BIOLOGICAL REVOLUTION & HUMAN WELFARE

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PREFACE

The biological revolution unleashed in recent decades, which has benefited not only agriculture and industry but the medical field as well, forms the theme of the J. Srinivasan Memorial lecture, organized under the auspices of the Indian Institute of World Culture. Dr. T. Sankaran, who delivered this year's illuminating address, is one of the few eminent scientists of this country.

He has served the Government of India in several capacities in the Council of Scientific and Industrial Research and other departments for more than a decade. His services were initially loaned to the Commonwealth Agricultural Bureaux, where he is permanently absorbed and made the Chief of the Commonwealth Institute of Biological Control, Indian Station, Bangalore.

Dr. Sankaran is well-versed in French and German languages too and has traveled extensively in Europe, the United Kingdom, the United States and South-East Asia in connection with research projects. He has also served in Malaysia for more than a year.

He is a Fellow of the Royal Entomological Society of London and Vice-President of the South-East Asian Regional section of the International Organization for Biological Control.

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Friends,

I am very grateful to the sponsors of the J. Srinivasan Memorial Lectures for having given me the honour of delivering the fifth lecture in this series. These lectures commemorate an illustrious man that Sri J. Srinivasan was in every sense of that term. As many of you are aware, his interests were by no means confined to the limits of his profession as a chartered accountant but they encompassed almost all aspects of human endeavour. It is, therefore, but appropriate that the subjects covered by these lectures should be as diverse as the varied facets of J. Srinivasan's life.

Being basically a student of biology X shall devote this lecture to a brief review of how biology, starting from simple and small foundations, has, particularly in the last three centuries, enlarged its domain and exerted a tangible impact on almost all spheres of human existence and welfare.

Biology is simply defined as the study of living things, be they animals or plants, covering an infinite array of organisms ranging from microbes to man, if one may use these familiar examples to represent two extremes in terms of evolution, organization and functions. With the increase of knowledge and the ramifications of specialization we now have a multitude of divisions and subdivisions of biology, interacting with one another and also with other branches of science, such as biochemistry, biophysics, neurobiology, microbiology and even exobiology which is the study of life or anything comparable to life as we know it, outside the earth. Like every other branch of knowledge, biology has always been and is still constantly enriched by innumerable discoveries of basic facts and complex phenomena. No doubt many of these might escape the notice of contemporary men but as it always happens in the world of science subsequent workers will sooner or later bring them to light and even use them to initiate, support or expand their own ideas and efforts to advance knowledge and to achieve practical results of value to humanity. Within the limited time available I can do no better than give you some glimpses of the varied nature of the subject.

Ancient and Medieval Biology

It is difficult for us to trace the history of biology too far back and to say precisely that any particular observation or study constituted the first milestone in biology. As we look back, fact and fancy may get interlaced. For instance, the ancient religious texts and mythological stories of various countries refer to many human and ultra human acts and achievements, which might have appeared to be miracles to the common man living in the earlier eras, such as regeneration of parts of the animal body and uniparental reproduction, not to mention the revival of life itself. How far these biological possibilities inspired the scientifically inclined men of the past is anybody's guess but the remarkable surgical feats of Susruta, and other reliably documented records from the history of medicine, do show that those medical men had a fair working knowledge of the biology of man. One wonders how far it is proper for the modern intellectual to discredit everything that was observed and narrated by men of the past. Going through a classical work like the Bhagavat Gita from a scientific angle, one may pick up numerous references to biological terms and phenomena, such as the amnion, phototrophic behaviour of insects, etc. Man's forefathers were keen observers of fife and nature, which gave them an insight into many biological facts. Philosophy, religion and science were very closely connected and, unfortunately, very often unevenly blended! This naturally led to occasionally serious, but not universal, imbalances in thinking and judgment, as witnessed by the persecution of some great men of science. The

Greek philosopher and scientist Aristotle dissected many kinds of animals to see what they were made up of and later Galen, a Greek physician, studied and published articles on animal and human anatomy. However, it was the invention of the compound microscope at the end of the 16th century that enabled biologists to learn minute and more details of the way animals and plants were organised. Nevertheless, applications of biological knowledge to human affairs were by no means intensive or extensive. I may mention an example. Honey bees, lac insects and silk worms were encouraged and cultivated in several countries in ancient and medieval periods but they were merely accepted as Nature's gifts to mankind but not studied in depth to be used as subjects capable of improvement through scientific methods.

Human settlements had far fewer basic needs, relatively to what are considered basic needs today, to throw up constant challenges promoting innovation and experimentation. Most scientific instruments had not been invented until the last three or four centuries and one had to depend almost entirely on one's sense organs to study and interpret things. The well-known adage that the proof of the pudding is in the eating may be said to have been taken very seriously by the people of those times, and experience confirmed by further experience, rather than by deliberate experimentation, seems to have given them some remarkable benefits. Take for example the advantages of mother's milk in the nutrition of babies. These have been known for many centuries past, even when modem analytical and testing methods were totally lacking. Doctors and dieticians have now confirmed the rationale of the age-old belief that mother's milk not only nourishes the baby best but that it also immunizes it against some common disorders. The milk of white, brown or black cows is credited with specific curative properties against certain human ailments. Experimental proof of this is probably yet to come but when I asked a senior Indian dairy science expert for his view he thought that one possible explanation is that these skin colors reacting differently to sunlight may affect the animal's physiology and the quality of its secretions in diverse ways.

Modern Biology

What I have said earlier does not necessarily imply that several scientifically unfounded notions were not current in the past. Take, for example, the ancient belief that locust plagues were visitations of divine wrath on people. It was not until the third decade of the present century that some basic truths about locusts were published by Dr. B. P. Uvarov, who became a world authority on the subject. We now know that locusts are a specialized breed of grasshoppers which live in a solitary place and under certain changed ecological conditions become gregarious and form swarms invading fresh pastures in their search for food and breeding ground. They come in large crowds, rather like dense clouds, from distant areas and all over the sky. In the second half of the 15th century, in certain European countries some insect pests were even taken to secular and ecclesiastical courts, with the generous appointment of a defense counsel for them, and ultimately convicted of the offence of destroying crops and punished by execution!

The last three centuries have seen numerous outstanding achievements in the biological (or life) sciences. However, the present century has contributed the most spectacular developments with their application to man's well-being, with genetics becoming, as some people put it, the queen of biological sciences. The invention and constant improvements of new scientific equipment have made it possible to break through the limitations of the human sensory structures and to gain a far deeper understanding of living organisms. Research methods in biology are getting more and more sophisticated in keeping with advances in other areas of science. In 1975 it was estimated that some 2.4 lakh abstracts of articles in biology appeared every year in a wide range of journals and other media. This puts a premium on specialization and team work. Computers and other modem aids, if a biologist can afford to use them, may relieve him of much drudgery in storing, retrieving and analyzing information. However, ultimately he has to use his own ability to identify problems concerning human welfare and to apply the wealth of knowledge to their practical solution.

There is a time lag between the discovery of a basic principle and its practical application. This has even prompted some people to take the view, although this may sound cynical, that scientists can now afford to stop or at least go slow with basic research for some years and to concentrate on efforts to apply the existing knowledge to provide greater benefits to man. For example, artificial fertilization of frog's eggs with semen obtained from a male frog was first demonstrated in the late 18th century. In the following century several biologists experimented with this idea. However, the technique of artificial insemination to improve the quality of domestic animals and even to solve problems of infertility in human couples has become widely known and is actually used in many countries only in the past few decades.

Biology in Food Production,

One of the most basic needs of man is food. Therefore, agriculture is the mainstay of the economy of many nations which cannot afford or for various reasons do not wish to be constantly depending on imports. This has set self-sufficiency in food production as an urgent goal of many nations. The tremendous human population growth, particularly in the developing countries which are mostly situated in the tropical region, and die shrinking area of land available for growing food crops have made it imperative to produce better and more food from each unit area of land. This is achieved to a large extent by crop improvement, better management and diversification programmes. Rice, wheat, com and other grains, legumes, vegetables and fruits are the primary food sources and all these crops are targets for genetic improvement. Most of the agricultural research workers are basically trained in the biological sciences before they specialize in particular fields like animal husbandry, genetics or plant physiology.

Although varietal differences in plants were known for centuries attempts to explore and exploit the full range of possibilities of improving the plant characteristics from the agricultural point of view had to follow the progressive developments in genetics and plant breeding. From simple experiments with garden plants Gregor Mendel learnt the basic laws of heredity more than a hundred years ago.

With interest in the biological study of plants in the early 19th century attention was also directed to food plants, such as wheat. The world's first major agricultural research station was established in 1843 at Rothamsted in England. The study of soil types and their relationship to plant growth, the incidence of pests and diseases, and other aspects of farming proved to be of practical value. The discoveries of the role of chromosomes and of the occurrence of polyploidy, the development of techniques of inducing genetic reorganization to bring forth desired improvements in plants, etc., led to what is now popularly known as the green revolution. Many years of painstaking research were involved in these efforts.

Man's quest for new sources of food continues vigorously, aided by his increasing scientific knowledge of animals and plants. Yet, according to an estimate, from pre-historic times only about 80 species of food-bearing plants have been domesticated by man. Myriad species of wild plants and also many others that are grown and used only under exceptional conditions still await detailed studies that may help in reducing, if not altogether eliminating, undernourishment and malnutrition.

Food of animal origin is largely consumed by vast sections of people. The health, productivity and other qualities of livestock are amenable to improvement on the same lines as those of food plants. Studies on the "energy economics" of meat production have shown that some 5-7 units of calorie input in the form of food grains and various other types of vegetable feed are required for each calorie unit of animal food produced. On the other hand, a unit area of sea or other aquatic body may yield more food in the form of fish, edible algae, etc., than an equal unit area of land. Aquatic biology, particularly as related to fishery science,- has made rapid strides in many countries and contributed to the manufacture of a large range of foods that are rich in proteins,, fats, vitamins and other essential nutritive elements. It is well known that a thorough knowledge of the biology and habits of fish and other aquatic organisms is a prerequisite for their exploration.

Poultry farmers also benefit from the adoption of scientific methods of breeding and disease control based on sound biological principles.

Microbial Technology

Microbial technology owes its origin and existence to studies of certain useful micro-organisms and has in turn contributed to the growth of the food and beverage industry. Agricultural plenty in many parts of the world is still precariously dependent on favourable weather. Micro-organisms harnessed to produce protein, etc. are completely independent of weather. Immense quantities of agricultural and industrial waste products contain carbohydrates which are convertible into microbial protein. The organisms used are able to synthesize protein very rapidly. For instance, a test tube culture of baker's yeast increases in about two weeks to a mass of 100 tons, half of which is protein. Single-celled algae have great potential for protein production. Pilot plants for the production of a species of blue-green algae have been established in countries like France and Mexico. Certain species of fungi are also grown on liquid wastes from factories manufacturing palm oil, starch products, etc.

Another important result of the study of algae is that certain nitrogen fixing species are now grown commercially for use as natural fertilizer. Some bacteria are also similarly valuable in agriculture.

Recent advances in the study of photosynthesis in plants have given rise to new concepts and techniques of tapping natural and almost perennial resources like solar energy and carbon dioxide in the air. Dr. Melvin Calvin's research on the latex of Euphorbie plants, containing 30 to 40 per cent hydrocarbons with properties comparable to those of crude petroleum, may be mentioned in this connection.

Economic plants cultivated by man for food, fibre, building and industrial raw materials and for various other uses are subject to damage by a large number of species of insects and other destructive organisms. Cockroaches, houseflies, mosquitoes and hordes of other harmful animals pose a constant threat to man's well- being and also to that of livestock and other beneficial animals, by directly attacking them and also by transmitting disease-causing microbes.

Early attempts to reduce the ravages of these noxious organisms included hand collection of insects and their destruction in simple ways, such as by drowning them in water, applying poisonous substances like sulphur, arsenicals and mercurials, burning the affected crops, etc. The use of some of the inorganic chemicals in this manner was no doubt based on their toxicity to man. According to the Greek historian Herodotus, who lived in the fifth century B.C., the Egyptians of that time even knew the value of mosquito nets. In some areas they slept in high towers where mosquitoes could not fly up because of wind currents carrying them elsewhere. It may be noted that these protective measures hardly needed any detailed knowledge of the biology of the insect enemies.

The Swedish naturalist Carl Linnaeus (18th century) published his Systema Naturae outlining a method of classifying and naming animals and plants. This introduced a much-needed order in the study of living organisms. In the following centuries biological studies on various species of animals and plants gained momentum and an extension of these basic studies to pests provided the foundation for novel control strategies.

New Era of Research

The discovery of DDT in 1939 ushered in a new era of insecticide research and of widespread chemical control of pests. Unfortunately, this also upset the natural ecosystem in many areas of the world. Moreover, some of the pests became resistant to the modern organic pesticides while their parasites and predators which had a natural controlling effect on many species were killed by these chemicals. Paul Muller. the discoverer of DDT, was awarded the coveted Nobel Prize by Sweden. By ironical coincidence, it was in the very same country, Sweden, that the housefly was reported as the first species of insect to become resistant to DDT. In the struggle for survival the little housefly proved itself no inferior to mighty man! Man and insect have waged an unending battle against each other for millions of years. The insect's challenge to man is yet to be successfully met.

The study of natural enemies of insects and other pests has led to attempts to use them in controlling some of these pests. The Chinese were the first to use predacious ants to suppress insect pests. This method of biological control of pests has made much progress in the present century. In the late 19th century the citrus industry of California was saved from a calamitous plant bug by the introduction of a predacious lady-bird beetle from Australia, whence the pest itself originated. Since then a very large number of beneficial insects, which kill harmful insects and mites and also weeds, have been deliberately moved from one part of the world to another to bring down pest populations to economically insignificant levels. Several species of fish are used to kill mosquito larvae and aquatic weeds choking ponds and other water bodies. Pathogenic .micro-organisms, such as bacteria and viruses, have also been effectively and safely used in biological control campaigns in some countries. One notable example is the control of the rabbit population in Australia by the importation of a myxomatosis virus from South America. Rabbits were a pest in Australia and after the introduction of the pathogen in 1950 their population dropped to less than one per cent of its earlier level in many areas.

In several countries, including India, extensive thickets of prickly pear plants have been practically eradicated by employing certain species of cochineal insects. In Australia the caterpillars of a moth, originating from Argentina, gave such spectacular control of prickly pear that the grateful citizens erected a monument to honour the insect. Only about 2,500 eggs of this weed-killing insect were imported into that country but the species multiplied rapidly and was also artificially -distributed with the result that within a decade nearly 25 million acres of weed- infested land were cleared and put to productive use.

Dung beetles have been known for a very long time and although the ancient Egyptians held them to be sacred, I am sure, most people in other countries do not share this veneration but actually regard them as filthy creatures. A professor of zoology from Oxford recently narrated how some people, when told of his special interest in the ecology of dung beetles, suddenly changed their countenance to one of utmost disinterest, if not of disgust! Dung beetles have been enlisted to solve a peculiar ecological problem in Australia. The native Australian dung beetles cannot satisfactorily dispose of the dung pads of cattle and other introduced bovine mammals because they are not habituated to them but only to the dung of the kangaroo and ether marsupials which have co-evolved with them. The accumulation of hard dung pads of the larger introduced herbivorous mammals reduced the area of pasture land and also encouraged pestiferous insects to breed in them. The problem was solved by bringing in dung beetles from Africa. The species occurring in Africa and Asia are capable of dealing with cattle dung. The introduced beetles not only helped in disposing of the cattle dung pads and reducing the pest populations but they improved the soil structure, increased the soil fertility by tunneling and incorporating the dung in the soil, and they could even prevent water logging of loamy soil. The selection of suitable species of dung beetles for this campaign was made after a careful study of their biology and habits.

Economic botanists and plant breeders are incessantly in search of varieties of cultivated plants that have in the course of evolution developed morphological and other characteristics that render them resistant to pests and diseases. By selective inter-breeding with these plants it is possible to produce resistant strains of cultivated plants,

A less common method of biological control is to sterilize field populations of insects and other pests by introducing into them colonies of the same species artificially bred in the laboratory and sterilized by irradiation or chemical sterilants.

Biochemical investigations on insects have pointed to exciting new ways of pest control. Characteristic secretions (or their synthetic analogues) of certain species are now used to lure the pests to death traps, to cause mating disruptions by confusing and confounding the males in search of mates, to arrest the growth of immature stages and thus prevent them from reaching adulthood and to produce 'developmental and functional abnormalities.

Role of Biology in Medical Progress

Man's body organization and functions are basically not very different from those of other mammals and this makes it possible for biologists and medical specialists to study and experiment with guinea pigs, rats, monkeys and other mammals in normal and diseased states of health and to use the data as a basis for comparison and for understanding the causes and finding out methods of preventing and curing human ailments. The study of animal behaviour has helped in interpreting human behaviour. Ivan Pavlov's famous experiments on conditioned reflexes in the dog may come to mind in this context.

Several major branches of medical sciences, such as anatomy, epidemiology, physiology and parasitology, have progressed side by side with advances in biology. When William Harvey investigated the action of the heart and the circulation of blood within the body he could not provide direct proof of the capillary junction between arteries and veins. The lacuna was bridged after Robert Hooke's discovery of the cellular structure of plants and Leeuwenhoek's microscopic probe into the world of protozoa, bacteria and spermatozoa. The measurement of blood pressure in man was first attempted nearly a century after Harvey by Stephen Hales, who conducted a study of fluid pressure in animals and plants. In almost every decade of the 19th century some significant biological finding of relevance to the human body was reported and most of these had direct or indirect implications for medical advancement.

Louis Pasteur laid a strong foundation for microbiology with a series of studies on organisms that caused fermentation, spoiled wine and beer, produced diseases in silkworms, etc. He also observed that heating destroyed the organisms, which is the basis for the process of pasteurization. Pasteur's work resulted in the germ theory of disease and paved the way for spectacular strides in the field of immunology. His ideas prompted Lister to invent antiseptic methods, which were followed in hospitals, reducing mortality rates from surgery. About the same time the techniques of identifying, isolating and culturing specific microbial pathogens were applied to a variety of diseases such as diphtheria, leprosy and tuberculosis. The discovery of the role of arthropod vectors in the transmission of viruses, protozoa, bacilli, helminths and other disease organisms and also the study of alternate animal hosts of some of these pathogens opened up new vistas of disease prevention and control. Epidemiology and parasitology received increasing attention, with outstanding achievements in dealing with a large number of diseases, particularly filariasis, leishmaniasis, leprosy, malaria, schistosomiasis and trypanosomiasis, which are the six most common tropical communicable diseases that threaten the life and health of populations in developing countries. Smallpox has now been practically eradicated. River systems and other water supply sources are the breeding places, for snails, mosquitoes, blackflies and other vectors. The authorities responsible for their proper monitoring and maintenance have therefore a great responsibility for safeguarding public health.

Molecular Biology

Molecular biology has provided some new approaches to the alleviation of human misery. Research on DNA (deoxyribonucleic acid), the ubiquitous hereditary chemical substance that stores and passes on information for the synthesis of specific proteins through the medium of RNA (ribonucleic acid), has generated what are commonly referred to as genetic engineering techniques. Bacteria which do not produce insulin, a drug used for controlling diabetes, can be induced to produce it by introducing into them a specific gene for insulin found in animals, such as pigs. Industrial production of insulin in this manner will increase its availability at reduced cost. By turning bacteria into living factories, scientists can today cure diseases and create new forms of life. Inherited disorders in man like sickle cell anaemia, Rh blood-type incompatibility and phenylketonuria, are no longer dreaded because they can be diagnosed even prenatally, corrected or prevented by genetic counselling and other appropriate action. Paradoxically, progress in cell biology and molecular genetics is creating new dilemmas in some societies as pointed out by an earlier lecturer of this series. We are now at a stage of evolution where man, like any other organism, may be looked upon, as what one socio-biologist puts it, as- nothing more than a manifestation of DNA's way of making more DNA!

This new technology, popularly known as recombinant DNA, is barely a few years old. Already its impact on the world's economy could almost equal the recent revolution in micro-electronics. Single-celled organisms can yield the proteins that now come from cattle, which would help alleviate world food shortages. By implanting genes, the yield of alcohol from com can be increased. Genetically engineered bacteria are being experimented in the West to eat their way through oil spills and to extract scarce minerals from the soil. Peter Farley, president of a new corporation organised to capitalize on recombinant DNA's potential, remarks:

> "There has been a golden age of chemistry and a golden age of physics. Now it is biology's turn.".

As pure science, this advance represents the most significant step in genetics since James Watson and Francis Crick discovered the double helix nearly three decades ago. This will enable scientists to identify each and everyone of nearly a lakh of genes in the human cell, thus opening up a new era when defective genes can be replaced by healthy ones, overcoming such genetic diseases as hemophilia and sickle-cell anaemia. Will this breakthrough enable science to fashion “better” human beings or new Frankenstein’s as the scenario outlined in Aldous Huxley’s Brave New World? But this fear seems to be baseless, as all scientific revolutions from Galileo’s observations of the planets to the splitting of the atom evoked the cry of heresy. Scientists themselves have imposed voluntary moratorium on most recombinant studies and research programmes have begun from 1976 only after the National Institutes of Health issued guidelines imposing strict safeguards in the laboratory.

It is gratifying to note in this connection that it was our countryman Dr. H. Gobind Khorana created the first artificial gene from simple organic chemicals. Time is too short for us to dwell on the fascinating study of the biological marvels of the generic revolution, but let us confine to only a few of them. Dr. Elena Otto Lenghi-Nightingale has succeeded in making the first successful gene conversion in mammals. After Dr. James Danielli reported the “first artificial synthesis” of a living cell, consequent to Dr. Khorana’s discovery, a conference of scientists at Ames Research Centre discussed the proposal of the NASA to seed the planet Mars with artificially created life forms!

Revolutionary Changes

Are we aware of the possibility of producing beneficial, hereditarily transmissible changes? The appendix might be eliminated, or tissues strengthened to prevent hernias or intervertebral disc disease. Would it not be helpful to grow extra sets of teeth or more hair, or to arrange different rhythms for heart beat and menstrual cycles? Increase of intelligence, artistic ability or co-operativeness, and weakening of aggressive tendency may be looked forward to. At the present moment, many of the suggestions may seem fantastic. It is ore thing to understand the basic blueprint written in the genes and quite another to translate it into living reality. In the formation of any organism, many gene products interact and the circuitry is staggeringly complex. Further, the final product whether an Einstein, a Hitler or a fool—is also shaped by environment. We cannot afford to go now into the several changes that can be interpolated from the biological revolution of memory drugs, genetic engineering and plastic organs.

As stated earlier, the application of nuclear technology to biology and medicine offers new solutions to problems of disease. Sterilization of food stuff by irradiation is one example. Radiation has also been found to be an effective tool in the management of cancer and in the production of attenuated vaccines that could be used for immunoprophylaxis.

The discovery of penicillin, streptomycin and other antibiotics of microbial origin is another major landmark in the annals of medicine. Millions of people all over the world are being saved from death and disability by the administration of antibiotics. Some 90 different kinds of these drugs are currently produced on a large scale for medicinal and veterinary use. However, the struggle for existence in bacterial populations continues with unabated vigour and the development of bacterial resistance to antibiotics (as also to synthetic antibacterial agents like sulphonamides) makes it necessary to restrict the use of these drugs.

Malnutrition is the main cause of low susceptibility to many diseases, particularly the classical deficiency diseases, among human populations in the developing countries, and also to some extent in economically advanced countries. Biochemical and physiological studies on animals and human beings have greatly helped in recognizing the nutritional factors responsible for these diseases and finding remedial measures.

Various newer research aids like the electron microscope, radioactive tracers, immunochemical techniques and computer systems are now used in neuro-scientific investigations to treat mental and other neurological disorders.

Biomedical scientists are discovering a wide range of chemical compounds of pharmaceutical value in marine animals and plants. Medicinal plants growing on land are another major source of drugs.

Biology has contributed reliable techniques, such as blood grouping, age determination by examination of bones, etc., to help crime detection and forensic medicine.

Cultural Value

Many species of animals and plants have found a place in the cultural life of man. Reference was made earlier to the role of dung beetles in the ancient religious beliefs of Egypt. Honey bees and flies are represented in hieroglyphs, which throw light on the way of life of people in the earlier periods. Who has not read or at least heard of the famous Aesop's fables and Panchatantra stories, each with its own moral, its sharpening effect on man's wit and wisdom? In Indian mythology honey is symbolic of ecstasy and love and the nectar-seeking bee or beetle (the two were often confused with each other) is an examplar of devotion and dedication.

More and more people all over the world are taking interest in the science and practice of yoga, which is based on very sound anatomical and physiological principles. This has even been verified and confirmed by modem scientific experiments.

The social life of animals has been studied by biologists and ecologists. The caste or class system is not confined to human societies alone. Bees and termites evolved and perfected it long before human social patterns came into being. It is based on the principle of division of labour, which helps the survival and success of the colony.

Several articles of aesthetic value are produced by methods or processes involving the study and exploitation of animals. Corals, pearls, lac and silk are some examples. Cosmetic preparations are prepared from certain animal and plant derivatives.

Many different species and varieties of animals and plants are kept by man for fancy or pleasure as one may see from the interest shown and large monetary investments made in gardening, pet animals etc., which in turn calls for research in horticultural science, animal breeding and related subjects. Some of these animals and plants are so highly prized that they are eagerly sought by amateur and professional collectors. Several countries have enacted legislation to prevent rare species from becoming extinct and the World Wild Life Fund has active teams working in almost all parts of the world to promote steps to protect and preserve specimens of rare fauna and flora.

The varied forms and colours exhibited by certain species have served as models for artists and sculptors, not to mention the architects and design engineers who gather ideas from animal and plant anatomy and morphology.

Ecology and Evolution

One of the major contributions of biology to human welfare is that it has focused attention on the inter-relationship between organisms and the environment. This is the concern of ecology, which is only a branch of biology. Ecologists everywhere are increasingly aware of man's indiscriminate and self-defeating onslaughts on nature. As pointed out by the naturalist Marston Bates: "Ecology may well be the most important of the sciences from the viewpoint of long-term human survival; but is among those least understood by the general public”. It is reported that our biosphere is presently subjected to pollution by some half a million substances, which include industrial wastes, toxic chemicals, etc. In the cost-benefit analysis of every new venture the invisible but vital losses in terms of ecological consequences are usually ignored. The administrator and the politician owe a great social responsibility to seek and heed the advice of the biologist.

When Charles Darwin published his monumental book The Origin of Species in 1859 the religious bigots of his time no doubt assailed him but the scientific study of organic life and evolution had made sufficient headway and Darwin himself spared no pains to substantiate his conclusions with positive proof from his own extensive and well-documented observations and also from the work of earlier and contemporary biologists. However, it is well to remember that while organic evolution has produced a highly evolved animal in man, the latter is by no means the final or perfect end-product of the process. Perfection is a superhuman ideal, call it divine if you will, which man by deliberate choice of his own or by mutational chances of evolution, may still try to attain. The human body is vulnerable to disease and destruction and even to sudden death from inevitable, if not altogether inexplicable, causes. Therefore, ultimately what man leaves behind in terms of what are understood to be the higher values of life will probably mean more to the future generations and to the further course of evolution than a mere accumulation of knowledge and material wealth bereft of the capacity for wise judgment and right action. While the theories of evolution and other apparently rational propositions may account for the origin and gradual progress of the human body, including a highly complex brain, they fail in one important respect. To quote Dr. Gunther Stent, a molecular biologist of the U.S.A.:

> “It seems very likely that the remainder of this century will see much progress in the under” standing of the brain. But it is not so clear at present that expected progress will actually provide for us a solution to the mind-body problem. In particular, it seems doubtful to me that a scientific explanation can ever be provided for the phenomenon of consciousness. That is to say, the final lesson of modern biology may be that the human brain, the most amazing of all the amazing biological structures selected for their fitness by Darwinian evolution, may not, in the final analysis, be able to provide an explanation for itself.”

The struggle for existence and the survival of the fittest may operate well in a wild and unprotected environment where the law of the jungle prevails. In human societies they are conditioned by cultural, ethical and moral desiderata. Consciousness plays a dominant role here and it draws a dividing line between man and the lower organisms. The failure of biology to explain it leads man to seek to understand it by recourse to other sources, for instance, from men and masters of religious or spiritual experience. I may conclude by stating that this only takes us back to my earlier theme that what cannot be proved by experiment and logical explanation may still be verified by direct personal experience!