demanding uniformity is to simplify the process of filtering we call examinations. They used to be for a few mundane jobs, previously of clerks and now not much different. Examinations have become the aim, the purpose, not the means of ensuring good learning, not even for finding the right people for the right functions.

If one allows oneself to be carried along by this line of thinking one can almost persuade oneself that the cause of many of our inadequacies lies at the bottom of our education system. That should be something easy to correct. But, as I posed right in the beginning of this presentation, just because it is so easy it becomes almost impossible in our society. Perhaps we should make it a bit difficult and then it would happen. We just have to turn that switch.

So the current engagement of many of my friends and colleagues, most of them of the Jatha and the MANAR vintage is the Lokshala programme, where our slogan is 'From Pathshala to Lokshala'. I invite all of you to participate. You may think that we are tilting at the wind mills. I personally do not think that is such a mad way of living, not in the present day world.

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Biodiversity, conservation and evolution of plants

D. D. Pant

People dealing with more exact sciences like physics and chemistry feel somewhat uncomfortable with biology. A reason for this could lie in the undefinability of life. It has to be stated with all emphasis, which I can muster, that among all the branches of science, biology is the only branch that cannot define the object of its studies. There is no strict definition of life and even all its exact experiments are performed on dead cells or tissues.

Among all the branches of biology, biochemistry and biophysics approach the more exact sciences wherein experiments can be conducted and repeated to confirm their conclusions. However, there are branches like taxonomy, morphology and palaeobiology that are mainly descriptive and even historical, relying more on observations, descriptions, and classifications of the diversity of form and structure of the organisms under study. It is, at the same time, necessary to add that even among the 'hard' physical sciences, astronomy too is observational and non-experimental. Compared to the diversity of chemical elements, which number about 10^8 or more, the diversity of form and structure in plants and animals is infinite and the exact numbers of genera and species cannot be accurately stated. Furthermore, between the genera and species of plants and animals, infinite varieties exist which tend to intergrade them and I can only repeat a statement, which I made in 1954 (ref. 1), while classifying spores and pollen grains that it is difficult to draw boundary lines in the fine gradations of Nature: Classifications are after all, all artificial.

However, underlying this biodiveristy of our undefinable objective called 'Life' is the process of diversification: evolution. This process has been going on for nearly 4000 million years from now when life arose on our earth, and I must emphasize that it is still going on. You have only to look around and find for yourselves numerous examples of the process continuing among our plants and animals. Take, for example, the use of DDT and the new antimalarial drugs for the eradication of *Anopheles* mosquitoes and malarial parasites for the control of malarial fever. Very soon thereafter we came to know that the use of DDT and some of the newer drugs being used had given rise to breeds of mosquitoes and malarial parasites which showed resistance to these drugs and the threat of malaria has reappeared. To me this is clearly an example of the continuing diversification of life and shows that plant and animal taxa are in the process of continual change. We must also remember that diversity not only increases but also decreases. This is obvious from the fossil records which show that many plants and animals have indeed become extinct. Some of them like, dodo, of which one species *Raphus cucullatus* was living up to 1680 in Mauritius but thereafter it became extinct. Another species *R. opterornis* lived in the island of Reunion until the late 18th century. This flightless bird was killed by man for food and thus became completely extinct[2].

Before I go on further, I must say that the present century has witnessed two great advances in science, both concerned with the fission of nucleus.

One of these advances led to the fission of the atomic nucleus by physicists, resulting in generation of atomic power. The use of this power caused unparalleled devastation of two Japanese cities of Hiroshima and Nagasaki, and I should add that we are still experiencing its after effects. A second outcome of the same fission of atomic nucleus has resulted in generation of atomic power for peaceful purposes. It is claimed that this power, in the long run, would be able to replace our fast-depleting sources of energy and irretrievable fossil fuels. But many scientists differ, and have already cautioned us about the hazards of ionizing radiations resulting from atomic wastes, like plutonium, whose radioactivity takes a long time to decay before it attains safer levels.

The second great advance was made in the field of biology and once again it involved the fission of the cell nucleus which resulted in our coming to know the genetic code of the DNA molecule, responsible for inheritance of characters from parents to the progeny. A result of this knowledge has given us the capacity to manipulate the genes in the code by what is called genetic engineering. This can give us the power to create novel forms, species and genera.

Thus far nature and natural factors were manipulating genes due to aberrations or mistakes in the replication of DNA, thereby leading to mutations by factors which were mutagenic. Their mode of action was largely unknown, but now we are learning to manipulate genes. We may thus create new forms at will and thereby enhance or retard the rate of evolution in nature. In this manner we can manipulate the biodiversity to an extent. Thus like the fission of atomic nucleus, this too gives us immense power to create new forms of life. However, this power has to be used with caution and there should be a restriction on creating forms which may turn out to be like the ghost of Frankenstein—the case of 'Terminator-III' gene is a relevant example.

There are additional new surprises like jumping genes and prions. The discovery of prions, which seem to be self-replicating proteins, transferable from one individual to another, resulted in awarding of Nobel prize to Stanley B. Prusiner[3]. Despite these modern advances, the basic need of biology is to study biodiversity because therein lies the raw material essential for all biological studies. The biodiversity which we study not only extends into the three dimensions of space but in the fourth dimension of time as well, taking us back to 4000 million years or more and covering the entire span of time from then up to the present day.

Studies of Pre-Cambrian rocks initiated by Barghoorn and his coworkers, like Tyler[4], Schopf[5], around 1965 have given us glimpses of the earliest forms of life from these rocks. Studies of this kind give us insights into the manner in which life originated and evolved on our planet, and the possible conditions under which it arose. This work has opened up new lines of research for specialists of diverse groups of plants to look back for early traces of organisms.

These researches have finally shown that prokaryotic organisms are indeed older than eukaryotic organisms. This has lent indirect support to the theory about the eukaryotic cell being a permanent symbiotic association of a number of prokaryotes—the organelles like mitochondria, chloroplasts, etc. Each one of these organelles have their own nucleic acids, which though replicate independently, these live together in the nucleated cytoplasm of an eukaryotic cell in a mutualistic symbiotic association within every cell of the body of a multicellular organism. Imagine the repercussion of this theory which supports the conclusions that all of us have bodies containing bacterial cooperatives in each one of our cells.

Coming back to diversity of life in our present day world, I have to mention that many surprise discoveries await the explorers of biodiversity who are in search of new forms of life on land, and in sea and air. As late as 1977, geologists aboard the research submarine *Alvin*, discovered in a deep sea bottom warm water vent, at a depth of 3600 m below the ocean surface and located about 320 km south of Galapagos Islands, an ecosystem of previously unknown animals like metre long tube worms (*Riftia pachyptila*), about 30 cm long clams (*Calyptogena magnifica*) and mussels (*Bothimodiolus thermophilus*) along with other animals like shrimps, crabs and fishes. The waters in these vents or cracks in the sea bottom are superheated to temperatures above 300°C and are under extremely high pressure, rich in hydrogen sulphide, and contain chemosynthetic sulphur bacteria which also live inside the cells of *Riftia* worms like chloroplasts in the cells of photosynthetic plants. These also live in the cells of clams and mussels, which live in water at a temperature of 20°C, and provide energy to these clams and mussels by chemosynthesis in the darkness of the ocean floor[6]. The endosymbiotic sulphur bacteria in the cells of these dark-dwelling animals thus provide an indirect proof about the chloroplasts of green plants being endosymbionts for photosynthesizing in the presence of sunlight. These examples of biodiversity from the ocean floor substantiate the importance of such studies in confirming the *Serial Endosymbiotic Theory*[7], which assumes that the eukaryotic cell is an association of a number of prokaryotes—the independent, self-replicating organelles from pre-existing organelles like chloroplasts, mitochondria, and the independent DNA and RNA of the endosymbionts and their host cells. In the place of the photosynthetic bacteria or chloroplasts living inside the cells of green plants growing in sun light, the dark-dwelling deep sea animals like *Riftia* have chemosynthetic sulphur bacteria as their endosymbionts.

Barring these novel forms of life described from deep sea vents, it would be well nigh impossible to mention the names of new genera which have been recognized among the lower groups of plants during the present century. Even among the higher plants, which are conspicuously growing around us, many new genera have been recognized during the 20th century. Even in a small group of plants, like liverworts, Kashyap[8] recognized quite a number of new species and endemic new genera from the Western Himalayas while our liverworts from other parts remained uninvestigated. Subsequent workers like Hattori and Inoue and others, reported novel bryophytic forms like *Takakia*[9], *Marchasta*[10], *Carrpos*[11,12], *Crytothallus*[13], *Haptomitrium*[14], *Sphaerocarpos*[15], *Pachyglossa, Chondrophyllum* and *Personella*[16] from Japan, Australia, New Zealand, Patagonia and the Eastern and Western Himalayas besides many new species and genera of foliose liverworts and mosses. Likewise many new pteridophytes have been recognized in the recent past in the flora of our country and elsewhere. There is thus an urgent need for their study. It would take a lot of space to mention the new genera of our present-day dominant groups of seed plants included in the angiosperms which have been recognized lately, but I can take up the new genera of a small group of higher plants, the gymnosperms, to mention the need for the study of biodiversity of plants. Among the five major groups of living gymnosperms, we knew only nine genera among the cycads; Johnson[17] however recognized a tenth genus, *Lepidozamia*, which is distinct from *Macrozamia*, and in 1987 Stevenson discovered[18] an eleventh genus, *Chigua*, in Columbia in northern South America. In a second group of living gymnosperms the Pinales or Coniferales, in the wider sense, we have found at least nine genera during the 20th century. Beginning with *Acmopyle* recognized by Pilger in 1903 and *Amentotaxus* recognized by him in 1916, the Taxales acquired *Austrotaxus spicata* Compton, 1922 (ref. 19) and *Nothotaxus*, Florin[20]. The history of the discovery of the genus *Metasequoia glyptostroboides* of the Taxodiaceae is unique. Its fossils, usually mistaken for those of *Sequoia*, were first recognized by Shigeru Miki in 1941 (ref. 21) and the type of the genus was a fossil. But in 1948 Hu and Cheng[22], two Chinese botanists, recognized the living trees of *Metasequoia* in southern China and after much controversy a living tree of the species became the generitype. Another genus recognized almost ten years later in 1958, again from southern and western China, is *Cathaya* of the Pinaceae[23].

The two genera, *Sequoia* and *Sequoiadendron*, remained lumped together for a long time, but as a result of the work of Buchholz[24] the older species *Sequoia* *sempervirens* remained in the genus while the species *S. gigantea* was assigned to a new genus, *Sequoiadendron*. A parasitic conifer, previously called *Podocarpus ustus* from New Caledonia has now been assigned to a new genus *Parasitaxus ustus* (Viellard) de Laubenfels, 1972 (ref. 25).

The latest addition to the list of new genera of conifers is *Wollemia nobilis* Jones, Hill and Allen, 1995 (ref. 26) which becomes the third genus of the Araucariaceae. It is clearly different from *Agathis* as well as *Araucaria*.

An example of gymnospermous diversity at the specific level may be taken from the genus *Cycas*. In his monograph on *Cycadales*, Schuster[27] recognized only eight species as valid and regarded the rest, about one hundred names, as varieties, forms, or synonyms. In 1985, Osborne and Hendricks[28] mentioned the names of 15 species as valid, but the next year they added two more species making the total up to 17 (ref. 29). In 1995, Stevenson, Osborne and Hill[30] raised the total number of valid species of this genus to 52. However, the total number of valid species of this genus should be near a hundred or more out of about 150 species named by various authors.

Intimately connected with the theme of biodiversity is evolution and conservation. The biodiversity which we find around us is the result of the process of evolution which has been going on for the past millions of years. The fossil record substantiates Tennyson's words in *Passing of Arthur*, 'the old order changeth yielding place to new'. During the vast stretch of time which Hutton[31] estimated from the deposition of immense piles of sedimentary rocks and declared 'Time is to nature endless and as nothing', and added, 'I see no vestige of a beginning and no prospect of an end'. Evolution of plant and animal life has seen many vicissitudes and in the past numerous new forms arose to replace the old ones which became extinct. In due course of time the new ones also met the same fate.

There were, in addition, large-scale extinctions or sudden appearances of new forms; when some catastrophic change like the fall of a meteorite, or other unknown factors like glaciation, or sudden rise in temperatures in our unstable earth, caused mass extinctions like that of the dinosaurs or the rise of the Glossopteris flora. Besides such changing or attenuating lines, there were numerous other forms of life which have continued unchanged up to date or have changed only slightly.

However, life on this planet has to reckon with an unprecedented factor: the modern man. Equipped with his machines he is destroying forests to build his fields, roads, dams, industrial set ups and dwellings. He is thus upsetting the balance of nature with a terrific speed. This emphasizes the need for conservation of plants and animals *in situ* in what are called sanctuaries or national parks, or *ex situ* in captivity in zoological or botanical gardens. I must add that *in situ* conservation has the distinct advantage of allowing the animals and plants to remain in their own environment that is conducive to their proper growth and progress in terms of evolution. In contrast, though zoological parks and botanical gardens keep them protected, they lack the conditions which nature provides them for proper growth and further evolution. We do not have any national parks for the protection of our rare and slow-reproducing relics of past ages, like cycads, and we have far too few botanical gardens. In China, Australia, USA, South Africa and other countries practically every city has a botanical garden.

In the end, I must emphasize that the prime need of biological studies is to teach as well as do research in biodiversity where exploration and protection of our biodiversity must be continued with renewed vigour. On this will depend our preservation of animal and plant diversity and, ultimately, it will create an awareness of the ecological balance in nature. We need to lay special stress on exploration of our flora and fauna and survey the areas of the distribution of our plants and animals. Wherever necessary census of our endangered plants and animals should be prepared at regular intervals.

Furthermore, the collectors of plants and animals should take special care in not endangering the rare species and genera by overcollecting them.

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