Darwin and the Theory of Evolution

The Breakthrough Science Society is going to observe the three years from 2007 to 2009 as "Darwin Years". The year 2007 will mark the 125th year of his death and the year 2009 marks the 200th year of his birth as well as the 150th year of the publication of his seminal book "Origin of Species". Darwin's theory of evolution brought about a radical change in the outlook of the contemporary man. Its impact was felt not only in the fields of the biological sciences but also in all the fields of knowledge involving history. Even today his ideas and arguments appear as instruments of struggle in the scientific campaign against irrationalities of all sorts. So, during the next three years, we will study and cultivate the life and works of Darwin through various kinds of science programmes. On this occasion, we intend to publish a series of articles dealing with the theory of evolution as well as the evolution of plants and animals upto man in the form of translation from the second volume of the Bengali booklet "V*ivartan Yuge Yuge*" (Evolution through Ages) published by the BSS in 1999. In this issue the first two chapters are presented. – *Editorial Board, Breakthrough*

WHEN THE SOLAR SYSTEM was born about 4.6 billion years ago, the planet Earth was just a lifeless sphere. Today the same sphere is full of life: trees, grass, insects, birds, reptiles, fish, mammals, and the greatest product of the biological world: thinking man.

But how could such a metamorphosis take place? Till the 17th century, people thought that God has created man and the higher animals and birds; and lower organisms like insects, frogs and snakes are born spontaneously in clay and rotting biomass. Doubts about such belief appeared when people started finding skeletons, bones and other fossil remains of animals whom nobody has ever seen. Some people said that these were unsuccessful creations of God. When God did not like some of His own creations, He discarded them without putting life into them.

A group of inquisitive people was not happy with such answers, and tried to look deeper. The famous painter and engineer Leonardo da Vinci was among them. When he saw fossils of sea-dwelling organisms in the high mountains of Italy, he did not assume that God created and placed the fossils there. Instead, he described the observations in detail and wrote that those regions were under the sea at earlier epochs, and these animals lived in that sea. Their bodies got buried in the sediments, which, in course of time became compressed into rocks. When the sea moved away from that area, these rocks were exposed. Later, geological processes pushed them up to create mountains. Thus, according to him, the present unusual placement of the fossils is the result of a completely material process.

Some clues were provided by the findings in geology. As regards sedimentary rocks it is generally possible to say which rock layer was formed earlier and which one later, because they occur at different depths. It was found that different types of animal fossils occur in different layers. This implies that all the organisms on the Earth did not appear at the same time. Some appeared earlier and some later. Depending on the fossils' positions in the rock layers, it is possible to identify the order of appearance of the different extinct organisms. Moreover, dating of rocks may also suggest the probable time of their existence.

A deeper probe revealed that there is a general rule in the order of appearance. The organisms which appeared earlier

have simpler anatomical structure and physiological function. The organisms that appeared later have greater variety and complexity in their structure and function. This does not mean that fossils of simple organisms are not found in more recently formed rock layers. Indeed, simple organisms (like amoeba) are found in all layers as they are found even now. But it is true that fossils of organisms of complex anatomy are not found in older rock layers. Before a particular time in the Earth's history, one finds no fossil records of vertebrate animals. Mammals are not found before a specific but later time. Another point. What is said above about animals also apply on plants.

It thus became clear that certain groups of species appeared on the face of the Earth at a certain specific time. Most of the species existed on the Earth for a specific period, and became extinct. Once an organism became extinct, it never came back. The species that appeared at different points of time, but have not become extinct, are found on the Earth today. This idea was clearly put forward by the French naturalist George Buffon (1707-1788).

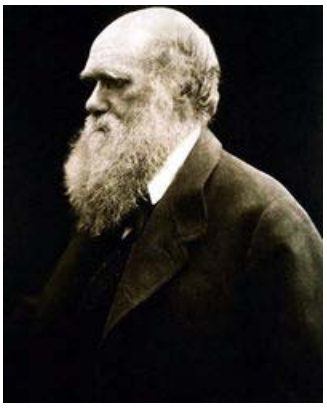
The focal problem was: How did the different species evolve? Probing this question, people realized that the changes actually occur in the *population* of each species – not at the level of the individual organisms. Some scientists looked for the cause-and-effect relations in an attempt to find the explanation. A French naturalist Jean Baptiste Lamarck (1744-1829) first tried to probe this question in the year 1801. According to Lamarck, the process of evolution is essentially the process of morphological change of the organs belonging to the members of a species, resulting in the transformation of a section of one species into another. Why do the organs evolve? Because of the influence of the environment on individual organisms. An organism may face a change in the environment to which it is adapted — which may happen on account of climatic change or migration to a different location.

Jean Baptiste Lamarck (1744-1829)

"Lamarck was the first man whose conclusions on the subject excited much attention. This justly celebrated naturalist first published his views in 1801. . . he first did the eminent service of arousing attention to the probability of all changes in the organic, as well as in the inorganic world, being the result of law, and not of miraculous interposition." – Darwin

A change in the environment causes changes in the needs of organisms living in that environment, which in turn causes changes in their behaviour. Altered behaviour leads to greater or lesser use of a given structure or organ; increasing use would cause the structure to increase in size over several generations, whereas gradual disuse would cause it to shrink or even disappear. This rule — that use or disuse causes structures to enlarge or shrink — Lamarck called the "First Law" in his book *Philosophie Zoologique*. Lamarck's "Second Law" stated that all such changes were heritable. The result of these laws was the continuous, gradual change of all organisms, as they became adapted to their environments.

This is known as Lamarck's use-disuse theory. Though it provided a reasonable explanation of the evolution of many organisms, it also left many questions unanswered. For example, one can talk about the use or disuse of an organ that is already present in a species. But how can we explain the creation of an entirely new organ? How could lungs come into being when marine animals first moved to the land? In philosophical terms, it explained only the quantitative changes, but failed to explain the qualitative changes.



Charles Darwin (1809-1882)

In this position, Charles Darwin (1809-1882) noticed some common features of the biological world. These facts are so common that those who were engaged in the observation and objective analysis of the biological world cannot but notice them. However, it was Darwin who first realized that they are invaluable clues in understanding the process of evolution.

First, even though the members of a species look similar, there are always some differences among them. We easily notice these differences between two humans, because our "human" eyes are trained that way. But even if we do not notice such differences in other species, two tigers or two mosquitoes are never exactly the same. Owing to an elementary similarity, we can identify them as members of the tiger or mosquito species, but two members of the same species are never exactly identical. This is called "variation".

Secondly, in all species, far larger number of individuals are born than can grow to maturity. Most die at a young age – either out of attacks by the enemy species, or because of their inability to gather enough food. Only a small fraction can reach maturity and can give birth to offsprings. It would be disastrous if all rats could live — in a few years they would increase in number from a hundred to a million. Even elephants — whose rate of birth is quite low — would increase in number from one pair to 1,90,000 in a matter of 750 years. This general observation applies to snakes, frogs, insects, fishes, and all other species.

But we see that in nature, the number of members of every species remains within a limit. It is because for every species, the foodstock is defined, and limited in a given time and space. There is a struggle going on among the members of a species over this limited food-source. This is called the "intra-species struggle".

On the other hand, for every species there are some "enemy" species. Tiger is the enemy of deer; snake is the enemy of frog. Seen from another angle, the deer species is also enemy of the tiger species, because if deer are able to avoid being eaten by tigers, the latter will die of hunger. Two plant-eating species are enemy of each other on the question of collecting food from the same environment. Every species has specific disease carrying germs as enemy. Every organism has to enter into struggle with the enemy species in order to remain alive. This is called the "inter-species struggle".

The same thing was observed by the botanists also. Trees, shrubs and plants in the same land are in constant struggle with each other for access to nutrients, water, air, and sunlight. All the pollens in the flowers cannot take part in

fertilization; all the seeds cannot germinate into saplings; and only a tiny minority of the saplings manage to get enough water, nutrients and sunlight to mature into trees. In course of this inter-species and intra-species struggle some succeed and some do not.

Owing to their existence in these two types of struggles, most of the members of any species are eliminated before reaching the age of reproduction. Because of the variation within a species, each member is different from all others in some respect. Some may have features that make them better suited to succeed in this struggle. This characteristics is called "adaptation." The organism that is better adapted to a given environment (both physical and biological), has a higher probability of surviving to maturity and producing offsprings. On the other hand, variation within a species render some organisms less suited for a given environment. They have a higher probability of dying young.

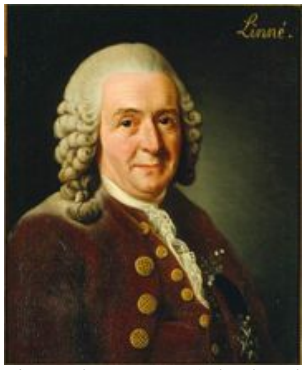
In the predator species, the organisms that are faster and stronger, have a better guarantee of food. The insects whose body shape and colour allow them to camouflage under leaves and tree-trunks, have a lesser probability of being seen by birds and being eaten. Different organisms are differently adapted to physical environments like temperature, humidity, rainfall, and soil composition. Within a species, all the organisms cannot be equally adapted to the environment, because of variation. Most die of attacks by enemy species like predators and germs, or because they cannot get enough food. Only a tiny minority of the members of a species can take part in the process of producing the next generation.

The traits in physical structure that allowed an organism to be better adapted to a given environment, will have a higher probability of being transmitted to the next generation. Thus, in the next generation, the number of individuals better adapted to the environment will increase. Such overall change of the composition of a species is generally not perceptible in a few generations. But if this process continues for a long time, in every species, some characteristic traits will be selected and will be found in larger proportion of the individuals. Some other physical characteristics will prove to be detrimental to an organism's adaptation to the environment. Such features will be found in lesser and lesser number of individuals, and will eventually be eliminated from the population. Darwin called this long-drawn process as "natural selection", which causes a gradual change in the overall characteristics of a species.

Moreover, the "environment" for any species is not something fixed. If antelopes become better adapted to their environment, lions can survive only by improving their predatory skills. If lions improve their technique of catching prey, antelopes cannot survive without improving their adaptation to the environment that includes lions. In addition, the physical environment also changes with time due to geological reasons.

Thus we see an overall process of evolution in the biological world. All the species are undergoing evolution at the same time, in different directions. The driving force behind this evolutionary mechanism is natural selection. This is the main content of Darwin's theory.

In the above discussion, the word "species" appeared many times, and it was tacitly assumed that the reader understands what it means. Indeed, the meaning of the term is intuitively clear in most cases, as the members of a species can be identified by their physical features. Nobody ever has a problem of seeing the bovine characteristics in a cow or the feline characteristics in a cat. In fact, Carolus Linnaeus (1707-1778) started the job of classifying organisms into separate species using such physical characteristics.



Carolus Linnaeus (1707-1778)

In the nineteenth century, many new regions of the globe were explored, and naturalists started visiting far-off places and deep forests, to collect samples of plants, birds, insects, and other animals. It was then found that serious difficulties appear in identifying the species to which the animals belong. In many cases, the physical features of two animals were palpably different, but it was not clear whether it was just variation within the same species or the two belonged to two different species. In some cases, different species were found to have very similar physical features.

So it became necessary to have a clearer definition of "species". It was found that the members of different species normally do not mate; if they do, no offspring is produced; and in the rare cases where offsprings are born, they are sterile. It is not possible to have reproduction between an elephant and a goat. Horses and donkeys can mate and produce mules. But mules are not capable of further reproduction. So efforts started to classify organisms on such definition of species. But there also problems cropped up. An example will illustrate this. In the Kolkata zoo, scientists have allowed reproduction of lions and tigers, and that has produced the hybrid animal, "Tigon". The tigon was then allowed to reproduce with a lion, and in the next generation that produced "Litigon". Thus the tigon was evidently not sterile. But the fact that lion and tiger are two separate species is clear to the naked eye!

Considering such cases, the modern definition of species is "a group of organisms that reproduce among themselves in the natural environment, and is sexually isolated from other such groups." This means that reproducibility by artificial means is not the issue. Reproducibility in natural environment is the main factor to be considered.

Darwin's main thesis was that a species develops variations. If organisms belonging to a species somehow become divided into two or more physically separated and reproductively isolated groups facing different environments, they tend to diverge into two species. As each adapts to its environment, natural selection may favour the organisms with certain characteristics. If natural selection allows the group to adapt successfully to its niche, it survives as a new species. If it does not, it becomes extinct. Thus two or more species can be created out of a common stock in the process of evolution.

They in turn cause the creation of newer species. This way the first life-form has, through the process of evolution spread over millions of years, given birth to the millions of species that we see on the Earth today.

Represented diagrammatically, it looks like a many-branched tree of Fig.1. The stem started in the primordial life-form, and branched over to form today's species. In some cases one can see unbroken lines starting from the first life upto one of the modern species. In most cases however, the branches end before reaching modern age — when a species became extinct. The dinosaurs are such a blind lane in the path of evolution. If a species, say x, bifurcates into two species x and y, we see a continuous line of x. If, then, y becomes extinct, the continuity of that branch is broken. The process of

evolution never again gives rise to *y* — since both *x* and the environment changes continuously. The existence of a species is therefore particular and irreversible.

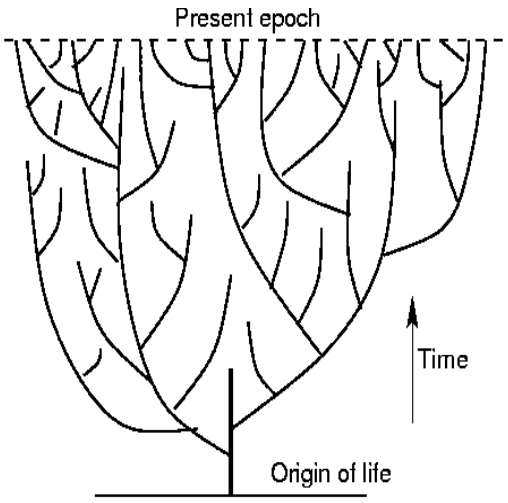


Fig.1: The evolutionary tree.

This evolutionary "tree" implies that there is a general law or direction in evolution. It has not proceeded haphazardly. It has proceeded from the simple to the complex, from lower to higher, towards more structural and functional specialization. Immense biodiversity has been created through addition of branches to the tree. But never has a unicellular organism evolved from a multi-cellular one. Never has a reptilian evolved from a mammal or an invertebrate from a vertebrate. Since evolution has such an "arrow", when a new fossil is discovered, scientists can quite accurately pinpoint a time before which that organism could not have existed.

Today man has learnt this process of evolution. This has created the general concept that in this material world nothing is static, unchanging; nothing is unchangeable. Everything is changing — in a natural process of evolution — the sun, the Earth, the biological world, the human race, and their society. □