Life Complexity and Diversity

6. Whither Diversity

Madhav Gadgil

The evolutionary history of life is one of continual expansion, of coming into being of increasingly greater diversity of more complex organisms, colonising ever newer environmental regimes. It is a cosmic drama that has become ever more elaborate, as it retires some, but inducts an even larger number of increasingly sophisticated actors into its fold. But the process has by no means been monotonic. It is as if the stage is cleared from time to time to make for fresh beginnings, with major bouts of extinction. Humans are amongst the most complex products of evolution having in turn populated the world with ever growing numbers of complex artefacts. These artefacts are now threatening to overwhelm the diversity of life. But humans may one day engineer life capable of surviving in outer space, and thereby trigger off a new phase of expansion and diversification of living organisms.

Madhav Gadgil who is associated with the Indian Institute of Science and the Jawaharlal Nehru Center for Advanced Scientific Research has not only been fascinated by the evolution of life, but with that of human cultures and artefacts as well.

Mega Extinctions

The most massive episode of extinction of life forms occurred 245 million years ago, at the boundary of the Permian and Triassic periods of geological history. At that time as many as 96% of marine animal species seem to have been wiped out. There have been four other major episodes of extinction in geological history, although none as severe as the one 245 million years ago. The latest of these was 65 million years before the present and it wiped out the dinosaurs (*Figure 1*). These dramatic episodes of mega extinctions were probably due to some geological convulsions; either a hit by an enormous asteroid or a major volcanic eruption.

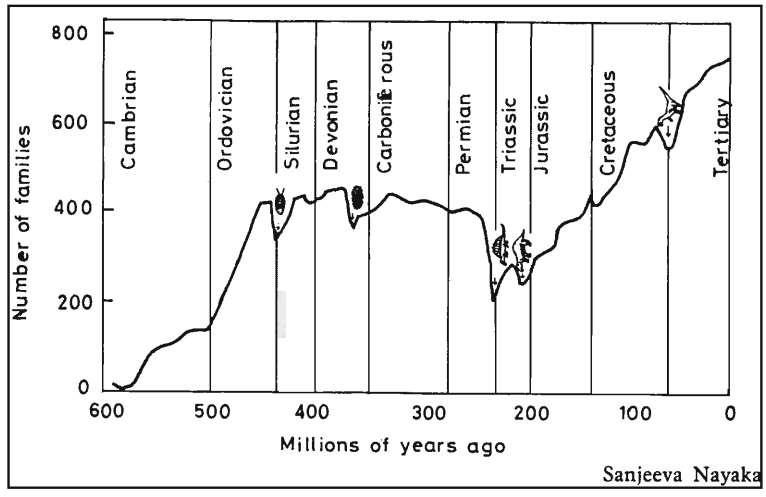

Figure 1 Diversity displays a saw - toothed curve of increase over evolutionary history. While, by and large, more species have been added than deleted from the ecological stage, there have been several catastrophes in which a large fraction of the existing variety of living creatures has been wiped out. Indicated in this figure are the major animal groups that have suffered in such episodes.

Leaving such episodes aside, the background extinction rates have been rather low. Given the relatively complete fossil record, they can be estimated with some accuracy for the last 100 million years. Over this period they have remained at around one species of mammals every 400 years and one species of birds every 200 years. The rates of origins of new species have more than kept up with these, so that the world is now populated by around 9000 species of birds and 4000 species of mammals.

Pinnacle of Complexity

The warm blooded birds and mammals with high metabolic rates and well developed brains are amongst the most complex of living organisms. This is because complexity resides in diversity of linkages amongst the manifold components of any system. All higher plants and animals are made up of numerous units, the cells. The simplest, like sponges or mushrooms have just a few kinds of cells, more complex organisms like crabs or frogs have tens of different kinds of cells. These cells relate to each other in many different ways; the most advanced of these is through connections of nerve cells. Each nerve cell has many processes which link to other nerve, muscle or gland cells. The brain is of course a bundle of millions of nerve cells, and these can connect to each other in a variety of ways depending on the conditions to which the animal is exposed. This diversity of

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possible linkages of nerve cells has conferred on birds and mammals a high level of complexity, leading to a substantial capacity to learn and to adjust their behaivour.

It is the evolutionary trend of development of ever higher levels of complexity that has thrown up our own evolutionary lineage. Humans and their ancestors are notable for the long period of slow growth of the brain, permitting ample opportunity for nerve cells to develop specific interlinkages based on the conditions to which we are exposed. This qualifies humans for the rank of the most complex of living organisms; an animal with an incredibly flexible pattern of behaviour. This flexibility of behaviour, this capacity to learn, has rendered humans tool makers par excellence. Other animals do employ tools; elephants use bits of sticks to scratch themselves, and chimpanzees to draw termites out of the mounds. But the human capacity for production of artefacts far exceeds that of all our ancestors.

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Explosion of Artefacts

Members of our ancestral species, *Australopithecus africanus* were already fabricating and using simple stone tools on African savannas 2 million years ago. Their descendants *Homo habilis* and *Homo erectus* elaborated these tool industries further, although at a very slow pace (*Figure 2*). *Homo sapiens* achieved their present day mental capabilities, with a complex symbolic language, some time between 50 to 100 thousand years ago. This permitted them to fabricate increasingly complex artefacts and put them to a variety of uses. Such uses not only include purely practical ones such as sticks for digging tubers, but also those that acquire meaning only in a social context, such as necklaces of shells.

Artefacts, like living organisms are replicating entities. One of them can catalyse the production of many more. As a result, artefacts too have been evolving (*Figure 3*). Artefacts help people improve their access to resources, enhance their social status and dominate others. Bigger and more complex dams, cars, or guns all serve such purposes. So people have been continually fabricating

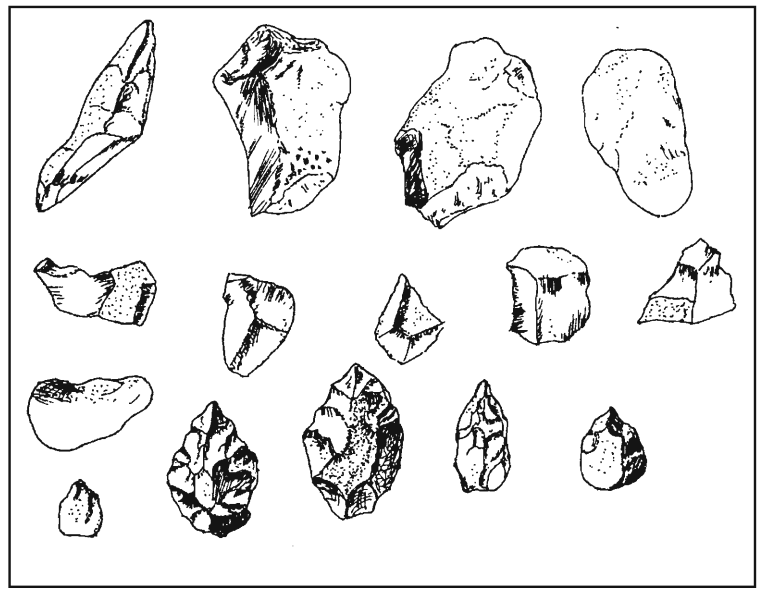


Figure 2 Beginning two million years ago our ancestors began fabricating tools, such as these simple stone scrapers. For hundreds of thousands of years the forms of these artefacts changed but little.

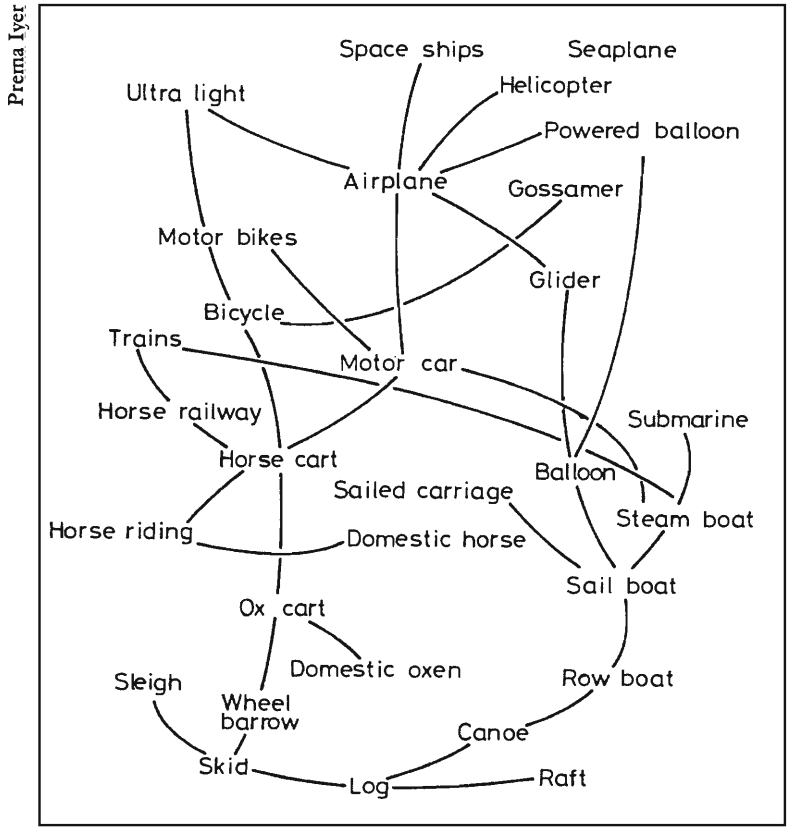


Figure 3 Human artefacts have evolved rapidly over the last fifty thousand years. But unlike living organisms their evolutionary history constitutes a web rather than a bush.

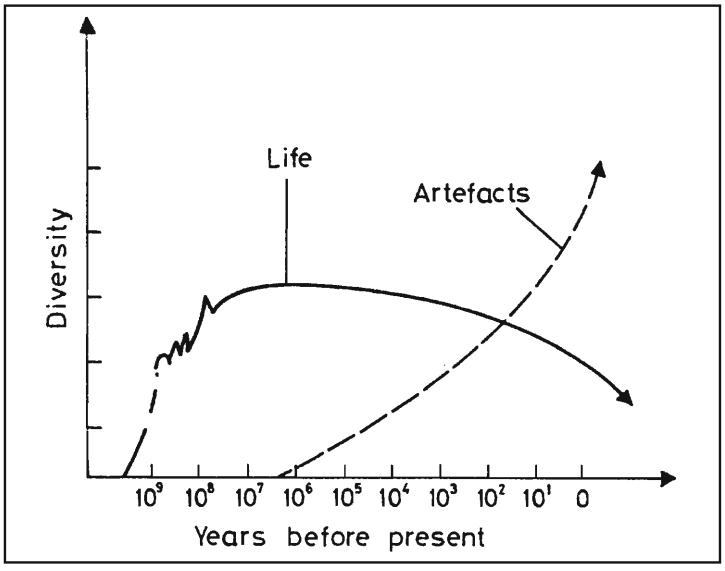
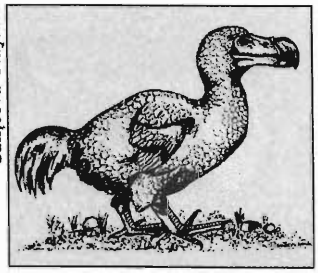


***Figure 4** A schematic depiction of the history and future of diversity of living organisms and of artefacts fabricated by humans, the most complex of the living organisms.*

larger and more complex artefacts. Growing populations of these artefacts have been competing with the natural world, eroding the variety of living organisms, even as the diversity of artefacts is continually on the increase (*Figure 4*).

Over the last three centuries, for instance, the rates of extinction of birds and mammals have increased by a factor of fifty compared to the background rates, and it is feared that between 10% to 25% of all living species will go extinct in the next few decades (*Figures 5 and 6*).

***Figure 5** The Dodo lost its ability to fly in the absence of any large predators on its island home. Human colonizers of oceanic islands have hunted many such flightless birds to extinction over the last several centuries. The Dodo was amongst the last to go; in fact, a painting suggests that Emperor Jehangir possessed a live specimen in his aviary.*



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Living Artefacts

Without doubt then much of human influence on the biosphere has been destructive. But ours is also the only species capable of consciously understanding its impact on nature and doing something about it. As a result, human beings have not only destroyed, but deliberately promoted the diversity of life. The wolf was among the first living species to be moulded by human design. It gave rise to the domestic dog with many new physical and behavioural traits fitting its role as a hunting companion and a

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Figure 6 Blackbuck once roamed the Indian countryside in tens of thousands. Today the species has been driven to the brink of extinction by competing demands on land and by hunting using the gun and the jeep.

guard at camping sites. With time there developed enormous varieties of dogs, widely varying in size, form and behavioural attributes. These may then be thought of as living artefacts (*Figure 7*). Over time humans similarly brought under control and moulded the characteristics of hundreds of other plant and animal species (*Figure 8*). Today these living artefacts cover vast tracts of earth - as paddy fields or teak plantations, as fishponds or herds of cattle and sheep.

These living artefacts differ only a little from natural life forms. The last two decades have however witnessed a qualitative increase in the human capacity to manipulate living organisms. Techniques of molecular biology now permit us to move pieces of DNA from one organism to another, creating entirely new forms of

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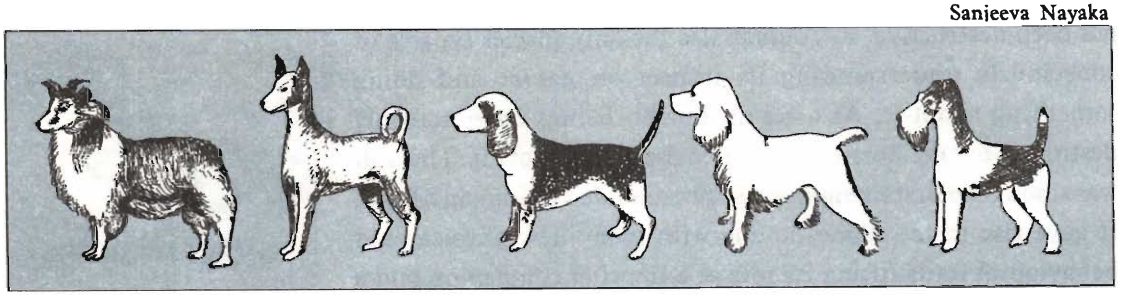
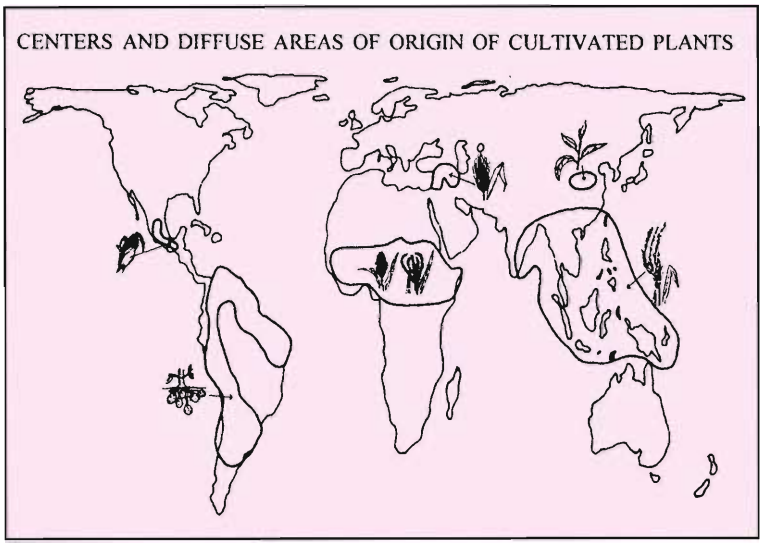


Figure 7 Humans have promoted diversity in many species that have been domesticated. The earliest and the most varied of these is the dog.

Figure 8 Plants and animals have been brought under domestication by humans in a few major centers in the world; the middle east, and the Mesoamericas being amongst the most important of these. The Indian subcontinent has served as a secondary, yet significant centre of domestication of a number of species of plants and animals. Rice and water buffalo might have been brought under domestication in India, although China and Southeast Asia too have claims as possible centers for origin of these important species. The humped Zebu cattle was domesticated in India, although several centuries after the original domestication of cattle in the middle east. Yak and mithun, two species allied to cattle were domesticated in Western and Eastern Himalayas. North Indian red jungle fowl gave rise to the domestic chicken. Several species of legumes, such as chick pea and green gram, oil seeds like sesame, spices like pepper and cardamom and fruits like mango and jackfruit are other significant contributions of India to the global stock of genetic diversity of husbanded plants and animals.



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transgenic creatures. Thus we can transfer the gene responsible for the production of insulin from a horse to yeast, and that for the production of luciferin, the luminescent substance in glowworms, to the tobacco plant. These developments have enhanced human capabilities for putting other organisms to use - and of making a profit out of them.

Biodiversity Convention

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held in Rio de Janeiro in 1992 and has resulted in the International Convention on Biological Diversity. By now 150 countries including all major nations, with the exception of USA, have become parties to this convention. India, China and almost all our Asian neighbours are members of this convention. The convention accepts the sovereign rights of all nations over their genetic resources and promises countries of origin of such resources special privileges when those resources are put to use. At the same time, all nations are expected to organize inventories of the diversity of life within their territories, to monitor what is happening to such diversity, and to develop strategies for conserving it. This is a major scientific challenge, especially for a megadiversity country like ours. We hope that India's community of biologists, old and young, whether they work for, teach or study in surveys, research institutes, universities or colleges, will turn this challenge into a major opportunity.

Future — Bleak or Bright?

But what does the long term future hold for life on earth? There are two alternatives scenarios. The pessimistic scenario, which has a wide following, runs thus: It visualizes a world increasingly polarized between the north and the south; with the north controlling much of the world's wealth as well as technologies, with a stable human population, but exploding material consumption; and the south, harbouring most of the world's poor people with rapidly growing numbers, possessing very low levels of technology. But it is the south that has much of the world's store of biological diversity. This the pessimists expect will be rapidly decimated as the growing populations of the poor degrade the environment at an ever accelerating pace in their attempts to eke out a living. In the meanwhile the northern industrial corporations will drain the biological diversity resources of the south to be maintained in ex-situ collections under their own control to serve as the raw material for future technological developments. Once this has been accomplished the biotechnology industry will in no way be concerned with the destruction of nature in the south. But in their greed these industries would push for the release of

genetically engineered organisms with little forethought. One or other of these organisms would eventually turn against all natural life, of the north as well as the south and wipe out the wonderful diversity of living organisms slowly built up over 3.5 billion years of evolution.

Today's world holds few optimists; but one of the most remarkable of these is the well known physicist, Freeman Dyson. He asks us to contemplate on the history of life on earth, originating in some one obscure place, in the warm shallow seas. Life has gradually expanded from these humble beginnings to occupy all of the oceans, all of the freshwaters, most of the land and the lower reaches of the atmosphere. But today it is confined to the earth, and possibly to a few other planets. It is the open spaces of the universe that are now beckoning life to occupy them. These, life shall occupy with the help of humans, the most complex, albeit the most destructive of organisms that has so far come into being. Freeman Dyson has worked out the attributes of life that can sustain itself in cosmic space. Dyson believes that humans will eventually engineer such organisms and send them out in space. Perhaps they will be prompted to do so by another episode of mega extinction, this time brought about by human interventions, rivalling what happened at the boundary of the Permian and Triassic periods. Out in the interstellar space, the specially engineered organisms will grow, multiply, evolve, spread out and ultimately bring the whole cosmos to life. That would no doubt be a fitting finale to the cosmic drama that began here on this obscure planet three and a half billion years ago.

Life has gradually expanded from these humble beginnings to occupy all of the oceans, all of the freshwaters, most of the land and the lower reaches of the atmosphere.

Suggested Reading

- Dyson, Freeman. *Infinite in All Directions*. Harper and Row. New York. p. 321, 1989.
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