General Article

DARWIN'S THEORY OF EVOLUTION
BACKGROUND ACHIEVEMENT AND CONSEQUENCES

[Part I] Background

Ashoke Mukhopadhyay *

He had travelled most of the major coastlines of the globe. For five years at a stretch. He had surveyed the flora and fauna of the islands, coastal waterfronts, and the nearby peninsula. He had also studied the marine reefs, landmass, rocks, soil and climatic characteristics. He had collected crates of specimens from the entire area under survey. And in the process there were two metamorphoses in his life – one academic and the other ideological. He had started the journey across the Atlantic in 1831 with a view to making a secure career in geology; but when he came back to the shores of England in 1836 he had already embarked on the path to become a biologist – and a foremost biologist of the nineteenth century. Second, he had boarded the ship HMS Beagle as a devout Christian; and five years later, when he set foot on the banks of the Thames, he had turned into an agnostic.

Yes, you have rightly guessed that we are talking of Charles Robert Darwin. Since last year we are observing his 125th death anniversary. And in the next year, in 2009, we shall celebrate the bicentenary of his birth and the 150th anniversary of publication of his epoch making magnum opus – *On the Origin of Species by means of natural selection* (in the subsequent editions, the preposition *On* was dropped and the book became known as *The Origin* etc.).[1]

* Mr. Mukhopadhyay is a science writer and a member of the Advisory Board, Breakthrough Science Society.

Darwin's is one of those rare examples of scientific theories which received immediate public attention, which became a subject of frequent discussions and debates not only by specialists but also and perhaps more by the lay public, and which had its impact felt in a much larger territory beyond biology. His book was translated in many languages and read by an ever wider public. And thus, lastly, his theory had its appeal conveyed to the whole world in a very short time. For example, Bankim Chandra Chattopadhyay in his Bengali magazine *Bangadarshan* had published an article[2] on Darwin's theory just in 1875.

Why? What was its specialty?

The Changing Outlook

To understand that we have to sift the pages of history through the preceding three centuries since Copernicus. From our day-to-day experience, our simple observations and common sense it is not easy to see the changing scenario of the natural world. Since the very olden times man had been thinking all over the globe that everything around him is unchangeable. There are cyclical changes, periodically repeated. But the earth, the other planets, the stars twinkling in the vast expanse of the sky, the seasons, have remained and will continue to remain the same forever. The mountains and plateaus do not move; the oceans, the rivers, the lakes do not change. Plants and animals have, similarly, been what

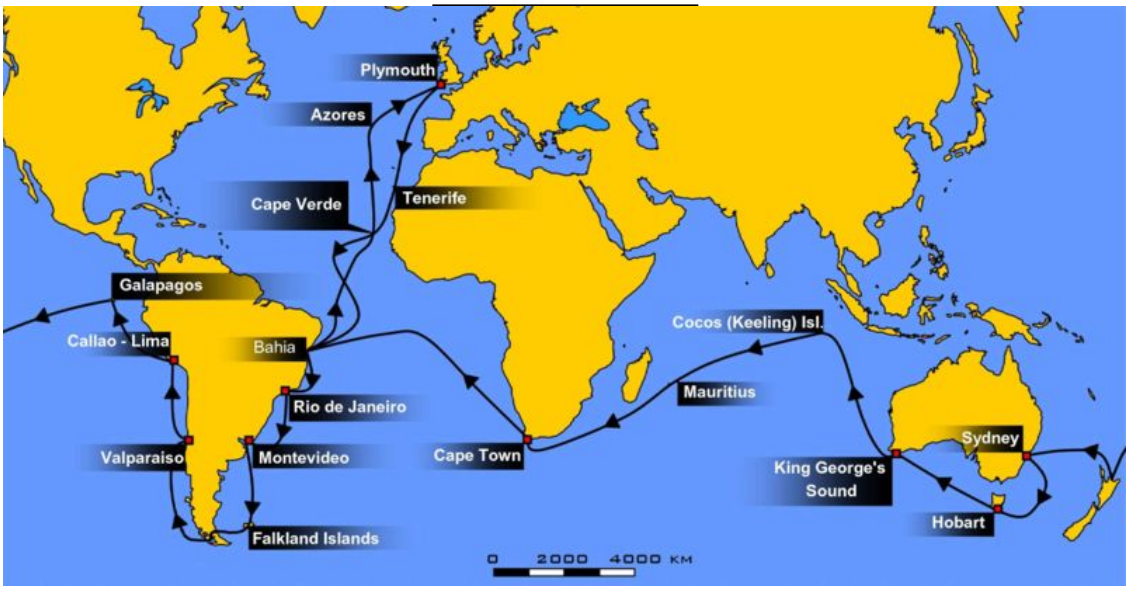

Figure 1 Route of the ship HMS Beagle, 1831-1836

they are for all times; they have reproduced their kinds without fail. Nobody saw a dog give birth to a cat; nobody saw banana born in a mango tree. These naked eye observations led man to believe that God had created all the inanimate as well as living things as they are, and since then they have not changed. Even though there were people in ancient Greece who doubted this line of thought, this was the mainstream belief. Later, with the advent of Christianity in Europe, the religious scriptures documented this as a fact of divine creation, and also a proof of that. The basis tenet of Christian Church was a belief in omnipotent God who created everything in this world--the living and nonliving entities. The Church considered that once these are created by God, they do not change and remain the same for eternity. This philosophical premise of the Christian Church was in consonance with the Aristotelian logic on thinking where the emphasis was on things as they are, and not on their change or transformation. Hence the Church upheld Aristotle as the authority in the interpretation of nature. The authority of Aristotle, with the Church sanction, lent it an unshakeable position in the academies. Thus it became a part of religious dogma, and nobody questioned it all through the Middle Age. Today we describe this as the error of empiricism in philosophy. Modern science, which in its initial years developed by fighting against the scholasticism of the Church-sponsored wisdom with the weapon of empiricism upheld by Bacon, soon found a disguised adversary in this very empirical approach.

For example, why were men before Copernicus wrong? They really saw the sun daily move round the earth. Every body including Copernicus saw this. They saw the stars move round the earth in a year. But what Copernicus saw and the rest of the people then did not was a lot more things. Why did not the planets undergo any regular annual rotation? Why do they change places in the sky from year to year in an apparently haphazard manner? Ptolemy had tried to fit these empirical observations into the same overall picture with the Earth at the centre, by introducing the idea that the planets revolve not only in circles, but in small circles over big circles (called epicycles). But the picture did not fit with

observations very well. Copernicus looked at the problem from a completely different angle. If one supposed the planets (including Earth) to orbit round the sun at different distances, the difficulties disappeared. Thus he brought forth a new idea basic to the growth of scientific knowledge, namely, that science is neither a body of observed facts nor based on common sense; observations read with a web of logical analysis capable of explaining ever newer facts make true knowledge possible. And once this error of empiricism was dispelled, the way was steered clear for the rapid advance in astronomy and physics.

Galileo similarly dispensed with a platter of common sense logic and empirical ideas prevailing from the time of Aristotle in the field of physics, in relation to force and motion, falling bodies, etc. and thereby gave birth to modern physics. Newton's laws of motion and the law of universal gravitation were also great triumphs over the empirical thinking.

But in the case of biology the change in outlook did not come so easily. The idea of divine creation of all living beings by the Providence as described in the Bible was still a strong deterrent to look beyond. It also fitted very nicely with the observed fixity of inanimate things and living beings. However, in ancient Greece, people like Anaximander in the sixth century B.C. or Empedocles in the fifth century B.C. speculated change of one organism to another.[3,4] Even in the Middle Age, some of the clergy argued for creation of new organisms, though upholding it in support of the biblical thoughts and accepting the existence and the hand of God in it. Of course these were simply stray speculations. Then, since the fourteenth century onwards the traders of Europe who went out to explore new trade routes, new sources of raw materials, new mines of coal, gold and diamond within and beyond the continental contours, the adventurers who went to conquer and plunder new resources, and the Christian missionaries who accompanied them to recruit and redeem new sinners from these lands, soon began to find out new peoples, new animals, new plants, new languages, new cultures, etc., nowhere described in the sacred books. Then in course of excavation for mining here and there they came across fossils of plants and animals now not seen anywhere on the earth. The Bible as a source book of information seemed to them to be very selective in terms of space and time. Had these plants and animals peopled the earth in some time past and later gone out of existence, the history of the planet was surely much longer than presumed in the creation stories of the Bible. Belief in the authenticity of the Church dogma, already shaken by Copernicus and Galileo, began to teeter more and more.

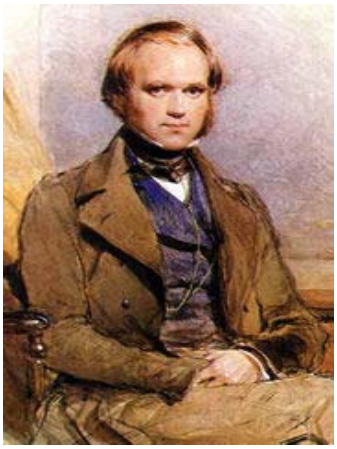

Figure 2 Charles Darwin after returning from the Beagle voyage

From the mid-eighteenth century, there took place a series of advances in various fields of science, which increasingly broke the trammels of empirical thinking on the one hand and pushed the time element longer and longer back. They gradually shook this metaphysical mode of thinking, as termed by Hegel, and brought forth a changing view of nature.

It was a major breakthrough when the German philosopher Immanuel Kant published anonymously a treatise on astronomy, where he applied the Newtonian theory of gravitation to show an evolutionary development of the solar system from an unorganized nebula filled with cosmic dust and cooled gas particles.[6] Later, in 1796 the famous French philosopher, mathematician and scientist, P. S. M. de Laplace elaborated this theory with some technical mathematical sophistication.[7] This encouraged a Scottish geologist James Hutton to probe into the history of the earth. In his research he found that the earth had a much longer history than admitted by the Biblical theory of creation. He read a paper at the Royal Society of Edinburgh in 1785 and solemnly declared: "We find no vestige of a beginning, no prospect of an end."[8] Following the same trail, Charles Lyell, a contemporary geologist of Darwin's time, although senior to him, published his three volumes of *Principles of Geology* in the 1830s, in which he tried to explain on-going changes in the mountains, rivers, seas and lakes on the earth in terms of known physical and chemical processes.[9] Darwin boarded the vessel Beagle with a copy of the first volume of this book and gathered the other volumes by sea mail on tour.

In the field of biology too the idea of fixity of species began to yield place to that of mutability of plant and animal forms. Cultivation of rational outlook in the wake of the impending storms of Revolution made France the more easily abandon the Biblical static view of biological beings. For example, the French mathematician and the then President of the Berlin Academy of Sciences, Pierre Maupertuis, in 1745 and 1751 and the celebrated encyclopaedist philosopher of France, Denis Diderot in 1749 and 1754, were able for the first time to propose the possibility of mutation of species.[10] Then during the entire second half of the century Georges Buffon went on publishing successive volumes of his grand work on Natural History, in which he suggested several catastrophic salvoes of creation and destruction to account for the extinct species belonging to different times.[11] From Germany, Alexander Humboldt, while quite young, had travelled extensively in the two Americas in later part of the eighteenth century and collected an immense volume of scientific information related to botany, geology and meteorology. He gathered elaborate but accurate information on a large number of new plant species and genus. Publication of his detailed narratives of these data from France enriched biological knowledge for the coming generations.[12] In England Erasmus Darwin, grandfather of Charles and a physician by profession, added a two-volume treatise to the growing literature on modification of species.[13] He is also credited with coining the term organic evolution in the field of biological science. Almost by the same time, Georges Cuvier of France wrote on his discovery and study of ancient quadruped fossils in good number, particularly of ice age fossils of large animals resembling elephants, which made birth of new species and extinction of old ones easily traceable.[14] Then came the famous Lamarck, who not only spoke of evolution of organic life forms, but also tried to put forward a general theory of how the species got gradually modified bringing in new ones.[15] His first major work came out in the same year that Darwin was born.

It may be noted here that Buffon and Cuvier, in face of strong public reaction, supported divine creationism in the form of multiple special creations instead of single act of Biblical genesis. According to them, in periodic catastrophes in the body of the earth, a given club of plants and animals had been destroyed and others arisen in their places. But Lamarck was the first to bring out a coherent theory to account for the gradual change of species in a completely naturalistic way, without

invoking any divine hand or fortuitous disaster. He said: "Life is nothing more than a mere physical phenomenon. All appearances of life can be traced back to mechanical – physico-chemical – causes which lay in the very structure of organic matter. The simplest forms of animal and plant, which represent the lowest stage of the process of the evolution of life, have grown and are still growing out of the root cause. The old philosophers thought of life-force – of a soul – of the animal. They ascribed souls even to plants. Instead of positive knowledge they operated only with words, and set up an unfounded and unclear notion. But as soon as we leave nature and deliver ourselves to the fantastic fabrications of the power of imagination, we loose ourselves in confusion and blunder. The only knowledge that we can have is, and always will be, that which is derived from our positive study of the laws of nature."[15]

In his theory Lamarck addressed all the three issues of evolution: fact, course and mechanism. As to *fact*, Lamarck argued that species change through time. As regards *course*, he proposed progressive change along an ascending ladder from the lowest and simplest on the one end to the most complex and "perfect" (meaning humans) on the other. Regarding *mechanism*, he proposed that "need" itself produced structural changes inherited by subsequent generations. As environment changed, a need arose, metabolism got adjusted and existing organs changed or new organs were created. So there were changes, and modifications. It means, as organisms become adapted to their environment through their habits, *modifications* occur. *Use* of an organ *reinforces* it; *disuse* leads to *obliteration*. Once acquired, these new characters are passed on to offspring. This, in summary, was Lamarck's view.

Lamarck's was truly the first broad theory of evolution, which refuted metaphysical theories of 'creation by God', 'permanence of species' or the 'catastrophe theory' of Cuvier. As a naturalist, he was materialist too. However, Lamarck held that living organisms represent a linear progression, with humans as the highest form. Besides, he had the idea that the development of organisms was guided by an 'inner desire' or 'innate purpose'. This reflects the limitation of materialist thinking of his time to cope with the multifaceted problems of evolution.

Darwin, in a short historical sketch in the third edition of his *The Origin*, wrote that Lamarck upheld "the doctrine that all species, including man, are descended from other species. He first did the eminent service of arousing attention to the probability of all change in the organic as well as inorganic world being the result of law, and not of miraculous interposition."[16] In the same sketch he also mentioned many other contemporary thinkers propounding transmutation of species, including one Mr. Mathew who had in fact intuitively reached the general principle of natural selection as early as in 1831 without, however, grasping its full significance for the long-term process of organic evolution.

In a nutshell the intellectual climate of Europe had then been prepared for endorsing and embracing a naturalistic theory of organic evolution through time. And when you start looking for the things and processes of the past on the basis of the present-day available facts, you cannot but pass beyond narrow empiricism and enter the wider, inductive pathway to knowledge. It was in such a milieu that Darwin entered the scene.

Refutation of the argument of design

However, the Christian Church had devised a new safeguard against the mounting invasion of science into the provinces of religion, which was called Natural Theology. It was already invented by the great scholar of the late Middle Age, Thomas Aquinas, as a means to eulogize

the beauty of providential creation. He adduced to five reasons which required the existence of God as a necessary postulate, namely, [a] a Prime Mover to explain the origin of motion in the world, [b] the First or Efficient Cause to account for the existence of things in the universe, [c] the Necessary Being to support the contingent beings of the mundane world, [d] the embodiment of Supreme Perfection among the imperfect things, and [e] the Supreme Intelligence to maintain the order in the world.

Then, in the post Renaissance period, after Copernicus, Galileo, Kepler and Newton, when it became clear to the Church that Biblical and theological wisdom could no longer hold good in face of the contrary evidences supplied by the growing scientific knowledge, Christendom took recourse to a new path and elaborated its explanations of natural phenomena on the basis of the fifth postulate of Aquinas. It was termed as the *argument of intelligent design*.

For example, John Ray, a renowned biologist and a clergyman of the seventeenth century England, in his famous work *The Wisdom of God Manifested in the Works of the Creation* (1691) stressed the adaptation of structures to functions throughout the universe among living as well as non-living forms of matter as being designed by a super-intelligent power. Newton, his contemporary, also cited, in his last major work, *Optik* (1728), the fact that all the planets of the solar system and their satellites spin and rotate in the same direction and almost in the same plane as a convincing demonstration of the handiwork of a superbly clever being. He felt, "it's unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of a Chaos by the mere laws of Nature".[17]

A theologian immediately preceding Darwin, William Paley popularized the argument of design in his two well known works,[18] which ran as follows: When you see a block of stone on your path, you may consider it resting there since eternity by some natural process. But if you happen to come across a piece of clock there, you get interested. For then you know, it cannot be lying there since an indefinite time. It has been made by somebody and left there inadvertently. It is a designed piece of matter; so there is surely a designer who designed and made it.

Similarly, argued Paley, everything in

Darwin had thought of 'natural selection' earlier than Wallace did; it is mentioned in his 1838 notebooks. He even drafted a manuscript in 1844 laying out his ideas at length. But Wallace was the first scientist to make the idea of natural selection, public; he wrote a letter to Darwin from Malaysia, spelling out his ideas. In a different view, it is said that Darwin received a paper from Wallace for review with principles of evolution laid out in it. From it Darwin came to know of Wallace's views. Only after receiving this paper, Darwin rose to action. The then scientific world had such an ambiance in which Darwin proposed and published a joint paper in 1858 (perhaps at insistence of Lyell) in the Journal of the Linnean Society, presented July 1, 1858. Next year, Darwin published his abstracted book "On the Origin of Species by Means of Natural Selection". In the present-day cut-throat rat race among scientists, the Wallace-Darwin episode in which Wallace could claim the legitimate priority, would have given rise to brandishing of 'tooth and claw'. But Wallace gladly accepted the priority of Darwin's discovery and sent all his collection to the latter's disposal to give the theory a more exhaustive character. While mentioning Wallace, it should be noted that there are several instances in history, where two or more scientists are found to have simultaneously reached the basically same thought, nonetheless working independently. Obviously they shared and stood upon the same historical background of thinking, and they thought in the same way, thus having the same process of thinking, guided by the same historical position. – A. Roy

the world seems to be designed with a definite structure to serve a specific purpose. Inanimate nature provides living beings with what they require for the sustenance of life. Fishes swim in water; so they have fins suitable for that purpose. Birds fly in the air; they are, therefore, given wings and feathers. The quadruped live on land; they got strong legs for walking and running. Among the bodily organs, Paley chose the eye to highlight his case. The eye-lens of the fish is spherical because that suits well with the refractive index of the tissue relative to water; while that of the land animals is nearly flat for it fits perfectly with the refractive index of the tissue relative to air. The human eye is a superbly designed and very elaborately complex organ. "The marks of design are too strong to be gotten over. Design must have had a designer. That designer must have been a person. That person is God." This syllogism of Paley's left a profound impression on the young mind of pre-Beagle Darwin, who found in it the beautiful logical spirit of Euclid.

However, in course of his worldwide marine journey, Darwin gradually found facts that went blatantly against the design argument. For our convenience we can arrange them in the following four broad groups:

[a] Fossil records show that compared to the number of types that have existed so far on the earth, that of those which perished for ever was far greater; according to the design argument, therefore, the designs of those creatures which permanently perished were defective. This further implied that the Omnipotent Providence was a designer who created much more defective than faultless beings. One could hardly speak highly of such a designer. For example, if a clock maker makes watches of which, say, eighty per cent are faulty, will anybody consider him a good clock designer? Will people feel confident to purchase clocks from him? Similarly, there can be no intelligent designer behind the making of this vastly wasteful living world.

[b] There are regions on the earth surface, which are more or less similar in terms of various geo-climatic parameters, like, soil, rainfall, aridity/ humidity, temperature fluctuations, range of atmospheric pressure, wind, seasonal cycle, and so on. In order that the design argument be valid, the flora and fauna of these regions should have been same. But this was far from the reality. The tigers of Africa, Asia and South America are not same; nor are the monkeys of the Old and the New Worlds. Take any wild plants of these regions; you will see them to be different from one another. In the Galapagos Islands, Darwin found fourteen different types of turtles in the fourteen islands, which were situated side by side and had almost identical natural conditions. Moreover, he learnt that for a given catch the local residents could identify the islands for each of the turtles. This kind of variety smacked of random production rather than preconceived design. Darwin realized that the living beings were not created as fitting the natural conditions; they were created at random; some of them fitted with the given conditions and survived; others were mismatch and therefore unable to live longer. We see only the end result, those living creatures which fitted and therefore survived, and then in reverse of the fact: beings are so created that they may fit with the given conditions.

[c] Darwin also found that in certain conditions a good design proved disadvantageous, whereas defective designs were helpful for survival. For example, well-formed wings, which were advantageous for the birds and insects in general, proved fatal for the insects and birds in the coastal forests. For them ill-organized wings provided a survival advantage. Otherwise, with well-formed wings, they would be carried by wind into the sea and be deprived of foods and

shelters. If, however, they could not fly well and higher, they would be able to remain inland, gather foods and make shelters. Thus they would survive and proliferate.

[d] Another problem haunted Darwin in virtue of his own ailments while he was travelling. What intelligent purposes does God serve by creating the malaria and philaria producing mosquitoes for man? What are the worms inhabiting the intestines of the mammals created for? It appeared to him unbelievable – he wrote to Asa Gray in a letter on 22 May 1860 -- that a Supreme Intelligence could really design the cat to playfully prey the rat in a tortuous kill-game.

All these and many other similar facts, which Darwin later elaborated in his book, convinced him beyond doubt that the theory of natural theology with its design argument and divine creation in respect of the plants and animals was simply untenable. Biological diversity was a running product of the natural process of organic evolution, which proceeded with its own objective laws. The tasks of the biologists were to study and discover those laws.

To be fair to both Darwin and history, he made the point more than he actually said it. Evolutionists and rationalists of his time got hold of the point with all the more enthusiasm to clinch the issue of religious outlook in the field of education and cultivation of knowledge. The dominant spirit of the time may be gleaned in the story Robert Ingersoll, a contemporary prominent intellectual of the USA, narrated in one of his polemical essay, which ran thus:

A Father of the local parish church was out in the meadows for a morning walk with his son. While passing by a lake, he saw a crane wait on the brink of the waterfront and pick up, from time to time, a fish or toad from the muddy water. The priest in his good faith told the boy, "Look, look, my sonny, there you behold the grace of the All Thinking Almighty! How beautifully He has designed the beak of the crane to collect its food and survive!" The boy slowly turned his face from the crane to his father and asked with an astonished tone, "He thought only of the crane, didn't he, dad? Probably He does not know anything about the fish or toad in the lake!"[19]

The underlying moral is quite simple. You cannot make your God omniscient and perfectly just as well as an intelligent designer at the same time.

Acquiring the New Attitude

Thus Darwin first properly acquired the aspects of the new scientific approach to explain natural phenomena in terms of simpler known facts with the help of some simple conceptual tools; and in the process he further developed the contours of scientific attitude raising its analytical tools to a new height.

One important aspect of his newly acquired attitude was to refuse to accept something as truth only because it appeared to him to be true. First ideas are raw ideas; often based on incomplete and insufficient data as well as subjective fancy; but even then usually very tempting. No, he rather preferred to examine and reexamine his own database and the haunting ideas; explore all the possible alternative explanations; and only when it was evident that the other theories failed to explain the given volume of data and his was the only one to accommodate the large classes of phenomena in their entirety, he dared to conclude that it might be the most plausible one. And still he kept open the possibility that he might be proved wrong. This reflected a firm determination to guard against any kind of subjective bias. Right at the threshold of giving birth to an epoch making theory, reinforced with the enthusiastic support from a number of contemporary qualified specialists of the related fields, it was quite a formidable task for a man to shy away from the easy

way to fame.

He had to tackle another problem. Till then most of the naturalists, who had cared to subscribe to evolutionary ideas, confined their observations mainly to animals. Animals are easy to observe and study. Empiricism lures therefore to animals. It was only the Swedish naturalist Carl von Linnaeus, who in his later life wrote a compendium *Species Plantarum* (1653) on the plants and described nearly six thousands of species then known to man. Even the great Lamarck had concentrated on the animals. But Darwin understood that in order to build a satisfactory and comprehensive evolutionary theory, one must embrace the plant world with just as much thoroughness. So also he took time.

In fact, he had already arrived at his theory of natural selection by 1840, but suspended the publication of the results of his study for nearly twenty years. It was only when by some turn of events did he come to know that another naturalist, Alfred Russell Wallace, in course of his travels in the Malay Archipelago in 1848-50, had come to a similar viewpoint on the history of the living world, that he agreed – that too at the insistence of his close friends – to publish the research results in the form of a grand theory in 1859. Otherwise he might have waited still ten or fifteen years longer (see the box). This is the history behind the publication of a work that made him immortal in the annals of science. Not for personal name and fame, nor to earn a lot of money, but to discover, defend and disseminate truth – such was the motto of all his scientific works.

Similar was his attitude toward the evolution of man, on which he said nothing in the first work. In the last chapter of his *The Origin* there was a mere hint, "Light will be thrown on the origin of man and his history"[20] in some distant future. He could not handle the question of evolution of man on the basis of his study of plants and other animals. He had till then very few facts related to man's past history to work with. *The Origin* came out in 1859 and the first fossil of man was discovered only in 1856 in the Neander valley in Germany, the significance of which took another fifty years to fully understand. In this situation, to say anything elaborate on man would be sheer speculation, which he was wont to indulge in. So he waited; gathered facts about the morphology and ethology of the higher primates; studied comparative anatomy; compared embryological development of the great apes with that of man; analyzed cultural evolution of man as much as known till then. In this way, labouring for the next twelve years, side by side working on the succeeding editions of *The Origin*, when he felt confident to pronounce his opinion, he published *The Descent of Man* in 1871.

This ardour for strenuous and rigorous study, this strict adherence to objective analysis of facts in detail, this devotion to truth and reticence to publicity – these are some of the qualities we may still safely inherit from Darwin. But there was another aspect of his character, a rare quality, which is also rarely known. Most of the people, as much then as now, have the usual tendency to take note of only the favourable arguments and disregard the unsavoury. But he attached great importance to any contrary facts and objections that seemed to be, at the time, veritable confutations of his theory; mentioned them in his book in full; and expressed his inability to answer them with complete satisfaction. He did not try to ignore or bypass them. In his Autobiography he wrote: "I had … followed a golden rule, namely that, whenever a published fact, a new observation or thought came across me, which was opposed to my general results, to make a memorandum of it without fail and at once; for I had found by experience that such facts and thoughts were far more apt to escape from memory than favourable ones. Owing to this habit, very few

objections were raised against my views which I had not at least noticed and attempted to answer."[21] Thus he himself laid his theory open to rejection should those objections prove unassailable in future (we shall have occasion to dwell on some of them in the succeeding part). "How great is the stature of the thoroughly modest Darwin, who not only collects, arranges and elaborates thousands of facts from the whole of biology but takes delight in quoting any predecessor, however insigni-ficant, even to the diminution of his own glory" wrote Freidrich Engels[23]. This is a great moral lesson to the practitioners of science in all ages.

[*To be concluded*]

References

1. Charles R. Darwin – [On] The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life; John Murray, London; 1859
2. Bankim Chandra Chattopadhyay – "Mill Darwin and Hinduism" (in Bengali); Bangadarshan, April 1875; also see Works of Bankim Chandra (in Bengali), vol.I; Saksharata Prakashan, Kolkata; 1973, pp. 352-53
3. Samarendranath Sen – Bigyaner Itihas (in Bengali);Shaibya Prakashan Bivag, Kolkata, Reprint 1996, 782p.
4. Cesare Emiliani – Planet Earth ; Cambridge University Press , Cambridge, 1992, p718.
5. S. C. Stearns and R. F. Hoekstra – Evolution: an introduction; Oxford University Press, 2001, p381.
6. Immanuel Kant – General History of Nature and Theory of the Heavens, or A Tentative Description of the Structure and Mechanical Origin of the Universe according to Newtonian Principles (in German); Leipzig, 1755
7. P. S. M. de Laplace – An Exposition of the System of the World (in French), vols. I-II; Paris, 1796
8. James Hutton – Theory of the Earth, with Proofs and Illustrations, vols. I-II; Creech, Edinburgh; 1795, vol. I, p. 200
9. Charles Lyell – Principles of Geology. Being an Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation, vols. I-III; John Murray, London; 1830-33
10. See: Arthur O. Lovejoy – The Great Chain of Being; Harper and Bros., New York; 1936, p. 268
11. Georges Louis Leclerc de Buffon – Natural History, General and Particular, vols. I-XLIV (in French); Paris, 1749-89
12. Friedrich Heinrich Alexander Baron von Humboldt – Personal Narrative of Travels to the Equinoctial Regions of the New Continent, during 1799-1804, vols. I-XXX (in French); Paris, 1807-25; *Another important publication:* – New Genus and Species of Plants, vols. I-VII (in French); Paris, 1815-25, which described about 4500 new plants of the Latin America
13. Erasmus Darwin – Zoonomia, or the Laws of Organic Life, vols. I-II; London, 1794-97
14. Georges Cuvier – Researches on the Fossil Remains of the Quadruped (in French); Paris, 1812
15. Jean Baptiste de Lamarck – Zoological Philosophy, or an Exposition of the Relative Considerations on the Natural History of Animals, vols. I-II (in French); Paris, 1809; also see: – Natural History of Animals without Backbone (in French); Paris, 1815
16. Lamarck – Zoological Philosophy, ...; *cited by* M. N. Roy – Science and Philosophy; Renaissance Publishers, Kolkata; 1947, p. 132-33
17. Charles Darwin – On the Origin of Species by means of natural selection (reprint of 3 rd edition); Collins' Clear Type Press, London; 1922, p. 9 (All citations from this work refer to this edition)
18. Isaac Newton – Optiks; London, 1730; p. 376; *cited by* John C. Greene – Dawin and the Modern World View; The New American Library of World Literature, New York; 1963, p. 40
19. William Paley – (a) A View of the Evidences of Christianity, vols. I-II; London, 1794; (b) Natural Theology, or, Evidences of the Existence and Attributes of the Deity, Collected from the Appearances of Nature; London, 1802
20. Robert Ingersoll – Lectures and Essays, (A Selection); Watts and Co., London; 1904, p. 31 (dialogues slightly modified)
21. Charles Darwin – On the Origin of Species ...; p. 506
22. Nora Barlow (ed.) – The Autobiography of Charles Darwin, 1809-1882; (With Original Omissions Restored. Edited with Appendix and Notes by his granddaughter). Collins, London; 1958, p. 94.
23. Collected Works of Marx and Engels, Vol. 25, Progress Publishers Moscow, 1987, p. 599.