the next generation. Some of the variations between individuals are inherited. For example, mice inherit the colour of their coats.

In an area of dark soil, dark mice are less likely to be seen by predators, and they have a better chance of surviving to reproduce. So their characteristics are the ones most likely to be passed on to the next generation. In the next generation, there will be a higher proportion of dark mice than before.

If conditions remain the same, the proportion of dark mice in the population will continue to increase.



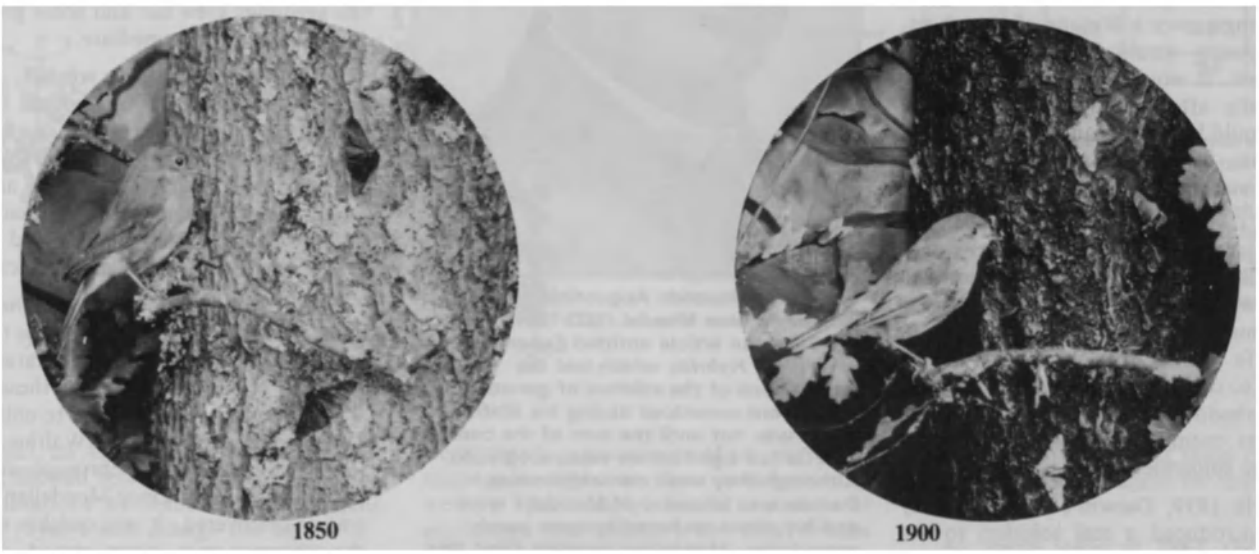


Over many generations, the proportion of well-adapted individuals in a population is likely to increase. Darwin called this process natural selection.

Natural selection provides an explanation of how the characteristics of a population can change as individuals become better adapted to their environment.

Peppered moths—changing with the times.

One effect of natural selection—the characteristics of a population can change.



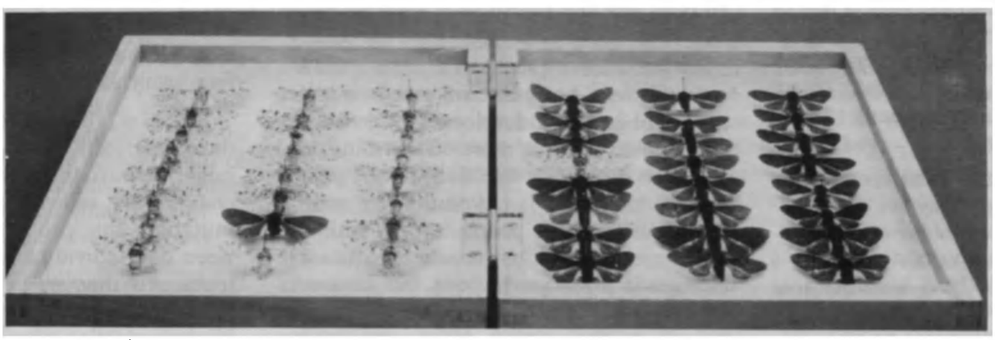
Peppered moths are fairly common in Britain.

Several species of birds eat peppered moths, taking them from the tree trunks where they rest during the day.

During the nineteenth century, the moths' environment changed dramatically. Before the Industrial Revolution, most tree trunks had a mottled, grey appearance because they were encrusted with lichens.

Towards the end of the century, soot and smoke from factories killed most of the lichens and blackened the trees in many industrial areas.

Compare the two environments. In each situation, which moths are more likely to survive and leave offspring?



These two collections are typical of the peppered moth populations around Manchester in 1850 and 1900.

CONTINUED FROM PAGE 12
in the tree of life, and gave hints as to the way in which particular species of life had evolved. For instance, there were horse-like animals that lived millions of years ago. They were small to begin with, and had as many as four hooves on each leg. As time went on, other species were found which were larger, and had fewer hooves, until finally the modern horse came into being.

There were other animals that left no descendants, like the magnificent "dinosaurs", huge creatures that were related to modern reptiles (particularly alligators), which all went out of existence, or became "extinct", 65,000,000 years ago.

Even though many scientists began to suspect that biological evolution had taken place, it didn't sound very convincing because no one knew *how* it could take place. What could possibly make one species change into another? No one had ever seen a species change. Cats always had kittens, dogs had puppies, and cows had calves. There were never any mistakes.

The first scientist to make a serious attempt to work out the how of evolution was a Frenchman, Jean-Baptiste de Lamarck. He thought it arose out of the way in which organisms lived. If an antelope fed on the leaves of trees, it would spend its life stretching its neck to reach leaves higher and higher on the tree. Its neck would grow slightly longer over a lifetime of stretching, and its young would inherit the slightly longer neck. It would stretch it still further until finally after a long, long time, the giraffe would have developed. This is called "evolution by inheritance of acquired characteristics."

It didn't work. In the first place acquired characteristics aren't inherited. You might cut the tail off a mouse, but its young will all be born with tails that aren't even shorter than normal. In the second place, how did the giraffe get its splotched coat, which blends in so usefully with the background of splotchy shadows cast by trees, thus hiding it from its enemies? Can the giraffe have *tried* to be splotchier? Of course not.

Then, in 1859, Darwin's *The Origin of Species* introduced a real solution to the problem.

He considered that living organisms generally have more young than can possibly be supported by the food supply. If all the baby deer that were born grew up to be adult deer, generation after generation, there would soon be enough deer to strip the trees and vegetation and all would starve. This doesn't happen because only a few of the baby deer live to become adult. Most are eaten by other animals. There is competition among the baby deer, so to speak, to see which can remain alive long enough to have baby deer of their own.

Consider this, too. When you study young animals, you find they are not exactly alike. There are always some differences. Some are a little stronger than others, or a little faster-running, or have a colour that blends in a little better with the background and hides them, or whatever. In the competition to grow up safely, some have advantages that work in their favour, in other words. They're the ones that are more likely to grow up, and pass their characteristics on to their children. These characteristics, you see, are not acquired, they are *inborn*. They are "natural variations."

Human beings take advantage of the natural variations in their domesticated animals and plants. They select horses that are faster, cows that give more milk, hens that lay more eggs, sheep that have more wool, wheat that grows more ears of grain, and see to it that those in particular give birth to young. In this way, over the thousands of years that people have domesticated animals they have developed breeds that are far different from the original—and far better, for human purposes.

Nature does this too. It selects, from among the young, those that have a better chance; those that are faster and can outrun their enemies; those that are stronger and can beat off their enemies; those that are cleverer and can outwit their enemies; those that have better teeth and can eat more efficiently, and so on.

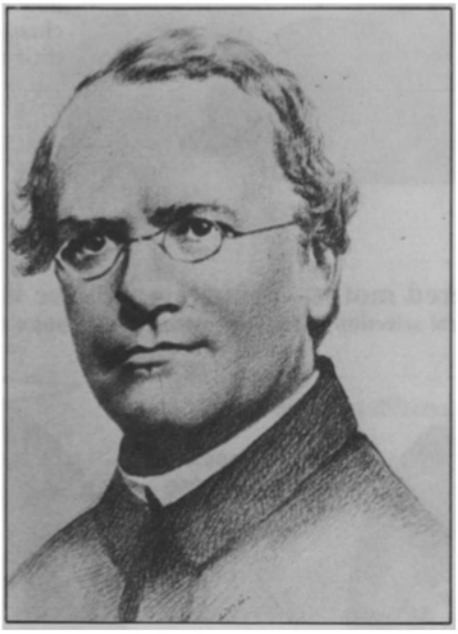


Photo © Palais de la Découverte, Paris

In 1866, an Austrian Augustinian monk, Gregor Johann Mendel (1822-1884), published an article entitled *Experiments with Plant Hybrids* which laid the foundations of the science of genetics. His work went unnoticed during his lifetime and it was not until the turn of the century that its full significance was recognized. Although they were contemporaries, Darwin was unaware of Mendel's work and his views on heredity were purely speculative. Mendelian genetics filled this gap by providing exactly the mechanism of heredity required for evolution by natural selection.

In this way, horse-like animals grew larger and stronger, and developed fewer hooves per limb so as to be more efficient in running. This is through selection, not by people but by nature. It is "evolution by natural selection." Since people work with intelligence, they can produce noticeable changes in a few generations. Nature works hit-and-miss, however. Often the better organism manages to get caught by an enemy through a stroke of bad luck. Evolution by natural selection can require millions of years, therefore, to form new species.

The ingenuity of Darwin's notion of natural selection, and the careful way in which he presented observation and reasoning in this book, convinced some scientists at once. As time went on, it convinced more. Nowadays, scientists generally accept biological evolution on an essentially Darwinian basis. They accept the importance of natural selection as the chief driving force of such evolution.

There were, however, problems from the start, and in the century and a quarter that has passed since Darwin's books, many improvements and advances have been made.

For instance, natural selection depends on inborn variations but how are these preserved? Suppose that a particular colour arrangement is useful as camouflage and that an animal with that colour is more likely to survive. It may mate with an animal with a different colour arrangement and if the young have intermediate colours, the advantage will be lost.

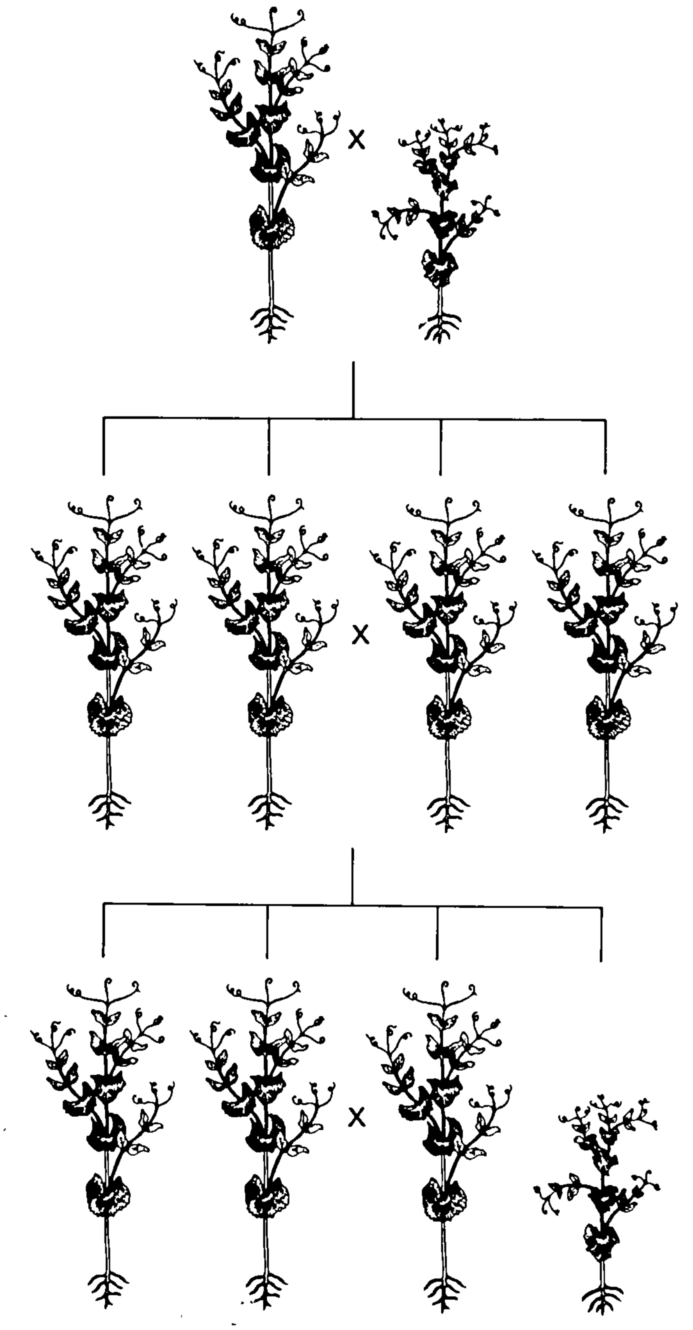
In the 1860s, however, an Austrian botanist, Gregor Mendel, experimented with pea plants that showed different characteristics of one sort or another. He crossed one with another and observed the characteristics in the seedlings as they grew. It turned out that characteristics did *not* blend into intermediate forms. Thus, if tall plants were crossed with short ones, some of the seedlings grew tall and some grew short but none were intermediate.

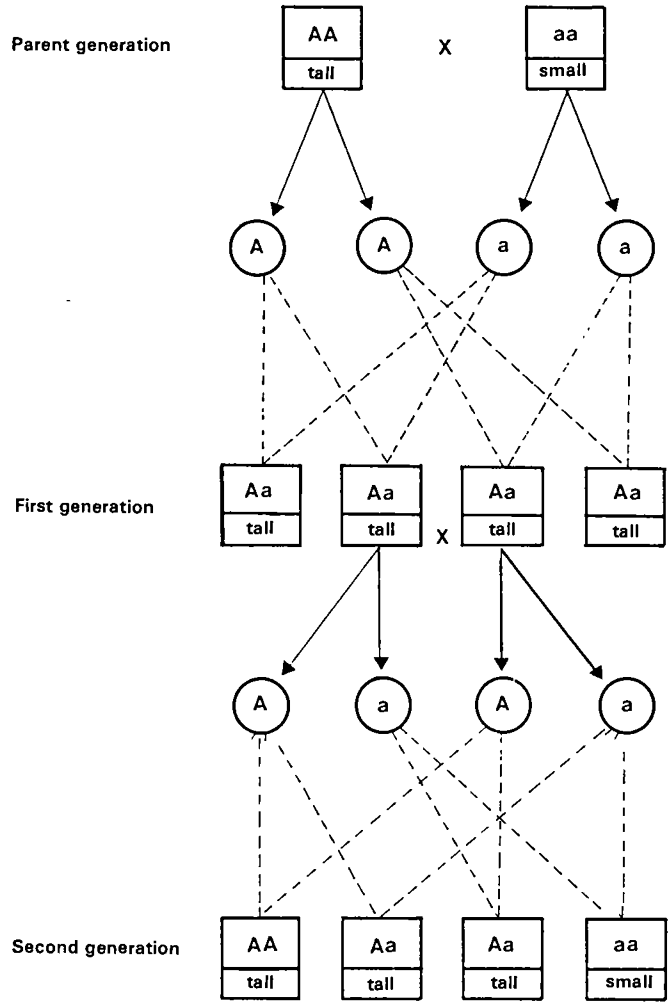
Mendel published his results, but his paper was ignored. It was not till 1900 that other botanists coming up with similar results looked through scientific journals to see what had been done before and came across Mendel's paper. Mendel had died in 1884 so he never knew that he had founded a new science: "Mendelian genetics".

Mendel had supposed that there were some sort of objects in organisms that controlled the individual physical characteristics of those organisms; and that these objects were passed on from parents to children. In 1879, a German scientist, Walther Flemming, discovered the tiny chromosomes inside the nuclei of cells. Once Mendelian genetics was re-discovered, it was quickly seen that the chromosomes were passed on from parents to young and that this took place in such a way as to account for the manner in which characteristics were inherited. The chromosome was considered to consist of a string of "genes", each of which controlled some particular characteristic.

These genes consisted of large molecules of "nucleic acid" which produced replicas of themselves each time a cell divided. Each new cell thus had the characteristics of those from which it arose.

However, the replica was not always produced perfectly. Tiny accidental changes might be introduced in the molecule. These changes are called "mutations". It is the mutations that produce the differences between one individual and another. It is the mutations that are responsible for the inborn variations among the young that make natural selection possible. Natural selection allows some mutations to flourish and others to die out, and as different mutations survive here and there, new species form.





Gregor Mendel's experiments with pea plants have entered the history of science. He started by crossing a pure-bred tall variety of pea with a pure-bred short variety. As the diagram above shows, all the first generation offspring were tall, because, although each plant carried both a tall character gene (A) and a short character gene (a), the tall character gene (A) was dominant. Of the second generation offspring, however, about a quarter inherited only the short character gene (a) and thus the pure-bred short variety recurred in one out of four cases.

Diagram © Andrew Farmer

By 1927, an American scientist, Hermann Muller, showed how one might actually produce mutations by bombarding organisms with X rays, which change the atomic arrangement in the genes. In 1953, an American, James Watson, and an Englishman, Francis Crick, explained the detailed structure of nucleic acids, and showed how a particular molecule produced its own replica and how it might make a mistake in doing so.

All this strengthened and improved the Darwinian theory of evolution by natural selection.

Meanwhile, since Darwin's time, more and more fossils have been found, and more and more has been learned about the behaviour of living organisms and their influence on each other. The actual details of evolution—which organisms descended from which and through what kind of intermediate steps—became better known.

In addition, it was found that natural selection did not always work with mechanical certainty; there were other factors involved.

For instance, chance played a greater part than might have been thought. Where there were small populations of a particular species, it might be that mutations that weren't particularly useful would be established just because a few lucky breaks insured that those individuals possessing those mutations would happen to survive.

In fact, nowadays some scientists, such as Stephen Gould, are thinking in terms of evolution that proceeds very slowly most of the time, but quite quickly under exceptional circumstances.

When there is a huge population of a species, it may be that no mutation can establish itself against the existence of numerous individuals with other mutations. What's more, a few lucky breaks this way or that wouldn't be enough to push evolution in one direction or another. The species might then continue without much in the way of change for many millions of years.

On the other hand, if a rather small population of that species is isolated in a difficult environment, it becomes much more possible that sheer chance will cause some mutations to die out among them altogether, while others survive in considerable numbers. Under such conditions, evolution will be faster and new species may be formed in merely thousands of years.

It is these intervals of rapid change that might be the chief agent for driving evolution forward.

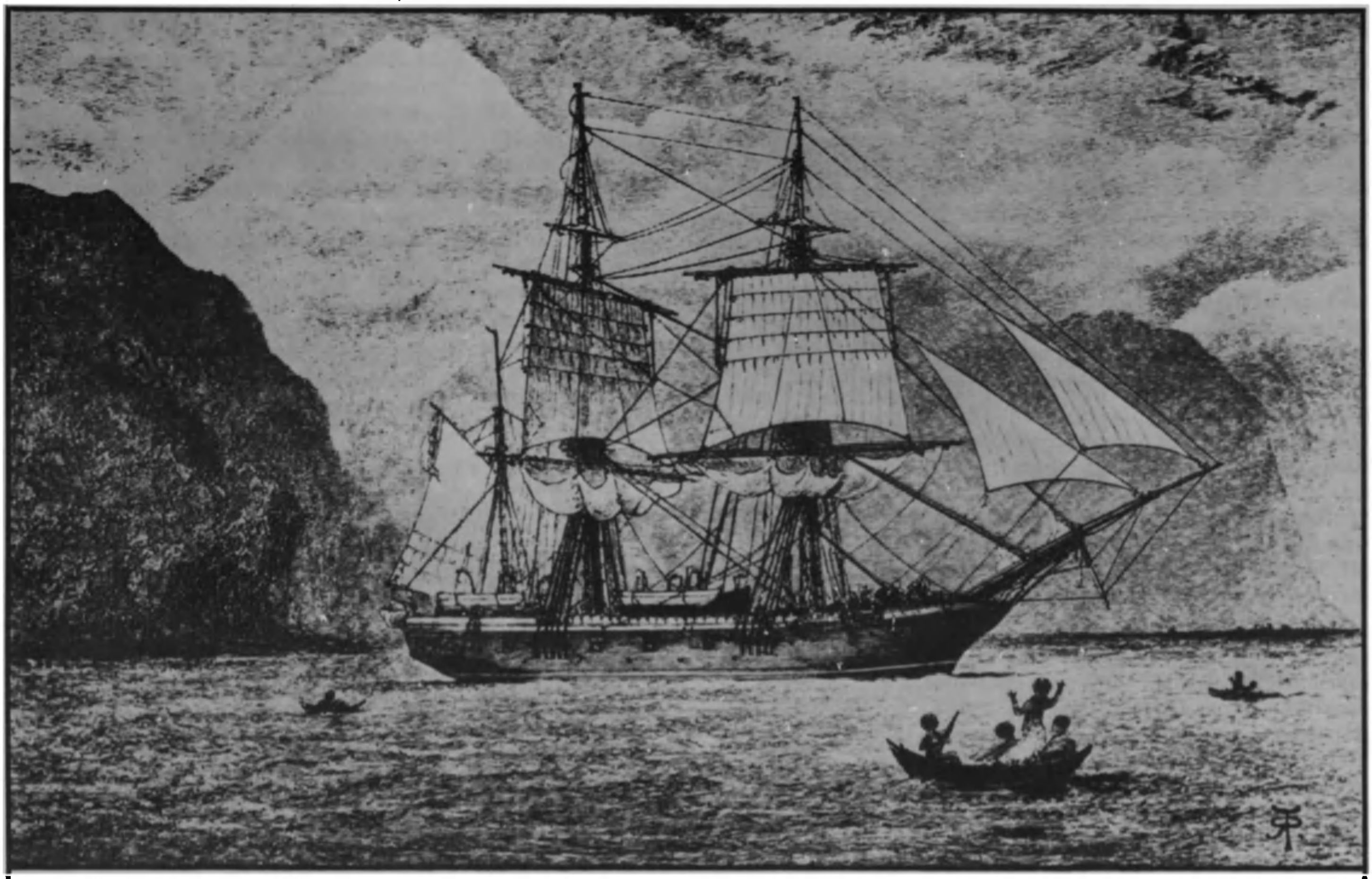
As things stand in 1982, then, we can summarize the status of biological evolution as follows :

1) Just about all scientists are convinced that biological evolution has taken place over a period of billions of years, and that all present species, including human beings, have developed from other species that existed earlier.

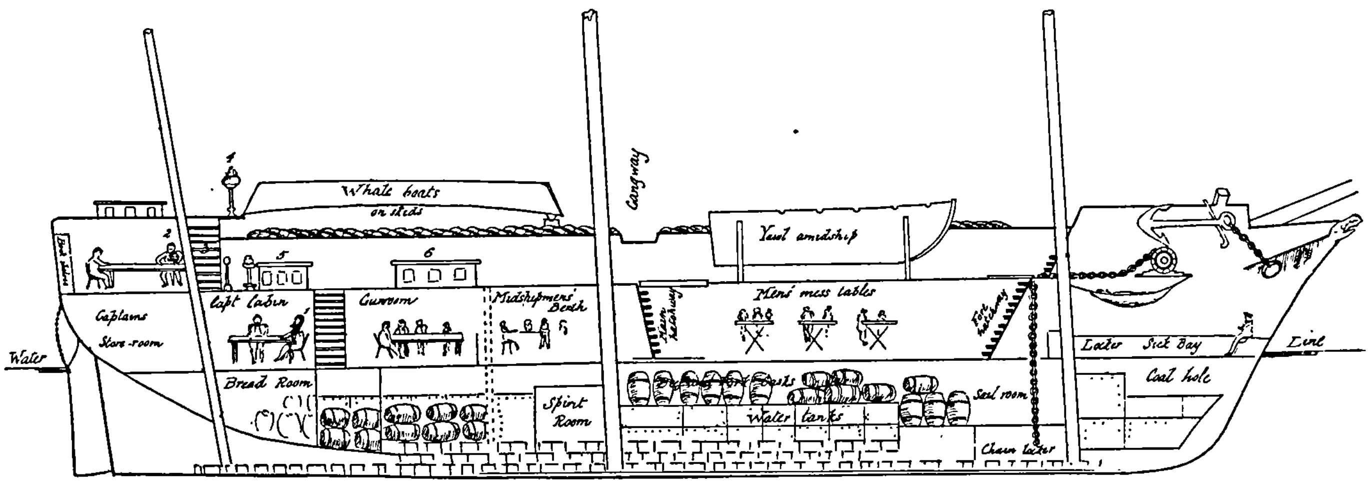
2) Just about all scientists are convinced that the manner in which biological evolution has taken place is essentially that described by Charles Darwin; that natural selection among inborn variations is the basic key.

3) Scientists who study evolution nowadays are in deep disagreement on some of the details of the evolutionary machinery, and we cannot yet tell which side will win out in these disputes. However, whichever side wins, that will not affect the general acceptance of Darwinian theory, along with its modern improvements, as the basic description of how life developed on earth.

■ Isaac Asimov



H.M.S. Beagle in the Straits of Magellan



1 - Mr. Darwin's seat in the Captain's cabin
2 - Mr. Darwin's seat in the poop cabin
3 - Mr. Darwin's drawers in the poop cabin
4 - Azimuth compass
5 - Captain's skylight
6 - Gunroom skylight

She was rigged as a bark; her masts were strongly supported by squarer cross-trees and tops, and by larger rigging than usual in vessels of her tonnage... Abaft the main-mast were four brass guns, two nine-pound, and two six-pound. The skylights were large; there was no capstan; over the wheel the poop-deck projected, and under it were the cabins, extremely small, certainly, though filled in inverse proportion to their size. Below the upper deck her accommodations were similar to, though rather better than those of vessels of her class. Over the quarter-deck, upon skids, two whale-boats, eight-and-twenty feet long, were carried; upon each quarter was a whale-boat twenty-five feet in length, and astern was a dinghy. (Narrative of the Surveying Voyages of His Majesty's Ships *Adventure* and *Beagle* between the years 1826 and 1836).

THE VOYAGE OF THE BEAGLE

Prelude

On September 11th (1831) I paid a flying visit with Fitzroy to the *Beagle* at Plymouth. On December 27th the *Beagle* finally left the shores of England for her circumnavigation of the world (...). These two months at Plymouth were the most miserable which I ever spent, though I exerted myself in various ways. I was out of spirits at the thought of leaving all my family and friends for so long a time, and the weather seemed to me inexpressibly gloomy. I was also troubled with palpitations and pain about the heart, and like many a young ignorant man, especially one with a smattering of medical knowledge, was convinced that I had heart-disease. I did not consult any doctor, as I fully expected to hear the verdict that I was not fit for the voyage, and I was resolved to go at all hazards.

(Darwin, *Autobiography*)

The departure

After having been twice driven back by heavy south-western gales, Her Majesty's ship *Beagle*, a ten-gun brig, under the command of Captain Fitzroy, RN, sailed from Devonport on 27 December 1831. The object of the expedition was to complete the survey of Patagonia and Tierra del Fuego, commenced under Captain King in 1826 to 1830; to survey the shores of Chile, Peru, and of some islands in the Pacific; and to carry a chain of chronometrical measurements round the world.

(Darwin, *The Voyage of the Beagle*)

The landlubber

Nobody who has only been to sea for 24 hours has a right to say that sea-sickness is even uncomfortable. The real misery only begins when you are so exhausted that a little exertion makes a feeling of faintness come on. I found nothing but lying in my hammock did me any good. I must especially except your receipt of raisins, which is the only food that the stomach will bear. On the 4th of January we were not many miles from Madeira, but as there was a heavy sea running and the Island lay to Windward it was not thought worth while to bear up to it. It afterwards has turned out it was lucky we saved ourselves the trouble: I was much too sick even to get up to see the distant outline.

(Darwin, letter to his father, 8 February 1832)

At noon lat. 43 South of Cape Finisterre and across the famous Bay of Biscay: wretchedly out of spirits and very sick. I often said before starting that I had no doubt I should frequently repent of the whole undertaking. Little did I think with what fervour I should do so. I can scarcely conceive any more miserable state than when such dark and gloomy thoughts are haunting the mind as have today pursued me.

(Darwin, *Diary*, 30 December 1831)

Darwin is a very sensible, hard-working man and a very pleasant messmate. I never saw a "shore-going fellow" come into the ways of a ship so soon and so thoroughly as Darwin. I cannot give a stronger proof of his good sense and disposition than by saying "Everyone respects and likes him" (...).

(Captain Fitzroy, letter to Captain Beaufort, 5 March 1832)

Crossing the line

We have crossed the Equator, and I have undergone the disagreeable operation of being shaved. About 9 o'clock this morning we poor "griffins", two and thirty in number, were put altogether on the lower deck. The hatchways were battened down, so we were in the dark and very hot. Presently four of Neptune's constables came to us, and one by one led us up on deck. I was the first and escaped easily; I nevertheless found this watery ordeal sufficiently disagreeable. Before coming up, the constable blindfolded me and thus led along, buckets of water were thundered all around; I was then placed on a plank, which could be easily tilted up into a large bath of water. They then lathered my face and mouth with pitch and paint, and scraped some of it off with a piece of roughened iron hoop: a signal being given I was tilted head over heels into the water, where two men received me and ducked me. At last, glad enough, I escaped: most of the others were treated much worse: dirty mixtures being put in their mouths and rubbed on their faces. The whole ship was a shower bath, and water was flying about in every direction: of course not one person, even the Captain, got clear of being wet through.

(Darwin, *Diary*, 17 February 1832)

The Captain

And now for the Captain, as I daresay you feel some interest in him. As far as I can judge, he is a very extraordinary person. I never before came across a man whom I could fancy being a Napoleon or a Nelson. I should not call him clever, yet I feel convinced nothing is too great or too high for him. His ascendancy over everybody is quite curious: the extent to which every officer and man feels the slightest rebuke or praise would have been, before seeing him, incomprehensible. His candor and sincerity are to me unparalleled: and using his own words his "vanity and petulance" are nearly so. I have felt the effects of the latter: but then bringing into play the former ones so forcibly makes one hardly regret them. His greatest fault as a companion is his austere silence, produced from excessive thinking: his many good qualities ▶

are great and numerous: altogether he is the strongest marked character I ever fell in with.

(Darwin, letter to his sister Caroline, dated 25 April 1832)

The Tropics

Decidedly the most striking thing in the Tropics is the novelty of the vegetable forms. Cocoa nuts could well be imagined from drawings if you add to them a graceful lightness which no European tree partakes of. Bananas and Plantains are exactly the same as those in hothouses; the acacias or tamarinds are striking from [the] blueness of their foliage: but of the glorious orange trees no description, no drawings, will give any just idea: instead of the sickly green of our oranges, the native ones exceed the portugal laurel in the darkness of their tint and infinitely exceed it in beauty of form. Cocoa-nuts, Papaws, the light-green Bananas and oranges loaded with fruit generally surrounded the more luxuriant villages. Whilst viewing such scenes, one feels the impossibility that any description should come near the mark, much less be overdrawn.

(Darwin, letter to his father, 26 February 1832)

I can only add raptures to the former raptures. I walked with the two mids, a few miles into the interior. The country is composed of small hills, and each new valley is more beautiful than the last. I collected a great number of brilliantly-coloured flowers, enough to make a florist go wild. Brazilian scenery is nothing more nor less than a view in the Arabian Nights, with the advantage of reality. The air is deliciously cool and soft; full of enjoyment, one fervently desires to live in retirement in this new and grander world...

(Darwin, *Diary*, 1 March 1832)

During our stay at Brazil I made a large collection of insects. A few general observations on the comparative importance of the different orders may be interesting to the English entomologist. The large and brilliantly-coloured Lepidoptera bespeak the zone they inhabit far more plainly than any other race of animals. I allude only to the butterflies, for the moths, contrary to what might have been expected from the rankness of the vegetation, certainly appeared in much fewer numbers than in our own temperate regions. I was much surprised at the habits of Papilio feronia. This butterfly is not uncommon, and generally frequents the orange-groves. Although a high flier, yet it very frequently alights on the trunks of trees. On these occasions its head is invariably placed downwards; and its wings are expanded in a horizontal plane, instead of being folded vertically, as is commonly the case. This is the only butterfly which I have ever seen that uses its legs for running.

(Darwin, *Journal*, April 1832)

I find the peep of Tropical scenery has given me a tenfold wish to see more; it is no exaggeration to say, no one can know how beautiful the world we inhabit is, who has only been in the colder climes. The chief source of pleasure has been to me, during these two months, from Nat. history. I have been wonderfully lucky with fossil bones—some of the animals must have been of great dimensions: I am almost sure that many of them are quite new; this is always pleasant, but with the antediluvian animals it is doubly so. I found parts of the curious osseous coat, which is attributed to the Megatherium; as the only specimens in Europe are at Madrid (originally in 1798 from Buenos Ayres) this alone is enough to repay some wearisome minutes. Amongst living animals I have not been less fortunate. I also had in September some good sporting; I shot one day a fine buck and doe, but in this line I never enjoyed anything so much as Ostrich hunting with the wild Soldiers, who are more than half Indians. They catch them by throwing two balls, which are attached to the ends of a thong, so as to entangle their legs: it was a fine animated chase.

(Darwin, letter to his sister Caroline, 24 October 1832)

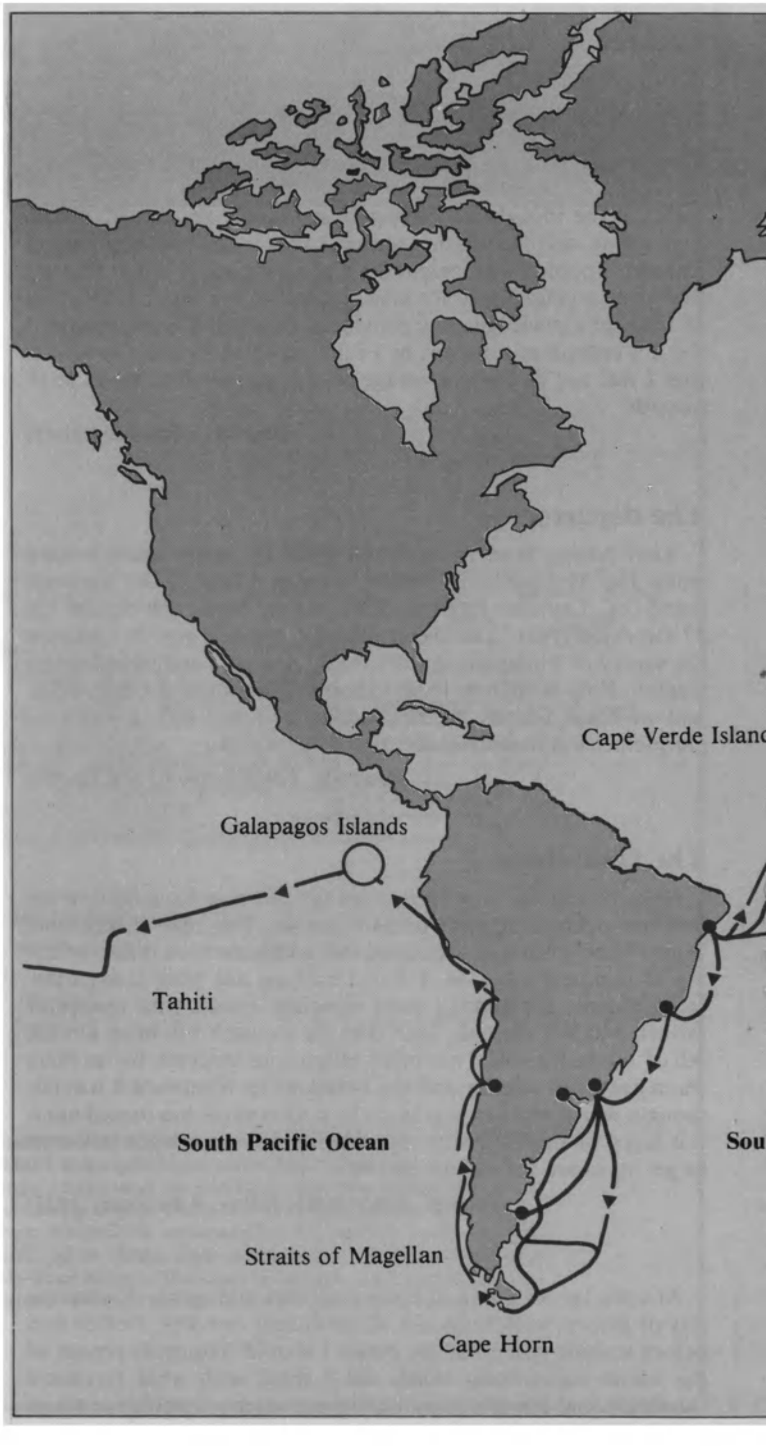
Tierra del Fuego

I will describe our first arrival in Tierra del Fuego. A little after noon we doubled Cape St Diego, and entered the famous Strait of Le Maire. We kept close to the Fuegian shore, but the outline of the rugged, inhospitable Statenland was visible amidst the clouds. In the afternoon we anchored in the Bay of Good Success. While entering we were saluted in a manner becoming the inhabitants of this savage land. A group of Fuegians partly concealed by the entangled forest, were perched on a wild point overhanging the sea; and as we passed by, they sprang up and, waving their tattered cloaks, sent forth a loud and sonorous shout. The harbour consists of a line piece of water half-surrounded by low, rounded mountains of clay-slate, which are covered to the water's edge by one dense gloomy forest. A single glance at the landscape was sufficient to show me how widely different it was from any thing I had ever beheld.

In the morning the Captain sent a party to communicate with the Fuegians (...).

The chief spokesman was old, and appeared to be the head of the family; the three others were powerful young men, about six feet high. The women and children had been sent away. These Fuegians are a very different race from the stunted, miserable wretches farther westward; and they seem closely allied to the famous Patagonians of the Strait of Magellan. Their only garment consists of a mantle made of guanaco skin, with the wool outside; this they wear just thrown over their shoulders, leaving their persons as often exposed as covered. Their skin is of a dirty coppery-red colour.

(Darwin, *Journal*, 17 December 1832)



The next day I attempted to penetrate some way into the country. Tierra del Fuego may be described as a mountainous land, partly submerged in the sea, so that deep inlets and bays occupy the place where valleys should exist. The mountain sides, except on the exposed western coast, are covered from the water's edge upwards by one great forest. The trees reach to an elevation of between 1,000 and 1,500 feet, and are succeeded by a band of peat, with minute alpine plants; and this again is succeeded by the line of perpetual snow, which, according to Captain King, in the Strait of Magellan descends to between 3,000 and 4,000 feet. To find an acre of level land in any part of the country is most rare. I recollect only one little flat piece near Port Famine, and another of rather larger extent near Goeree Road. In both places, and everywhere else, the surface is covered by a thick bed of swampy peat. Even within the forest, the ground is concealed by a mass of slowly putrefying vegetable matter, which, from being soaked with water, yields to the foot.

(Darwin, *Journal,* 17 December 1832)

There was a degree of mysterious grandeur in mountain behind mountain, with the deep intervening valleys, all covered by one thick, dusky mass of forest. The atmosphere, likewise, in this climate, where gale succeeds gale, with rain, hail, and sleet, seems blacker than anywhere else. In the Strait of Magellan, looking due southward from Port Famine, the distant channels between the mountains appeared from their gloominess to lead beyond the confines of this world.

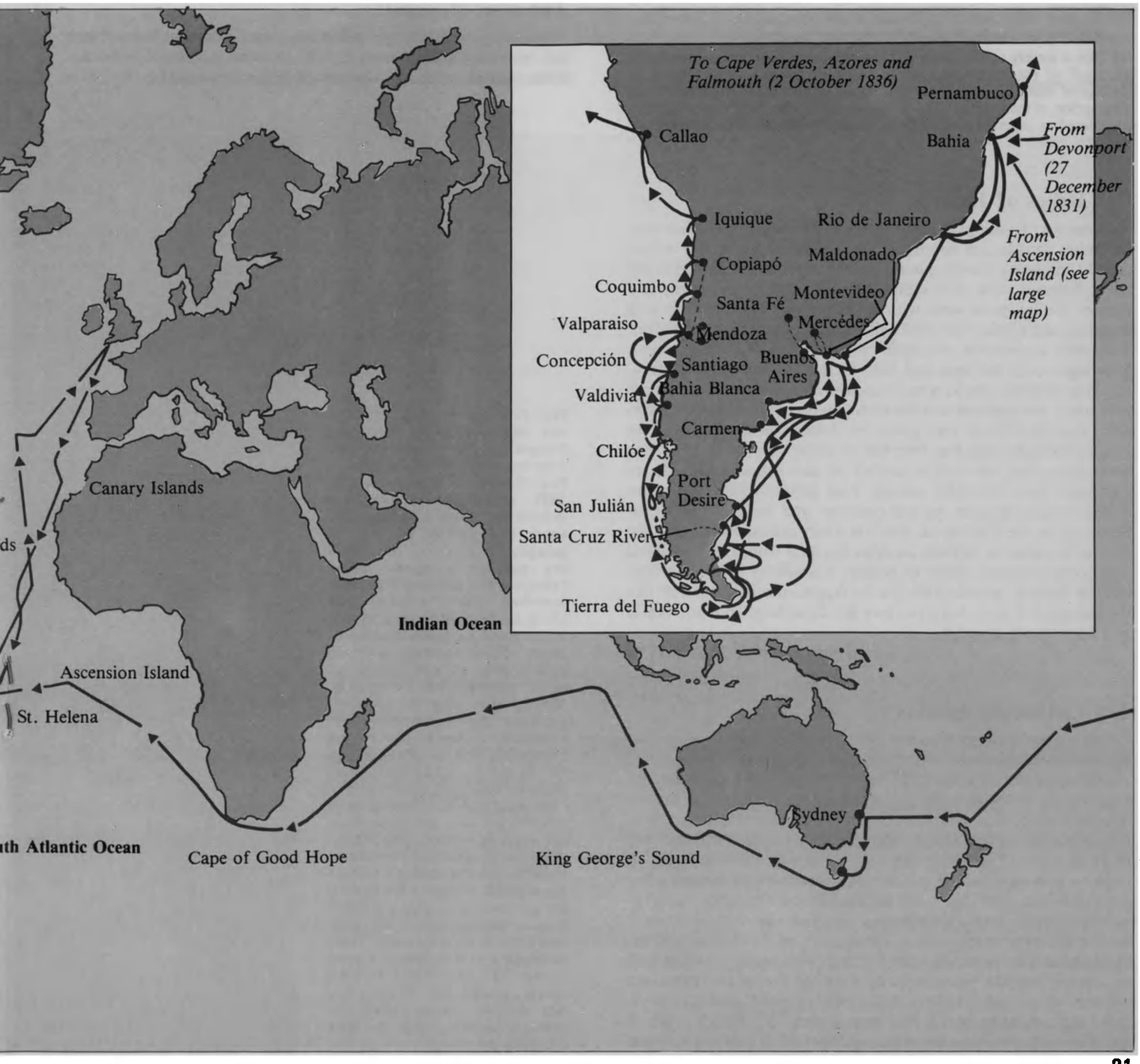
(Darwin, *Journal,* 20 December 1832)

The Andes

The appearance of the Andes was different from what I expected; the lower line of the snow was of course horizontal, and to this line the even summits of the range appeared quite parallel. At long intervals, a mass of points or a single cone showed where a Volcano had or does now exist. It hence looked more like a wall, than a range of separate mountains, and made a most complete barrier to the country.

(Darwin, *Diary,* 17 August 1834)

The descent on the eastern side of the Cordillera is much shorter or steeper than on the Pacific side; in other words, the mountains rise more abruptly from the plains, than from the alpine country of Chile. A level and brilliantly white sea of clouds was extended ▶



beneath our feet, and thus shut out the view of the equally level Pampas. We soon entered the band of clouds, and did not again emerge from it that day. About noon, finding pasture for the animals and bushes for firewood, in a part of the valley called Los Arenales, we stopped for the night. This was near the uppermost limit of bushes, and the elevation, I suppose, was between seven and eight thousand feet.

I was very much struck with the marked difference between the vegetation of these eastern valleys and that of the opposite side: yet the climate, as well as the kind of soil, is nearly identical, and the difference of longitude very trifling. The same remark holds good with the quadrupeds, and in a lesser degree with the birds and insects. We must except certain species which habitually or occasionally frequent elevated mountains; and in the case of the birds, certain kinds, which have a range as far south as the Strait of Magellan. This fact is in perfect accordance with the geological history of the Andes; for these mountains have existed as a great barrier, since a period so remote that whole races of animals must subsequently have perished from the face of the earth. Therefore, unless we suppose the same species to have been created in two different countries, we ought not to expect any closer similarity between the organic beings on opposite sides of the Andes, than on shores separated by a broad strait of the sea. In both cases we must leave out of the question those kinds which have been able to cross the barrier, whether of salt water or solid rock (1).

(Darwin, *Narrative,* 23 March 1835)

(1) This is merely an illustration of the admirable laws first laid down by Mr Lyell of the geographical distribution of animals as influenced by geological changes. The whole reasoning, of course, is founded on the assumption of the immutability of species. Otherwise the changes might be considered as superinduced by different circumstances in the two regions during a length of time.

The ladies of Lima

There are two things in Lima which all Travellers have discussed; the ladies *tapadas,* or concealed in the *saya y manta*, and a fruit called Chilimoya. To my mind the former is as beautiful as the latter is delicious. The close elastic gown fits the figure closely and obliges the ladies to walk with small steps, which they do very elegantly and display very white silk stockings and very pretty feet. They wear a black silk veil, which is fixed round the waist behind, is brought over the head and held by the hands before the face, allowing only one eye to remain uncovered. But then, that one eye is so black and brilliant and has such powers of motion and expression, that its effect is very powerful. Altogether the ladies are so metamorphised, that I at first felt as much surprised as if I had been introduced amongst a number of nice round mermaids, or any other such beautiful animal. And certainly they are better worth looking at than all the churches and buildings in Lima. Secondly for the Chilimoya, which is a very delicious fruit, but the flavour is about as difficult to describe, as it would be to a Blind man some particular shade of colour; it is neither a nutritive fruit like the Banana, a crude fruit like the Apple, or refreshing fruit like the Orange or Peach, but it is a very good and large fruit and that is all I have to say about it.

(Darwin, *Diary,* 29 July 1835)

The Galapagos Islands

The natural history of these islands is eminently curious, and well deserves attention. Most of the organic productions are aboriginal creations, found nowhere else: there is even a difference between the inhabitants of the different islands. Yet all show a marked relationship with those of America though separated from that continent by an open space of ocean, between 500 and 600 miles in width. The archipelago is a little world within itself, or rather a satellite attached to America, whence it has derived a few stray colonists, and has received the general character of its indigenous productions. Considering the small size of these islands, we feel the more astonished at the number of their aboriginal beings, and at their confined range. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period, geologically recent, the unbroken ocean was here spread out. Hence, both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth...

(Darwin, *Journal,* 8 October 1835)

I industriously collected all the animals, plants, insects and reptiles from this Island. It will be very interesting to find from future comparison to what district or "centre of creation" the organized beings of this archipelago must be attached (...).

(Darwin, *Diary,* 26, 27 September 1835)

When I recollect, the fact that the form of the body, shape of scales and general size, the Spaniards can at once pronounce, from which Island any Tortoise may have been brought. When I see these Islands in sight of each other, and possessed of but a scanty stock of animals, tenanted by these birds, but slightly differing in structure and filling the same place in Nature, I must suspect they are only varieties. The only fact of a similar kind of which I am aware, is the constant asserted difference between the wolf-like Fox of East and West Falkland Islds. If there is the slightest foundation for these remarks the zoology of Archipelagoes will be well worth examining; for such facts would undermine the stability of Species.

(Darwin, *Ornithological Notes*)

The men of Tahiti

In my opinion, they are the finest men I have ever beheld; very tall, broadshouldered, athletic, with their limbs well-proportioned. It has been remarked that but little habit makes a darker tint of the

This fine water-colour by Conrad Martens, who was the Beagle's official artist for nine months, depicts the scene at Port Desire on Christmas Day 1833, when the crew went ashore for a day of relaxation, sport and games. In the left foreground a group of sailors are playing a game called "slinging the monkey". A crew member, the "monkey", is slung by his feet from a tripod. In his hand he holds a piece of chalk. Other seamen gathered round flick at the "monkey" with twisted handkerchiefs. Meanwhile, the "monkey", working up a swinging motion, attempts to mark one of his comrades with the chalk. When he succeeds, the person so marked takes his place as the "monkey". In the background the Beagle and the Adventure are seen at anchor. The initials "R.F." in the top right hand corner indicate that Captain Robert Fitzroy had checked the sketch for authenticity. The pencilled note at the bottom, in the Captain's hand, which reads "Note Mainmast of the Beagle a little farther aft. Miz. Mast to rake more", shows that Fitzroy was not entirely happy with the artist's positioning of the Beagle's masts.

skin more pleasing and natural to the eye of an European than his own color. To see a white man bathing along side a Tahitian, was like comparing a plant bleached by the gardener's art, to the same growing in the open fields. Most of the men are tatooed; the ornaments so gracefully follow the curvature of the body that they really have a very elegant and pleasing effect.

(Darwin, *Diary*, 15 November 1835)

Sydney

Here we arrived on the 12th of this month. On entering the harbor we were astounded with all the appearances of the outskirts of a great city: numerous Windmills—Forts—large stone white houses, superb Villas, etc., etc. (...).

From Sydney we go to Hobart Town, from there to King George Sound, and then adieu to Australia. From Hobart town being superadded to the list of places I think we shall not reach England before September: But thank God the Captain is as home sick as I am, and I trust he will rather grow worse than better. He is busy in getting his account of the voyage in a forward state for publication (...).

From K. George Sound to Isle of France, C. of Good Hope, St Helena, Ascension, and omitting the C. Verds on account of the unhealthy season, to the Azores and then England. To this last stage I hourly look forward with more and more intense delight; I try to drive into my stupid head Maxims of patience and common sense, but that head is too full of affection for all of you to allow such dull personages to enter.

(Darwin, letter to his sister Susan, 28 January 1836)

The homecoming

On the last day of August [1836], we anchored for the second time at Proto Praya in the Cape de Verd archipelago; thence we proceeded to the Azores, where we staid six days. On the 2nd of October we made the shores of England; and at Falmouth I left the *Beagle*, having lived on board the good little vessel nearly five years.

(Darwin, *Journal*)

The voyage of the *Beagle* has been by far the most important event in my life and has determined my whole career (...).

I have always felt that I owe to the voyage the first real training or education of my mind. I was led to attend closely to several branches of natural history, and thus my powers of observation were improved, though they were already fairly developed (...).

Looking backwards, I can now perceive how my love for science gradually preponderated over every other taste. During the first two years my old passion for shooting survived in nearly full force, and I shot myself all the birds and animals for my collection; but gradually I gave up my gun more and more, and finally altogether to my servant, as shooting interfered with my work, more especially with making out the geological structure of a country. I discovered, though unconsciously and insensibly, that the pleasure of observing and reasoning was a much higher one than that of skill and sport. The primeval instincts of the barbarian slowly yielded to the acquired tastes of the civilized man.

(Darwin, *Autobiography*) ■

THE GALAPAGOS ISLANDS
The origin of 'The Origin'

by Jorge Enrique Adoum

IT was in the Galapagos Islands that Darwin became truly "Darwinian." When he set sail on the *Beagle* as a naturalist in 1831, he was only twenty-two years old and a fervent believer. At the age of nineteen he had entered Christ's College, Cambridge, with the vague intention of going into the Church. In his *Autobiography* he would say of that period: "I did not then in the least doubt the strict and literal truth of every word in the Bible." Consequently, there could be no doubt that the world had been created in six days (during the year 4004 BC, according to the calculations of Archbishop James Ussher; being completed, if further precision is needed, at 9 o'clock in the morning of Saturday 12 October).

He was first assailed by doubts during his voyage to South America: he found "new" fossils; he discovered that on either side of the Andes different types of vegetation grew in similar climates and on similar soils; he also found vast coral or lava concretions of later formation than that of the *cordillera.* He noted that the Galapagos Islands, formed as a result of successive eruptions of submarine volcanoes, were geologically more recent than America—that is, subsequent to the creation. Moreover they were quite separate, without any sunken ridges that might once have joined them to the continental shelf. He dubbed them "Satellites of the continent."

"Nothing could be less inviting than the first appearance..." he wrote in his diary, "a broken field of black basaltic lava, thrown into the most rugged waves and crossed by great fissures." The winds and waves had sculpted blocks smooth as the walls of natural fortresses, perforated cliffs like sponges, grooved surfaces like the fossilized tresses of a giantess on the rocks that rose from the underwater quarries. And, scattered on or between the islands,

JORGE ENRIQUE ADOUM, *Ecuadorian poet and writer, has published several volumes of poetry, including an anthology,* No son todos los que están. Poemas 1949-1979 *(Seix Barral, Barcelona, 1980). His play about the Spanish conquest of the Inca empire, published in English as* The Sun Trampled Beneath the Horses' Hooves *(The Massachusetts Review, Winter-Spring 1974) has also been translated into French, Swedish and Polish and performed in several countries of Europe and Latin America. He has taken part in Unesco's programme of studies on Latin American cultures, and is now a member of the editorial staff of the* Unesco Courier.

Photo © Fritz Polking, Federal Republic of Germany

Marine iguana of the Galapagos Islands.

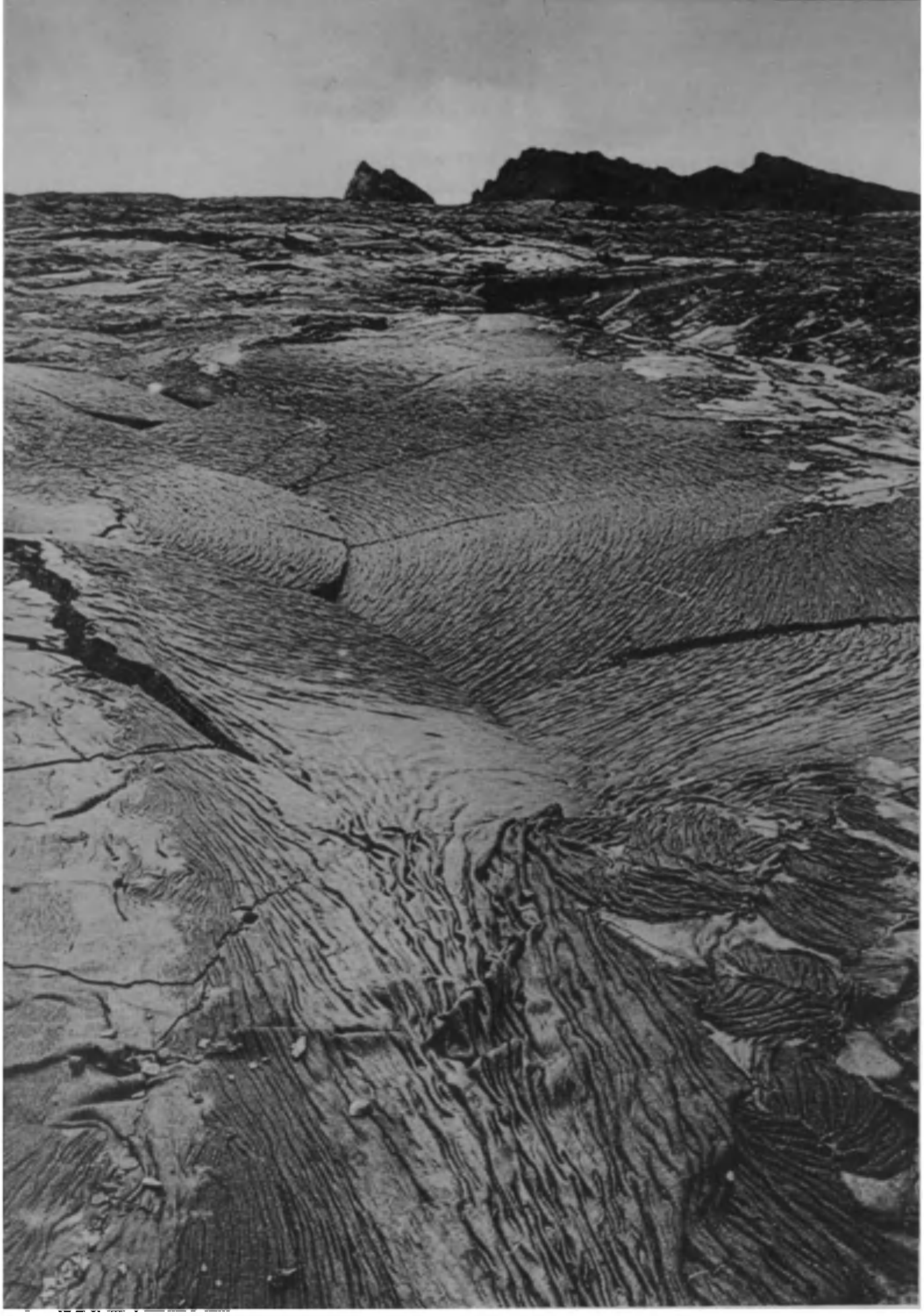


Photo © B N. Kelly, London

17 September 1835. "In the morning we landed on Chatham Island [Isla San Cristóbal]... Nothing could be less inviting than the first appearance. A barren field of black basaltic lava, thrown into the most rugged waves and crossed by great fissures..." (Darwin, The Voyage of the Beagle).

innumerable boulders lay like broken teeth, molars with lakes of lava at the bottom of their caries. We would call it a lunar landscape; Darwin described it thus: "I scarcely hesitate to affirm that there must be in the whole archipelago at least 2,000 craters." A few of these volçanoes have continued to be active and there have been eruptions until recently. An aerial view of the largest island, Isabela, shows that it is formed of lava flows from five or six volcanoes which were once separated by the sea. And on these edges of rugged basalt are fearsome marine iguanas of antediluvian aspect, slow-moving land iguanas "of singularly stupid appearance", the giant land tortoises known in Spanish as *galápagos,* so sluggish as to give the impression that they can hardly cope with their own weight. "A shore fit for pandemonium" was the entry Captain Robert Fitzroy made in the logbook of the *Beagle* on the day of its arrival, 15 September 1835.

The islands date back to a little over a million years. The winds blowing from the continent and the waves rolling to and fro between the beaches and the offshore rocks must have brought the particles of earth and spores of lichen and fern that were the basalt's first colonizers. Then came the birds bearing seeds among their feathers, in their stomachs or on their feet. The Humboldt Current must also have brought other animal species such as penguins, clinging to driftwood, to these islands which stretch from one degree north to two degrees south. These must have been the earliest inhabitants of the archipelago, which lies just under 1,000 kilometres off the coast of Ecuador and has a total land area of approximately 7,800 square kilometres. The largest island comprises more than half the total land area, with 4,588 square kilometres, while the smallest covers barely five.

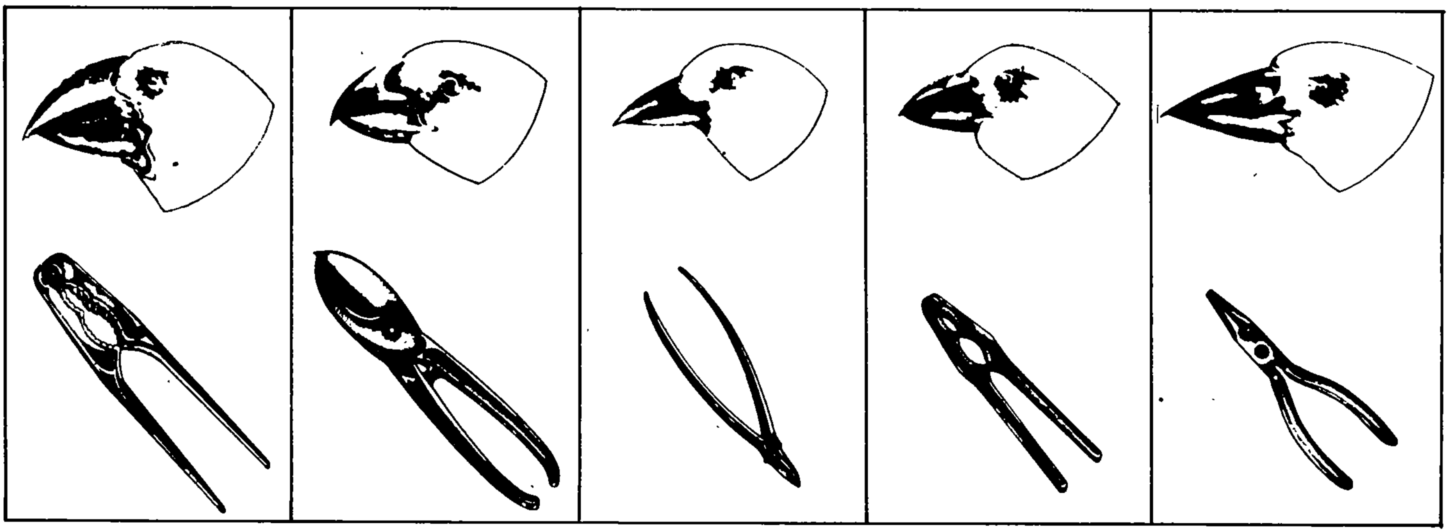
A few pieces of pottery and Thor Heyerdahl's Kon Tiki expedition have led some people to suggest that the Galapagos had been reached by pre-Columbian inhabitants of South America, in particular, the Incas. However, history records that it was the Spanish Bishop of Panama, Tomás de Berlanga, who was sent by the Emperor Charles V to arbitrate in the conflict between the conquistadores Francisco Pizarro and Diego de Almagra, who discovered the archipelago in 1535. It is possible that he was blown off-course, or that his ship was driven towards the islands by the mighty Humboldt Current. Berlanga and his crew were certainly the first to call the islands the Galapagos, and also the *Islas Encantadas* (Bewitched Islands) because of the mist that enveloped them like castles in a fairy tale.

The islands were of no interest to the conquistadores, but they were an ideal lair for pirates: there, freebooters and buccaneers set up their bases for operations against the galleons returning treasure-laden to metropolitan Spain. The area was frequented by adventurers such as Knight, Captain Morgan, Davis and Ambrose Cawley, who drew the first navigation charts on which the islands appear. Around 1800, Captain Collnet of the Royal Navy suggested fishing the whales which abounded around the archipelago, since those of the Atlantic had been virtually exterminated. From then onwards, English and North American whalers recklessly plundered the surrounding waters, depleting not only the stocks of cetaceans but also the tortoises that were so prized for their flesh and oil alike. A single boat would take up to fourteen tons of tortoises in four days and, according to the U.S. Navy's nineteenth-century archives, in twenty-seven years its whaling fleet caught over 13,000 of these mammals which, left alone, could live for more than two centuries. (In 1841 the islands were also visited by a whaler, subsequently a celebrated writer, Herman Melville, who described them in a fine work entitled *The Encantadas.* Even more significant, however, is the fact that in the early nineteenth century the North American whaler *Essex* was attacked and sunk by a sperm whale 30 degrees west of the Galapagos. This was the origin of *Moby Dick,* the white whale, incarnation of Evil on Sea and Land, and the vengeful and bloody persecution of Captain Ahab with his wooden leg and his epic failure.

On Charles Island (now Santa María) Darwin found a settlement of two or three hundred inhabitants, "Nearly all people of colour who have been banished for political crimes from the Republic of the Equator". Ecuador had taken possession of the islands on 12 February 1832 and called them the *Archipiélago de Colón* (the "Columbus Archipelago"), and gave them Christian names connected with the life of the illustrious Admiral: Isabela and Fernandina (after the Catholic Kings who had sponsored the ac- ▶

The right tool for the job

Darwin noticed that there were several species of finches on the Galapagos Islands and that each had a different shape or size of beak. The differences can be explained by natural selection.
Birds' beaks are like tools—different ones are suited to different jobs.
Beaks of different shapes are adapted to eating different kinds of food.



The large ground finch has a large, strong, crushing beak... like large nutcrackers.

This large tree finch has a strong, sharp beak for grabbing and cutting... like metal cutters.

The warbler finch has a small pointed beak for probing into cracks... like tweezers.

The small ground finch has a small but strong crushing beak... like small nutcrackers.

The cactus finch has a long tough beak for probing... like long-nosed pliers.

Large, hard seeds.

Large insects, such as beetles and caterpillars.

Small insects in cracks and crevices.

Small, hard seeds.

Cactus seeds and nectar.

▶ cidental discovery of America), Pinta and Santa María (after two of Columbus's caravels), Marchena (after the churchman and theologian who had aided Columbus), Genovesa (from Columbus's birth-place), San Salvador (the place where he first disembarked), Pinzón (his fellow-explorer), Santa Fe, Española, San Cristóbal...

The convicts, who were not necessarily all political offenders, had been taken to the islands by General José de Villamil, along with a handful of farmers and possibly a few craftsmen. The boat was a Noah's Ark in miniature, since the deportees took along dogs, pigs, goats, asses, cats and hens, which in turn attracted rats and fleas. On Santa María, people who had obtained concessions to exploit chinchillas harassed the settlers and convicts, so that by 1845 only twenty-five of the latter were left, twelve in 1851, and eventually none at all.

Nowadays, a population of fewer than 5,000 persons divided among three islands inhabit an area comprising one tenth of the total land area (the rest has been declared a National Park) and grow potatoes, lemons and coffee. On the higher ground small plains have formed where animal husbandry has begun. However, the acute shortage of water (provided only by a few springs and the persistent drizzle) the distance, as well as transport difficulties make both farming and animal husbandry an unprofitable occupation. Regular tourism is relatively new. (As recently as thirty years ago only one boat left the port of Guayaquil every four or six months with water, food, ropes, candles, matches and mail. The San Cristóbal "post office" consisted of a barrel sheltered from the drizzle by an improvised roof.)

Darwin encountered a veritable laboratory of evolution in the archipelago. And since "there is even a difference between the inhabitants of the different islands", he was able to observe not only the final product of the long evolutionary process, but also its different phases such as the thickening of the finches' beaks and the lengthening of the necks of the giant tortoises. "Most of the organic productions are aboriginal creations found nowhere else..."

Originally the tortoises on the Galapagos all belonged to the same species, later dividing into fifteen subspecies comprising three groups, according to the form of their shells. The shells of those on Española, Pinzón, Pinta, Fernandina and part of Isabela are shaped like a saddle, with the front edge raised to enable them to stretch their necks to reach the tall cacti on which they feed. Those on Santa Cruz have rounded shells and shorter necks and limbs, since they feed on plants which do not grow high. Between these two species there is a third which includes numerous variants according to size and the form of their shells.

The type of food they eat also determines how frequently these animals, the oldest living creatures on the planet, move in slow procession to the few springs of the uplands where each "buries his head in the water above his eyes and greedily swallows great mouthfuls, at the rate of about ten a minute. The inhabitants say each animal stays three or four days in the neighbourhood of the water and then returns to the lower country". Darwin supposed that this was why the tortoise needed to develop a bladder similar to the frog's which acts as a store-house for the moisture it needs in order to survive. Although some▶

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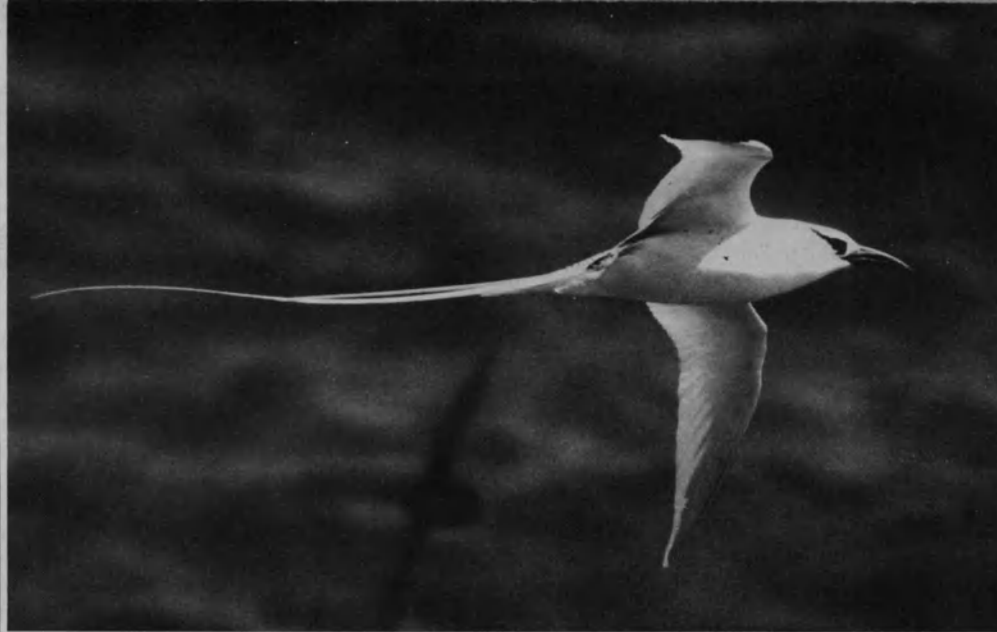

1
Short-eared owl

2
Red-billed Tropicbird

3
Giant tortoise and hawk

4
Galapagos penguin

5
Land Iguana

3

5

Photos © Fritz Polking, Federal Republic of Germany

4

▶of these species seem to be extinct—and in some cases attempts at cross-breeding between the sole surviving specimens of different groups have met with failure—large colonies still subsist, especially on Santa Cruz and Isabela.

According to Darwin, the islanders claimed that the tortoises were deaf, because they are indifferent to the presence of human beings. The same may be said of all the species of the Galapagos, in particular the marine iguana. These creatures sun themselves in serried groups on the rocks some distance from the water. One seemingly substantiated hypothesis has it that this crested animal, monstrous in appearance if not in size, with its serrated back and powerful claws, as if to enable it to cling to the ground, must have originally led the same sort of existence as the land iguanas. However, in order to escape from the land iguana, which belonged to a more powerful race, the marine iguana needed to acquire aquatic skills, although Darwin himself pointed out that once the danger is past it shuns the water. Consequently, it had to change its eating habits and, in order to eliminate the large quantities of salt it absorbs from the sea-weed on which it feeds, it possesses massive glands which enable it to eliminate the salt through its nose, thus supplementing the task of the kidneys. The sudden temperature changes caused by plunging from hot rocks into the cool water, and then returning back to land, have modified the rate of its heartbeat; laboratory experiments have shown that it loses heat about half as quickly as it regains it when the ambient temperature is raised or lowered. When Darwin visited San Salvador island there were so many land iguanas that he had difficulty in pitching his tent, the soil was so uneven on account of their holes.

The Galapagos penguin is the only one of its kind to have ventured so near the equinoctial line. It is also the smallest in the world, almost like a clumsy child, or a dwarf in comparison with its arrogant ancestors or its contemporaries in Antarctica. But in the archipelago, as if obeying some collective or ancestral memory, it seeks the deep, cold waters between the islands of Fernandina and Isabela, and on land it shelters in the cool of the hollows worn in the lava by the waves.

Of the thirteen known species of albatross, the species found on Española (*Diomedea irrorata*), is the only one in the world that inhabits the tropics. Likewise, the masked booby of the Galapagos is the only member of its family that has an annual reproduction cycle, although this varies from island to island; on Genovesa it runs from August to November, and on Española from November to February. Like the blue-footed booby, it lays its eggs directly on the ground, having lost the habit of nest-building, probably due to the scarcity of trees and the absence of animals and birds of prey on the coasts where they live. From the two eggs it lays, however, it only succeeds in rearing one chick: the other, less favoured, is doomed to die of hunger within a few days.

The lava heron and the flightless cormorant constitute unusual examples of adaptation to this environment. The former, which is only found in the Galapagos, unlike most herons, sometimes perches atop an overhanging bush before diving into the water below. The flightless cormorant, on the other hand, whose ancestors must have flown almost 1,000 kilometres to the islands, has practically lost its wing feathers. It was so easy to catch fish that it forgot how to fly and learned to swim instead. The fact that it is the only flightless bird in the archipelago is additional proof that the Galapagos are a young formation. So far, only one species has had the time to lose the use of its wings, whereas in New Zealand, for instance, several species have undergone this atrophy.

The case of the finch has become classic since Darwin used it as one of the pivotal arguments for his theory on natural selection. Observing the difference in the thickness of the beaks of the different species, he concluded that in the course of many generations the finches had to adapt their beaks to the size of the grains, seeds, insects and even leaves on which they depended for food. Of the thirteen species listed, the most interesting is the woodpecker finch which searches for insects and their larvae in the cracks of the bark of the lignum vitae, called "palo santo" because of the perfume it gives off when cut, or in the hollows of dead trees. But, as its beak is not sufficiently long, it uses a cactus thorn to poke into the cracks, thus being the only known case of a bird using a tool to obtain food.

Almost all the reptiles, half of the sedentary birds, a third of the vegetation and a large proportion of the insects of the Galapagos exist nowhere else in the world. Hence Darwin considered that his voyage to South America, and especially to the Galapagos, was by far the most important event in his life and that in these islands lay the origin for "all his ideas". He wrote in his diary that here "both in space and time, we seem to be brought somewhat near to that great fact—the mystery of mysteries—the first appearance of new beings on this earth".

More than man himself, it is the domestic animals he brought with him to the archipelago that endanger the survival of the aboriginal animal populations. Something similar is also occurring with respect to the plant species. Wild dogs devour the tortoises and iguanas; the goats flatten the vegetation; eggs and baby animals are the favourite food of the wild pigs. A 1963 report from the Charles Darwin Research Station states that on the island of Española "only one tortoise was found... during a two-day search made by three men. The island's vegetation has been severely devastated by goats; when the tortoise was found it was eating in the company of, and in competition with fifteen goats". In any event, indirectly, the most serious threat to the preservation of these species is, as the English playwright Tom Stoppard has put it, that in the Galapagos "the animals are in a state of innocence. They have no idea that you and I are, as the biologists put it, the most successful of the species, and that we could choose to wipe them out if we did not choose to cherish them; and so they are not afraid... One walks among iguanas, herons, doves, mocking-birds and finches as Adam and Eve in medieval paintings walk among antelopes and cranes".

■ **Jorge Enrique Adoum**

UNESCO AND THE CHARLES DARWIN FOUNDATION

IN 1935 the Government of Ecuador marked the centenary of Darwin's visit to the Galapagos Islands by establishing a nature reserve on most of the uninhabited islands. Today the "Galapagos Natural Park" covers 690,000 hectares, nine-tenths of the total area of the archipelago. In 1937, Julian Huxley, later to be Unesco's first Director-General, headed an international "Galapagos Islands Committee", but the Committee's plans to establish a research station in the archipelago were interrupted by the Second World War. In 1957, the plan was revived and endorsed by Unesco and, in 1959, the centenary year of the publication of *The Origin of Species,* the Charles Darwin Foundation for the Galapagos Islands was created in Brussels under the auspices of Unesco and the International Union for the Conservation of Nature and Natural Resources (IUCN). During the early 1960s, the first buildings of the Charles Darwin Research Station were erected near Puerto Ayora, on Santa Cruz island, with support from the Government of Ecuador, Unesco, IUCN, the United Nations Development Programme, and the Smithsonian Institution. The Foundation has drawn up a "Master Plan for the Galapagos National Park". In accordance with the Plan young tortoises are reared at the station and released in their natural habitat when they are 3 years old and can defend themselves against their enemies. Iguana are protected in the same way. Thousands of young fur seals (formerly believed doomed to extinction) have been saved, and measures have been taken to protect all the species from wild dogs and goats. The Government of Ecuador has adopted the Plan's recommendations for the limitation and control of tourism. No more than 5,000 visitors (usually accommodated on board the ship which brought them to the islands) are allowed, private visits are prohibited, and fishing is controlled. Conducted tours are led by trained guides along signposted footpaths. Feeding the animals is prohibited and each visitor is provided with a plastic bag for refuse disposal. The Foundation plans to include marine areas in the National park and Unesco is contributing to the creation of a marine laboratory which will also carry out geological studies. The Galapagos National Park has been included in the World Heritage List of cultural and natural properties of "outstanding universal value".

Every plant belongs to a species.

These plants have several features in common, but they can be divided into five different species. Chives *(Allium schoenoprasum)* grow in clumps, and have narrow bulbs and narrow leaves. Ramsons *(Allium ursinum)* grow in clumps, and have narrow bulbs and broad leaves. Leeks *(Allium porrum)* grow singly, and have long cylindrical bulbs. Onions *(Allium cepa)* grow singly, have round bulbs, and their flower stalks are swollen. Garlic *(Allium sativum)* grow singly, have round bulbs, and their flower stalks are not swollen.

You don't have to look at these plants to recognize them—each species has its own smell.

Looks aren't everything

Although they look almost identical, chiffchaffs and willow warblers belong to different species. The easiest way to tell them apart is to listen to their song. But once you know they are different, you can sometimes see small differences between them.

THE EVOLUTION OF EVOLUTION

by Pierre Thuillier

PIERRE THUILLIER, *professor of the history of science at the University of Lille III and the University of Paris VII, is a member of the editorial staff of the French scientific periodical* La Recherche. *His interests in epistemology (the theory and science of knowledge) and the broader questions of the relations between science and society are reflected in his* Jeux et Enjeux de la Science *(Games and Stakes of Science) published by Robert Laffont, Paris, 1972. His most recent book,* Darwin and Co., *was published last year by Editions Complexe.*

WHEN we think of evolution nowadays, our minds turn automatically to Darwin. Was it not he who, in the mid-nineteenth century, explained once and for all how the various forms of life had been constituted? But there is no reason why Darwin and his famous book of 1859, *The Origin of Species,* should blind us to the long and eventful history of transformism: a history that started before him, continued long after him, and is doubtless not closed. Evolutionism, it has often been said, has evolved. As the historical sketch he added to *The Origin of Species* proves, Darwin was aware of this.

He began the sketch by alluding to certain writers of Antiquity—and it is quite true that some Greek philosophers had vaguely surmised that living organisms might have undergone transformation. In the sixth cen- ▶

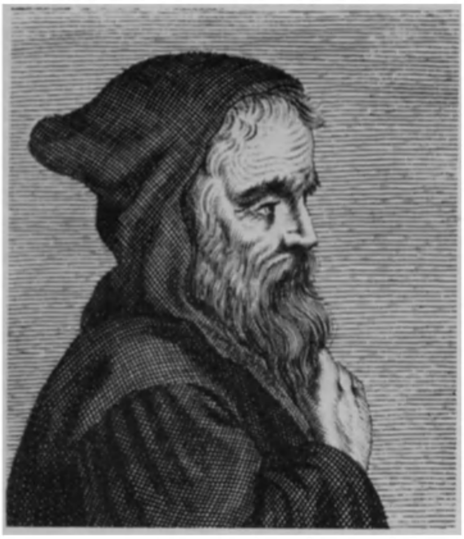
Photo © Bulloz, Paris

Empedocles of Acragas, 490 - 430 BC


Photo © Roger Viollet, Paris

Georges-Louis de Buffon, 1707 - 1788


Photo Boyer © Roger Viollet, Paris

Jean-Baptiste de Lamarck, 1744 - 1829

▶ tury BC, Anaximander of Miletus thought that "man, at the origin, was born of animals of another kind". This was, he said, borne out by the fact that human children take a long time before they can feed themselves unaided. In the fifth century BC another Greek thinker, Empedocles of Acragas (now Agrigento) put forward curious hypotheses about the development of organisms: "heads without necks appeared on earth, arms wandered without shoulders, and eyes with no forehead moved hither and thither...". In his view, these separate organs were brought together by the influence of Love, and that was how living beings were formed. His work contains the germs of a kind of natural selection: unviable organisms (such as cows with human heads!) became extinct, while those which were properly formed survived.

This is why some historians have seen Empedocles as a precursor of Darwinism—an opinion that is difficult to sustain. A few authors of Antiquity, however, had remarkable intuitions. Thus the Latin poet and philosopher Lucretius, in the first century BC, gave a very striking description of the "struggle for life". He thought it possible to account for the genesis of animals by the laws of nature alone, without invoking divine intervention. But however interesting, such ideas were never methodically or systematically developed, and many centuries went by before more exact speculations were made. Not until the eighteenth century did the first signs of modern transformism appear.

The development of a sense of history may well have played a part in the maturing of new ideas in biology. Little by little, theoreticians came to see social reality (customs, institutions, culture) in evolutionist terms, and it is not too surprising that this way of thinking should also have been applied to the study of nature.

It should be remembered that Christianity then dominated Western culture. According to the most widespread interpretation of the Bible, the different plant and animal species had been created directly by God and were immutable. It was a bold undertaking to attack that doctrine, especially since sciences such as palaeontology and embryology were still in their infancy. But a few bold spirits ventured nevertheless to suggest that living creatures might undergo "transmutations" from generation to generation.

The French writer Benoît de Maillet, for one, in a book published only after his death in 1748, said that all the land species might perhaps have come from corresponding marine species. He suggested that fishes had settled on the land and had given birth to new animals, including birds. Similarly, sea elephants had bred land elephants, and men too had stemmed from sea creatures—the Tritons! Obviously Benoît de Maillet is now seen as a gentle dreamer with an excessive imagination. But around the same time, other authors were formulating some highly interesting ideas.

Science historians have noted, for in-

Darwin and racism

DESPITE the influence of certain thinkers, race prejudice developed into a regular doctrinal system during the eighteenth and nineteenth centuries. There was indeed a relatively brief period when it appeared as though the spread of the principles of the French and American revolutions and the success of the anti-slavery campaign in England might lessen or even abolish such prejudice, but both the reaction which followed the Restoration and the industrial revolution in Europe at the beginning of the last century had direct and damaging repercussions on the racial question. The development of power spinning and weaving opened ever wider markets to cotton manufacturers, and "Cotton was king", particularly in the southern part of the United States. The result was an increasing demand for servile labour; slavery, which was breaking down in America and might have vanished of itself, automatically became a sacrosanct institution on which the prosperity of the Cotton Belt depended. It was to defend this so-called "special institution" that southern thinkers and sociologists developed a complete pseudo-scientific mythology designed to justify a state of affairs contrary to the democratic beliefs they professed. For the quietening of consciences men had to be persuaded that the Black was not merely an inferior being to the White but little different from the brutes.

The Darwinian theory of the survival of the fittest was warmly welcomed by the whites as an argument supporting and confirming their policy of expansion and aggression at the expense of the "inferior" peoples. As Darwin's theory was made public in the years in which the greater powers were building their colonial empires, it helped to justify them in their own eyes and before the rest of mankind: i.e. slavery or death brought to "inferior" human groups by European rifles and machine-guns was no more than the

Photo © Palais de la Découverte, Paris

August Weismann, 1834 - 1914

Photo © University College London

J.B.S. Haldane, 1892 - 1964

Photo © Benjamin Cummings, Menlo Park, California

Theodosius Dobzhansky, 1900 - 1975

stance, that around the mid-eighteenth century, Pierre de Maupertuis appears "to have had a fairly clear notion of the processes of mutation and selection". In his view, not only could living creatures change accidentally from generation to generation, but useful changes could be preserved and accumulate, while ill-adapted specimens, conversely, were doomed to disappear.

For his part, the naturalist Buffon seems to have accepted that a limited transformism was possible. He even wrote that it might be conjectured that "all animals have descended from a single animal which has over the ages, by improving and degenerating, produced all the races of other animals". We must beware of exaggerating the importance of such statements. But clearly, by the eighteenth century many naturalists entertained the proposition of the variability of the species. Charles Darwin's own grandfather, Erasmus Darwin, drew on various considerations taken from comparative anatomy, embryology, etc. to formulate an evolutionist theory. He is generally viewed as a predecessor of Larmarck, who in 1809 published a particularly important work: the *Philosophie Zoologique,* or Zoological Philosophy.

Lamarck's thought is often summarized as follows: in order to adapt to their environment, animals acquire new physical characters which are then hereditarily transmitted to their descendants. The usual example is the giraffe: in order to reach ever higher leaves and to meet new "needs", it adopted, or so the theory goes, the habit of stretching its neck, and passed the resulting change on to its offspring. But Lamarck's theory is far more complex. He does indeed accept that changing circumstances indirectly cause a kind of evolution, but he also asserts that life itself, through its own laws, causes as it were a "progression" in living beings. In other words, nature tends spontaneously to complicate the "general series of animals": all in all, environmental variations are, if anything, disruptive: they introduce "anomalies" into the "general scheme of nature". Lamarck did not succeed in convincing all his fellow-naturalists, but he did exert a lasting influence even when his system had been exposed to very severe criticism.

During the first half of the nineteenth century, other transformist interpretations were put forward. Examples are the Frenchman Etienne Geoffroy Saint-Hilaire, and the Englishman Robert Chambers, who published in 1844 an anonymous book entitled *The Vestiges of the Natural History of Creation.* But there was nothing of the nature of a breakthrough until the year 1858, when papers by Charles Darwin and Alfred Russel Wallace were read to the Linnean Society of London, clearly setting out the theory of natural selection. The following year, *The Origin of Species* was published. And this was a well-structured theory, supported by a large number of specific examples drawn from palaeontology, embryology, comparative anatomy and ▶

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implementation of the theory of the replacement of an inferior by a superior human society. In international politics racism excuses aggression, for the aggressor no longer feels himself bound by any consideration for foreigners belonging to "inferior" races and classifiable little, if at all, above the beasts.

The notion that the stronger is biologically and scientifically justified in destroying the weaker has been applied as much to conflicts within as to those between nations.

It is unfair to level at Darwin—as many have done—the reproach that he promoted this hateful and inhuman theory. The truth is that with coloured societies becoming potential competitors in the labour market and claiming the social advantages regarded as exclusively the heritage of the whites, the latter were obviously in need of some disguise for the utter economic materialism which led them to deny the "inferior" peoples any share in the privileges they themselves enjoyed. For that reason they welcomed with satisfaction Darwin's biological thesis and then by simplification, distortion and adaptation of it in conformity with their own particular interests, transformed it into the so-called "social Darwinism" on which they based their right to their social and economic privileges; it is a thing which bears no relationship to Darwin's purely biological principles. Herbert Spencer (1820-1903) applied to sociology the concept of the "survival of the fittest" and the same idea was used to defend Nietzsche's (1844-1900) doctrine of the "superman" with whom "fittest" was equated.

In this way progress in biology was misused to provide superficially scientific and simple solutions to allay scruples on points of human conduct.

Juan Comas, ***Racial Myths,*** **from** ***The Race Question in Modern Science,*** **Unesco, 1956**

▶biogeography, and providing a detailed explanation of the formation of species.

Darwin began by stating that the species were populations made up of individuals that could vary from generation to generation. He then spoke of the continual "struggle for life" in nature: the animals, he said, must not only face their competitors, but must endure bad weather, heat, drought, etc. He then brought in the idea of natural selection, basing it on a comparison with artificial selection: just as breeders improve their stock through methodical selection, so nature produced new species by selecting individuals. Those which bore favourable variations survived and multiplied, while those which bore unfavourable variations became extinct. Supposing that this mechanism operated over thousands of generations, Darwin said, then by cumulative effects of tiny changes, new populations (meaning new species) would be formed.

Darwin acknowledged that there were several other evolutive processes such as sexual selection, use and non-use of organs and the direct effect of circumstances. But in his eyes, nautral selection played the principal role. Properly speaking, as Darwin himself recognized, the theory was not "proved". A frequent objection, albeit one of many, was that no species had ever been seen to change into another. But Darwin was right to say that his explanations made intelligible a host of facts observed by specialists in palaeontology, embryology and other disciplines. Several scientists opposed the new theory but, in a few years, it won acceptance in very many countries.

There were, however, weaknesses in Darwinism. They were due in particular to the fact that in Darwin's day, little was known about genetics. Mendel's famous study of hybrid plants, which marked the start of modern genetics, was published only in 1865: Darwin never used the ideas it contained. But other scientists were soon to undertake a revision of the theory expounded in *The Origin of Species*. While Darwin believed, for instance, in the heredity of acquired characters, the German August Weismann, in the closing years of the century, asserted that such heredity was impossible. That led to the rejection of the concept of usage and non-usage of organs—but the theory of natural selection proper remained intact.

In 1900 there came a new development in genetics thanks to the "rediscovery" of Mendel's laws inspired by the Austrian Tschermak, the German Correns and the Dutch scientist De Vries. Paradoxically, however, it did not at once contribute to improving Darwin's theory. Quite the contrary, it was the occasion for a conflict over the nature of the *variations* through which natural selection operates. The advocates of Mendelism considered those variations to be sudden and sweeping. Hugo de Vries, for one, thought that evolution was the result of spasmodic "mutations", of "leaps" that suddenly produced new forms (mutationism). But Darwin had for his part stated that evolution was a continuous and cumulative process involving tiny variations. This led to a crisis in biological thinking in the early twentieth century, which was only really solved in the 1920s to 1930s, when R.A. Fisher, S. Wright and J.B.S. Haldane developed population genetics.

This discipline, which studies the way in which genes are spread among populations, made it possible to present Darwinism in a more satisfactory form. Around the year 1940, a new overall conception which is commonly called the "synthetic theory" of evolution came into being, based essentially on the work of Theodosius Dobzhansky, Ernst Mayr and George Gaylord Simpson. Under this theory, Darwin's beloved variations were defined as *mutations,* meaning chance accidents affecting certain genes. The new synthesis not only took account of progress in genetics, but incorporated various findings relating to the concept of species, biogeography, palaeontology, etc. It was accepted by a large number of scientists and is still today, in its broad outlines, the orthodox interpretation.

Recent developments in molecular biology and biochemistry have made it possible to analyse evolutionary phenomena with greater accuracy and detail. We can now follow under the microscope, so to speak, the evolution of certain molecules such as haemoglobin. By and large, the findings made in the various life sciences have borne out the theoretical constructs discussed above. It should not, however, be imagined that all the problems have been solved and that neo-Darwinian—or neo-neo-Darwinian—theory has reached its final and definitive form.

Even such apparently simple concepts as *adaptation* and *natural selection* are subject to various degrees of criticism. Some biologists, for example, point out that it is extremely difficult to ascertain exactly whether a given gene has really been selected for its biological "utility". In this regard, mention should be made of the "neutralist" theory of the Japanese M. Kimura, according to which many genes are neither useful nor harmful from the evolutionary viewpoint, but merely neutral. Additionally, the Americans Gould and Eldredge have recently suggested a theory (known as punctuated equilibria), which runs counter to the generally accepted ideas. In their view, evolution is not a regular and continuous process, but one of relatively sharp evolutionary "leaps". These and other points give rise to much debate, and neo-Darwinian theory may well in future years undergo major revision.

There has been much talk in recent times of a new discipline that is also part of the Darwinian tradition: sociobiology. Its purpose is to use biology to explain the social behaviour of animals in general and of man in particular. A preponderant role in the birth of this science has been played by the American Edward O. Wilson (*Sociobiology: The New Synthesis,* 1975). He has formulated a vast theory which takes up the essential lines of Darwinism but also draws on genetics, ecology, ethology and other disciplines. In his view, all social behaviour has an underlying genetic foundation and must be explained in that light: from the biological viewpoint, it would appear that individual organisms are designed only to secure the maximal reproduction of genes. In other works, genes are "selfish": they use animals (termites, geese, goats, chimpanzees or men) to reproduce themselves, and social behaviour such as sexuality, aggression or religion should be seen as strategies to maximize "genetic profit".

But Wilson has done more than formulate theories. Building on the principle that sociobiologists are best qualified in human behaviour, he has claimed that they should become the "new moralists" and guide the planning of society. This far-reaching ambition raises very many questions.

First we need to know whether this new form of Darwinism rests on sound foundations. Here certain reservations may be made. It is, for instance, by no means certain that there are genes for altruism, conformism or homosexuality. Nor is it beyond dispute that the development of human societies, which is sometimes very rapid, can be explained in terms of biological evolution which is, in comparison, extremely slow.

Another question immediately arises: is it the job of scientists—in this instance, biologists—to dictate ethical and political standards to mankind? The Wilson case has the merit of reminding us that this major problem is not new. Darwin himself applied his theory of evolution to the human race, and was led to speak of "inferior races" and to claim that woman too was inferior to man—less intelligent, less resourceful, less courageous. With such testimony to hand, more or less "scientific" arguments for racism and sexism could easily be fabricated! Similarly, the idea of *selection* could easily lead on to formidable eugenic projects to produce populations of "supermen".

Such was not, of course, Darwin's wish. But history demonstrates that dangerous ideologies have often sprung up around more or less suspect "Darwinian" ideas. Perhaps a lesson should be drawn from this: the development of evolutionary theories is not only a "magnificent adventure in science", but a cultural undertaking of immediate relevance to mankind. So let us admire all those who, from Anaximander to our times, have shed a little light on the origins of life and of our species. But let us not forget that theories are only human constructs. They may help us to see things more clearly, but our future depends on moral and social choices that transcend science, even Darwinian science.

■ Pierre Thuillier

COMPUTER CONFIRMS DARWIN WAS RIGHT

by Boris Mednikov

WHY did Darwin entitle his most important work *The Origin of Species?* Evolution is indeed a process which involves the emergence of new species; but it also encompasses phenomena ranging in scale from, for example, the extinction of the dinosaurs and the development of mammals to the appearance of insecticide-resistant strains of housefly.

Darwin obviously considered the formation of species, by which he meant the origination of new species through a process of development from earlier forms, to be the key to evolution, and that only by unravelling the secrets of that process would it be possible to understand all the other phenomena involved. But he failed to make a distinction between the development of varieties and the development of an increasingly complex hierarchy of genera, families, orders, classes and divisions or phyla. We should remember, however, that in Darwin's time genetics as a science did not exist and that he knew nothing of the work of his contemporary Mendel.

There can be no doubt that Darwin's thinking led him to the frontier which separates the formation of species from the development of more complex groups and establishes a distinction, for example, between the origination of the domestic dog, and that of the entire *Canidae* family. Not without reason did he devote a whole chapter of *The Origin of Species* to the subject of hybridization within and between species. Expressed in modern scientific language, what had caught his attention was the cessation of genetic interchange that occurs when a species is formed.

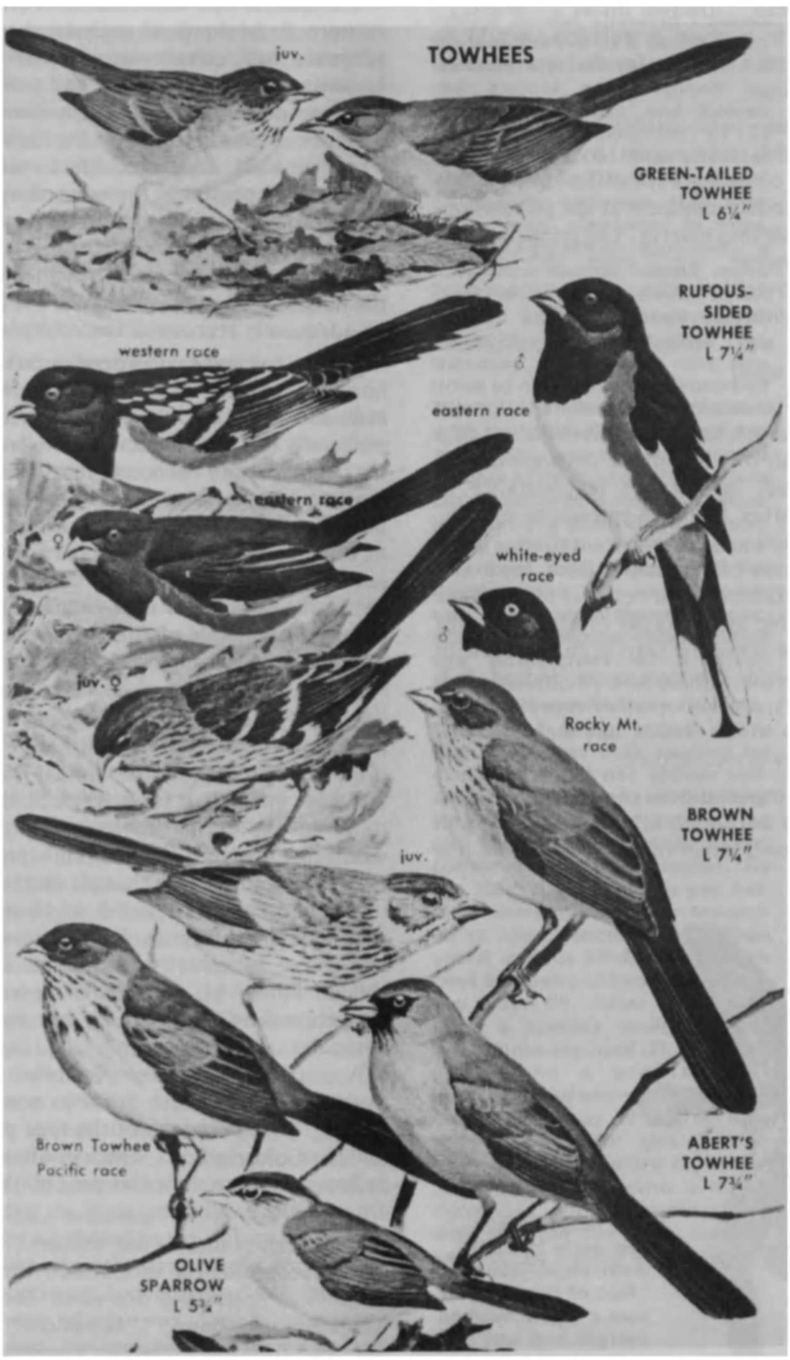

Photo © Delarhaux et Niestlé, Neuchâtel, Switzerland

Towhee songbirds of North America.

Today, it is possible to distinguish between micro-evolutionary and macro-evolutionary processes. Micro-evolution comprises the sum total of the developments which occur within species, over relatively limited geographical areas and during relatively short periods of time (measured in a few hundred or a few thousand generations), and which culminate in the formation of a new species or the separation of the original species into two sub-species.

The mechanisms of species formation are now fairly well understood. In plant and animal populations alike, successive generations are subjected over long periods of time to environmental pressures which ultimately result in the selection of inherited variations best suited to coping with those pressures. But where is the material for this process of selection to be found? Firstly, in the products of mutation, i.e. the accumulated hereditary changes which are primarily caused by modifications in the genetic structure of the cells of DNA (deoxyribonucleic acid).

The second source of variations which enable selection to occur is to be found in the process whereby bisexual organisms reproduce themselves. Since sexual reproduction permits the combination of genes inherited from both male and female parents, the number of possible combinations increases with each new generation. The combinations which prove most successful are those which are most likely to reproduce themselves. Little by little, the characteristics by which the individuals which form a population may be distinguished are changed, until a new species is formed.

Under normal circumstances, the genetic changes which occur in this manner, ▶

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gradually separating one population from others of the same parent species until it becomes a species in its own right, preclude interbreeding. Darwin quotes the example of a rabbit population introduced from Europe to the island of Madeira: after three hundred years, the Madeiran rabbits had changed in outward appearance, shrunk to the size of rats and could no longer breed with those of Europe.

The processes of micro- and macro-evolution meet at the point where species are formed. Here again, it was not without reason that Darwin's interest was roused by the infertility of hybrids from crossed species. It is important to remember, however, that when a population detaches itself from the parent species and becomes a new species, the micro-evolutionary process continues in each, in the same manner as before but along two distinct paths. Where the new species and its parent stock were formerly partners in the evolutionary process, each now becomes an environmental factor as far as the other is concerned, and the relationship of the newcomers to their forebears may be a competitive one. In so far as the differences between similar species may be very slight it is not always easy to draw a line between micro- and macro-evolution. Quite often the formerly clear limits which defined a species can be broken, for example, when human activity disrupts the ecosystem. An area straddling the border between the southern part of the United States and Mexico was formerly shared, but with clear territorial demarcations, by two species of towhee songbirds. One species frequented deciduous and the other coniferous woodlands; today, as a result of deforestation, an increasingly hybrid population may be observed.

Although it would not be difficult to give many similar examples, it is still correct, on the whole, to state that micro-evolution ends and macro-evolution begins at the line of demarcation of a given species.

Macro-evolution comprises the appearance and development—on an enormous scale at times encompassing the entire biosphere and over millions if not hundreds of millions of years—of the more complex organizational structures in which individual species are absorbed: genera, families, orders, classes, divisions (for plants), phyla (for animals) and kingdoms. Because their dimensions are so great, it is impossible to investigate macro-evolutionary processes with one of the most powerful tools of scientific enquiry—experimentation.

It was Hegel, I believe, who described the historian as a prophet who foretold the past. The same may be said of macro-evolutionists. At the end of the nineteenth century, Darwin's successors were for the most part concerned with macro-evolutionary issues. It was only after the rediscovery of Mendel's laws in 1900 and the stormy period of controversy during which the science of genetics was born that the investigation of micro-evolutionary processes assumed its rightful place in the development of a more comprehensive theory of evolution.

Today, the majority of scientists are inclined to believe that there are no fundamental distinctions between micro- and macro-evolution and that they are merely different phases of a single evolutionary process. All the evolutionary phenomena observed can be fully explained by modern genetics. But this is not, however, the unanimous view, and more than a few scientists consider that the evolution of supra-specific groups follows entirely different laws.

Richard Goldschmidt, who has been responsible for some distinguished research in the micro-evolutionary field, believes that families, orders and classes are the product of macro-mutations, that is, of extremely radical changes in individual members of a population. These individuals, that Goldschmidt calls "highly promising freaks", become the founders of new categories. According to this thesis, macro-evolution occurs by leaps and bounds; the first bird suddenly flies up from the class of reptiles, the first man walks away from the class of man-like apes, and so on.

But this theory of macro-mutation begs too many questions. It is hardly conceivable, for example, that the "highly promising freak", thrown up as a "one-off" example in a given population, would be able to find a partner for the reproduction of offspring.

Moreover, palaeontological evidence contradicts this extravagant hypothesis. The founders of new groups differ only slightly from the other members of the populations from which they emerge. The primitive bird, *Archaeopteryx,* was, after all, only a feather-covered reptile, and our ancestor *Australopithecus,* apart from his upright posture, was virtually indistinguishable from the apes.

All the examples of macro-mutation (of the type which led to the development of a second pair of wings in the *Drosophila* fruit fly) in fact involve the reappearance of earlier, rather than the emergence of new, characteristics. They reflect the phenomenon of atavism, as does, for example, the existence of a vestigial tail in some humans. No genus, order or class can exist and evolve otherwise than as an aggregate of all the species it encompasses; indeed, it is not orders, classes or other more complex categories which evolve, but the species of which they are composed.

Other explanations of macro-evolution have been advanced, all of them leading in the last resort either to the premise that it is a process which occurs in fits and starts or to the postulation of new laws governing the appearance of more complex categories. Indeed, attempts to drive a wedge between micro- and macro-evolution are renewed with such regularity that one may be inclined to ask whether there is not an objective reason for this. May there not be something in the very nature of our knowledge concerning the historical development of living things which leads scientists along paths that are marked out neither by facts nor by logic?

The first hominid, this early form of *Australopithecus* (or "Ape of the South") was a biped, walked upright and was able to run in the open plains.

Perhaps the main cause lies in our inability, for the time being, to observe the process of evolution in anything other than terrestrial terms. Let us imagine what would happen if a visitor from outer space were to pass judgment on human life in its entirety on the basis of the biography of a single earth-dweller. Some of his conclusions would undoubtedly be correct, but he might also be inclined to transform the chance events of that individual's life into laws which he considered applicable to mankind as a whole.

The same is true where macro-evolution is concerned. In the final analysis, the disappearance of certain groups of living organisms and the progress and prosperity of others depend in great measure on purely fortuitous circumstances. Perhaps only when we have discovered life forms on a dozen other planets in the universe shall we be able to distinguish what, in the process of evolution, follows a certain pattern and what is wholly accidental. Only then, to use the language of statisticians, will the sample be adequately representative.

Earlier I stated that experimentation was impossible where macro-evolution is concerned. This is not altogether correct. Experiments can be conducted if we translate the evolutionary process into computer language. Three years ago I was able to take part in a series of experiments carried out by V.V. Menshutkin—a specialist in the mathematical modelling of biological processes—concerning the evolution of segmented animals of the *Arthropoda* and *Chordata* phyla.

The computer's memory was fed with adequately detailed descriptions of a primitive segmented worm and of a primitive protochordate similar to the creature which has survived until modern times in the form of the amphioxus, a worm-like marine animal. This primitive species was subject to change; furthermore these changes were a matter of chance and were equally likely to be progressive or regressive. In other works, what Darwin called "Lamarck's nonsense of 'a tendency to progression'" was not fed into the computer.

Account was also taken of another rule of Darwinian evolution: *Natura non facit saltum;* violent changes of the type proposed in Goldschmidt's theory of macro-mutation were excluded as possibilities.

At intervals in the operation (corresponding to approximately one million years on the palaeontological time-scale), the computer was instructed to select the best-adapted variations. "Outsiders" were removed from the computer's memory and their cells replaced by the most successful competitors. Since the computer could simulate a million years in nine-hundredths of a minute, there was no difficulty in reconstructing the process of evolution from the Cambrian period up to the present.

The results of these experiments were highly significant. I shall merely describe here how the evolution of the chordates was seen by the computer to have occurred.

After the computer had been running for a period equivalent to 100 million years, the initial data fed into the machine, which concerned the primitive protochordate (a small, worm-like marine organism a few centimetres in length, with swimming muscles, a notochord—a rod made of gristle that extends down the length of the animal and supports the body—and an enclosing backbone, but without either a brain or cranium), had generated the characteristics of a great number of fish-like creatures with bony skeletons and scales, some of them aggressive and predatory, others peaceful and harmless. After 350 million years' worth of operation, the computer announced a creature which crawled up out of the water on to dry land, and then went on to produce the characteristics of amphibians, reptiles and, eventually, mammals. And when the operation had spanned the equivalent of 1,000 million years of evolution, a most outlandish creature emerged: a vigorous predatory animal with an extremely well developed nervous system, travelling on two legs, its forward extremities swinging free. It was not difficult to recognize in this phenomenon a mathematically-modelled *Pithecanthropus,* or at least *Australopithecus.*

All the subsequent experiments, which were based on identical source-data and programming, produced various results. Let me recall in this connexion that the computer had been instructed to perform in accordance with Darwin's concept of random variation. In one experiment, fish emerged on to dry land on three pairs of fins. In another, the computer announced four-legged creatures with arms, very similar to the centaurs of mythology. The exercise showed that in its details, macro-evolution was an unpredictable process, and the same is in all probability true where "real life" evolution is concerned. It is unlikely that in the future, however far our wanderings in the Galaxy take us, that we shall find two planets with identical biospheres.

There is another, no less important conclusion to be drawn from the type of experiment to which I have referred. The evolutionary process simulated by the computer continued satisfactorily under stable environmental conditions. In all likelihood, real evolution does not require disturbances of catastrophic dimensions, such as the drift of continents or the onset of ice ages, for new forms of life to develop or old forms to become extinct. Our experiments produced moments when new species were suddenly formed, and periods when species ceased to exist, but in each case these phenomena could be attributed to the influence of other biotic factors in the biosphere. For example, one experiment concerned a freshwater environment which was for a long time dominated by creatures which resembled fish, except that they lacked jaws (similar to the lampreys and hagfish of the *Cyclostomata* group of animals); when this environment was invaded by jawed fish from the sea, the earlier population declined rapidly; within a period of years it had virtually disappeared.

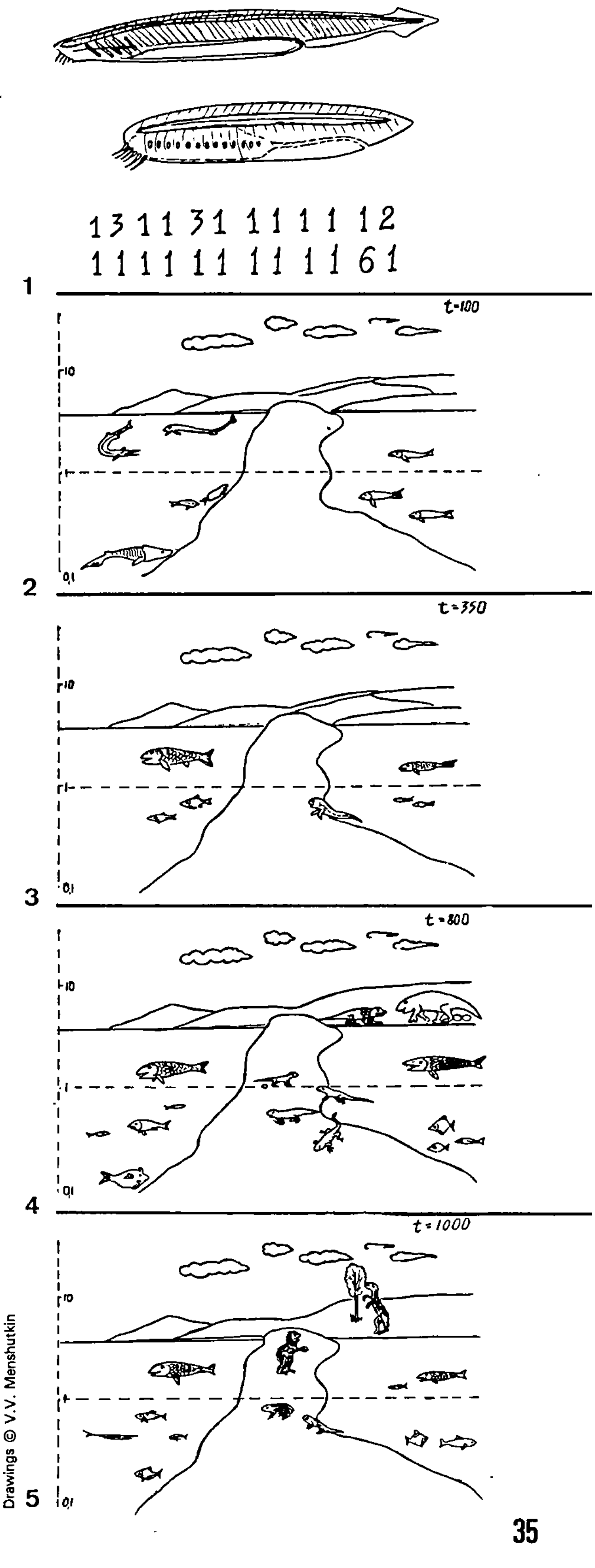
The most important conclusion of all, however, is that Darwin's principle of natural selection among random inherited variations is perfectly adequate for the mathematical modelling of progressive macro-evolution. In my opinion, there are no grounds for believing that the actual process of evolution on earth has occurred otherwise.

In the light of the experiments I have mentioned, it would appear advisable to adopt an even more sceptical attitude to every attempt to discern, in the macro-evolutionary process, different causes and mechanisms from those which Darwin announced in 1859. Should we not be guided by Newton's principle of simplicity: "We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances".

■ **Boris Mednikov**

Evolution by computer

These drawings by Soviet scientist V.V. Menshutkin were made from descriptions provided by a computer during an experiment designed to simulate the evolutionary possibilities of the chordates, one of the major groups into which the animal world is subdivided. The experiment was performed using a chordate called *Amphioxus,* a small worm-like marine animal. Drawing 1 shows the *Amphioxus* as it exists today (above); a primitive ancestor of the animal as imagined by anatomists (centre) and (below) the coded description of 24 characteristics of this ancestor which may be listed as follows: "A marine organism less than 10 cm long, elongated in form, with segmental muscles, a notachord (dorsal hollow nerve cord), and spinal marrow. It has neither brain nor cranium, no pairs of fins nor other extremities. It feeds on tiny particles of mud which are absorbed through its pharynx perforated with branchial slits. It is fertilized externally, lays tiny eggs, takes no care of its young." Each figure corresponds to a degree of development of a given characteristic; in the case of the brain, for example, from total absence to full development. For each generation, the random figures produced by the computer only modified the coefficient of a given characteristic by one point more or less; thus viviparity (the production of living young rather than eggs) and milk feeding for example, could not appear suddenly, through an evolutionary leap. The computer then sorted out the different variants and conserved the best-adapted. By the 100th operation (the gap between each operation corresponding to approximately one million years) various kinds of fish with jaws and pairs of fins appeared in the water (2). After 350 operations a species emerged from water onto dry land (3). After 800 operations a profusion of predatory and non-predatory land creatures up to 10 metres long appeared (4). By the 1,000th operation a predatory biped appeared, endowed with a highly developed nervous system and with the free use of its forward extremities (centre of drawing 5).



Drawings © V.V. Menshutkin

AN ASTRONOMER REFLECTS: WAS DARWIN WRONG?

by Chandra Wickramasinghe

I can hardly remember my first encounter with Darwin's Theory of Evolution, but it was surely taught in a classroom context at a very early age, long before I was in any position to assess the facts. It was presented, at least by implication, as a proven unshakable fact. I was asked to believe that lifeless inorganic matter sprang into life by a process of random shuffling of molecules at some distant time in the past on our planet. I was asked further to accept that the life that developed thereafter on our planet was entirely the result of neo-Darwinian evolution. The strong live on to become stronger, the weak die to be buried in oblivion. It impressed me as a great theory, seductive and compelling, even though it ran counter to my own cultural inheritance of Buddhist beliefs that the universe is eternal and that the patterns of life within it have a permanent quality.

Neo-Darwinist ideas became firmly imprinted in my mind and they became part and parcel of my scientific inheritance. I was trained first as a mathematician and later as an astronomer with a tacit acceptance of current biological dogma. Since I did not make a systematic study of biology until about five years ago, I had not until this time any opportunity of seeing for myself what the facts really were.

The reason for my coming to challenge accepted beliefs in Darwinian evolution stems from my joint work with the British astronomer Sir Fred Hoyle. In 1962 we began work on the nature of interstellar dust and we were led at this time to conclude that dust grains in space must contain a component in the form of microscopic submicron-sized graphite spheres. Then followed a long and painful struggle to find out what else there was in interstellar dust besides graphite. In 1972, I found that organic polymers—long chains of carbon-based organic molecules—were involved. Two years ago we reached the conclusion that a whole body of astronomical data pointed to micro-organisms being present on a colossal scale in space, some 10^{52} individual cells being present in our galaxy. We found that the way in which starlight of various colours was dimmed by interstellar dust was indicative of the presence of living cells in space, some of which had become selectively degraded into graphite. We concluded now with a considerable measure of confidence that microbiology operated on a cosmic scale.

In studying the spectral behaviour of micro-organisms in the laboratory we next noticed that a diagnostic thumbprint of biology existed in the infrared wavelength region. We compared laboratory data with the observed behaviour of infrared absorption for a star at the centre of our galaxy and found a remarkably close correspondence between microbiology and astronomy. Bacteria seemed, therefore, to be present on a galaxy-wide scale. These identifications are, in the view of Sir Fred Hoyle and myself, as decisive as any that could be obtained from a comparison between laboratory data and astronomical observations. More recently there has also been the decisive discovery of fossil micro-organisms in carbonaceous meteorites, bits of rock that fall from the skies and which cannot have any connexion with the earth. The failure on the part of most scientists today to recognize such obvious facts is due in large measure to their early indoctrination in Darwinism, a theory that tacitly implies a beginning of life on the earth.

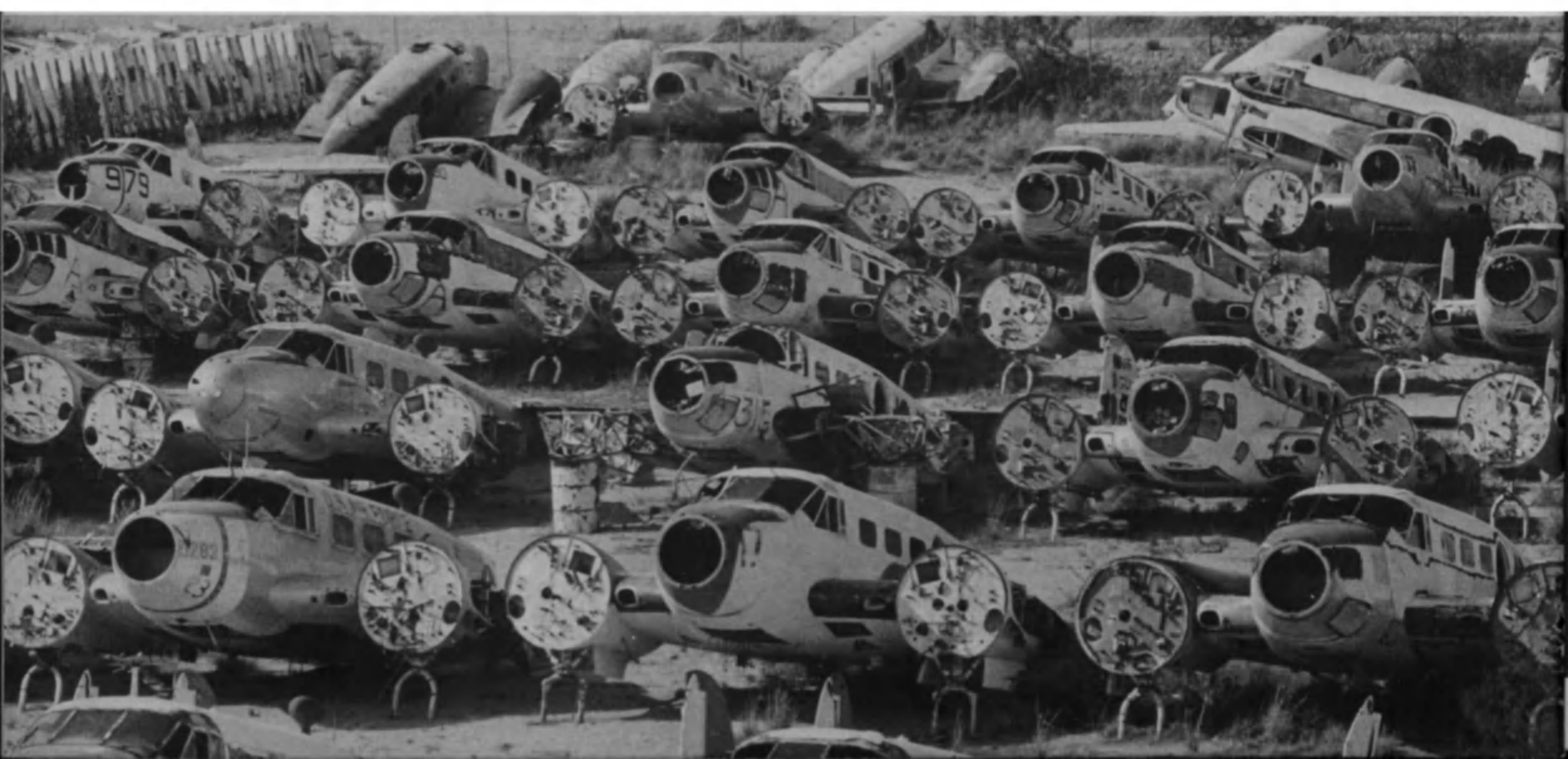
The facts as we have them show clearly that life on earth is derived from what appears to be an all-pervasive galaxy-wide living system. Terrestrial life had its origins in the gas and dust clouds of space, which later became incorporated in and amplified within comets. Life was derived from and continues to be driven by sources outside the earth, in direct contradiction to the Darwinian theory.

Recent evidence points to life first appearing on the earth about 3.8 billion years ago. This life was in the form of micro-organisms—bacteria and micro-fungi—now evident in the earth's oldest sediments.

It would seem significant that life appears in an instant, geologically speaking almost at the very first moment the earth possessed

NALIN CHANDRA WICKRAMASINGHE *is professor of applied mathematics and astronomy at University College, Cardiff, Wales, and Director of the Institute of Fundamental Studies, Sri Lanka. In 1962, while at Cambridge University, Professor Wickramasinghe, who is of Sri Lankan origin, was awarded the Powell Prize for English poetry. The views he expresses in this article are fully developed in two recent books,* Space Travellers: the bringers of life *and* Evolution from Space, *of which he is the co-author with Sir Fred Hoyle.*

"A tornado blowing through an aircraft scrap-heap has a better chance of assembling a brand new jumbo jet from bits of junk than life being assembled from its components by random processes."



a quiescent crust, an atmosphere and oceans, at the very first moment in fact that life was able to survive. Throughout subsequent epochs of geological time life developed and evolved both in complexity and sophistication. It is believed by neo-Darwinists that the full spectrum of life as we see it today as well as in the past is accounted for by the steady accumulation of copying errors and the consequent development of variety as a primitive living system is copied billions upon billions of times. It is stated according to the theory that the accumulation of copying errors, sorted out by the processes of natural selection, the survival of the fittest, could account both for the rich diversity of life and for the steady upward progression from bacterium to man.

Spiral nebula in the Ursa Major constellation.

Photo Courtesy of Mount Wilson and Mount Palomar Observatories, Pasadena, California

In our recent book Sir Fred Hoyle and I have argued strongly against this proposition. We agree that successive copying would accumulate errors, but such errors on the average would lead to a steady degradation of information. It is ridiculous to suppose that the information provided by one single primitive bacterium can be upgraded by copying to produce a man, and all other living things that inhabit our planet. This conventional wisdom, as it is called, is similar to the proposition that the first page of Genesis copied billions upon billions of times would eventually accumulate enough copying errors and hence enough variety to produce not merely the entire Bible but all the holdings of all the major libraries of the world. The two statements are equally ridiculous. The processes of mutations and natural selection can only produce very minor effects in life as a kind of fine tuning of the whole evolutionary process. There is above all an absolute need for a continual addition of information for life, an addition that extends in time throughout the entire period of the geological record.

Photo © Sygma, Paris

Frequent and massive gaps in the fossil record and the absence of transitional forms at the most crucial stages in the development of life show clearly that Darwinism is woefully inadequate to explain the facts. What the fossil record does show beyond doubt is that new properties of life at the level of expressed genes have been introduced by successive, natural experiments. Only when these experiments were successful did the changes endure. Lines with unsuccessful or inoperable gene addition simply died away.

Gene additions could take place by the interaction between space-borne viruses and viroids and the spectrum of life as it exists on the earth at any give time. When the structure of viruses was first discovered, it was argued by some scientists that these particles were the long-sought-for missing link in the Darwinian picture between non-living matter and life. Yet it was soon realised that the proteins of viruses were far too complicated for this to be true. In fact the structures of various viral proteins bore so close a relationship to those in higher life that it was thought at one time that these particles might in some way be derived from higher life. In our book *Diseases from Space* Sir Fred Hoyle and I argued that our genomes are chock-a-block with viruses and viroids. Viral invasions could lead to epidemic diseases as for example in the case of influenza. Patterns of influenza outbreaks clearly proved a direct space incidence for the causative pathogens.

In our view every crucial new inheritable property that appears in the course of the evolution of species must have an external cosmic origin. Although ape and man admittedly have much in common, biochemically, anatomically and physiologically, they are at the same time a world apart. We cannot accept that the genes for producing great works of art or literature or music, or for developing skills in higher mathematics emerged from chance mutations of monkey genes long ahead of their having any conceivable relevance for survival in a Darwinian sense. Just as for the case of the most primitive life on our planet, all these properties had to be implanted from outside. If the earth were sealed off from all sources of external genes, bugs could replicate till doomsday, but they would still only be bugs; and monkey colonies would also reproduce but only to produce more monkeys. The earth would be a dull place indeed.

Yet perhaps the most significant single difficulty associated with the neo-Darwinist view of life is that micro-organisms are far too complicated. When bacteria were created, or accomplished, or formed as the case may be, it is true to say that 99.99 per cent of the biochemistry of higher life was already discovered. Some 2,000 or so enzymes are known to be crucial over a fairly wide spectrum of life ranging from simple micro-organisms all the way up to Man. The variation of amino acid sequences in these enzymes are, on the whole, rather minor. In each enzyme a number of key positions are occupied by almost invariant amino acids.

Let us consider how these enzymes sequences could have been derived from a primordial soup containing equal proportions of the twenty biologically important amino acids. At a conservative estimate say ▶

fifteen sites per enzyme must be fixed to be filled by particular amino acids for proper biological function. The number of trial assemblies needed to find this set is easily calculated to be about $10^{40,000}$—a truly enormous, super astronomical number. And the probability of discovering this set by random shuffling is one in $10^{40,000}$. This latter number could be taken as a measure of the information content of life as reflected in the enzymes alone. The number of shufflings needed to find life exceeds by many many powers of 10 the number of all the atoms in the entire observable universe. A tornado blowing through an aircraft scrap heap has a better chance of assembling a brand new jumbo jet from bits of junk than life being assembled from its components by random processes.

Life, in my view could not be an accident, not just on the earth alone, but anywhere, anywhere at all in the universe. The facts as we now see them point to one of two distinct conclusions: an act of deliberate creation, or an indelible permanence of the patterns of life in a universe that is eternal and boundless. For those who accept modern cosmological views as gospel truth the latter alternative might be thought unlikely, and so one might be driven inescapably to accept life as being an act of deliberate creation. Creation would then be brought into the realm of empirical science.

The notion of a creator placed outside the universe poses logical difficulties, and is not one to which I can easily subscribe. My own philosophical preference is for an essentially eternal, boundless universe, wherein a creator of life, an intelligence considerably higher than ours, somehow emerged in a natural way. My colleague Sir Fred Hoyle has also expressed a similar preference. In the present state of our knowledge about life and about the universe, an emphatic denial of some form of creation as an explanation for the origin of life implies a blindness to fact and an arrogance that cannot be condoned. Just as the earth was proved not to be the physical centre of the universe, it seems to me equally obvious that the highest intelligence in the world cannot be centred on the earth.

■ **Chandra Wickramasinghe**

Photo © IPS, Paris

Earthrise on the moon.

"Just as the Earth was proved not to be the physical centre of the Universe, it seems to me equally obvious that the highest intelligence in the world cannot be centred on the Earth."

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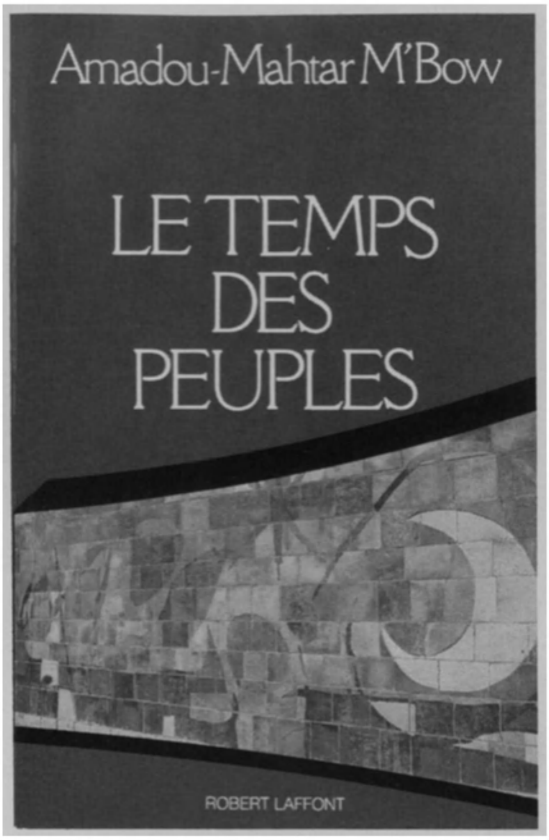

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