basic research scientists So was H. J. Bhabha, who transformed himself from a basic research scientist to a science manager.

There is another important aspect of basic research which is very relevant to Indian interests. The flow of information is free in the international basic research community and this is the knowledge that could form the basis for future technology development. Information flow gets restricted when you come to applied research and is totally blocked, unless you pay for intellectual property rights, once technology development is complete. In the field of crystallography, for example, with which I am familiar, a great deal of information on drug design is freely available in the basic research community and could be profitably used by the Indian pharmaceutical industry for its own technology development.

It may appear a contradiction of sorts but it is a fact that the latest technologies are needed for basic research and are, therefore, often first developed in large basic research laboratories. It is in India's interest to participate in international mega-projects in science.

Conclusion

Basic research is, of course, the fountainhead of ideas for technology development. The applied research edifice in India today is weak, except in mission-oriented agencies. Its growth in the future will be sustained by building a strong basic research foundation *now*. Otherwise, we run the risk of stifling our future S & T agenda. Of course, the S & T community must have a commitment to indigenous technology development. And the nation and its political system must have faith in the scientists. As Frederick Seitz once said: 'The advance of science requires money given with appreciation and wisdom.'

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Census of India's biodiversity: Tasks ahead

T. N. Khoshoo

There are varying and often conflicting estimates floating around nationally and internationally regarding India's biodiversity, particularly the number of animal species. Thanks to A. K. Ghosh (Director, ZSI), reliable information has been collated on animal species. Based on the current knowledge as summarized by Ghosh[1], Khoshoo[2] and Singh[3], the total number of living species identified in India so far is 126,188 (Table 1). With the publication of this table, speculations about the extent and nature of species richness in India should be set to rest till such time a formal census is undertaken.

According to the World Conservation Monitoring Centre (WCMC)[4], the total number of species described at the global level so far is 1,604,000. However, this Centre estimates that at the global level there are likely to be 17,980,000 species. i.e. about 11 times more than the presently known species. The increase is likely to be primarily from the tropics and subtropics. However, a more realistic and a working figure for species[4] at the global level is around 12,250,000.

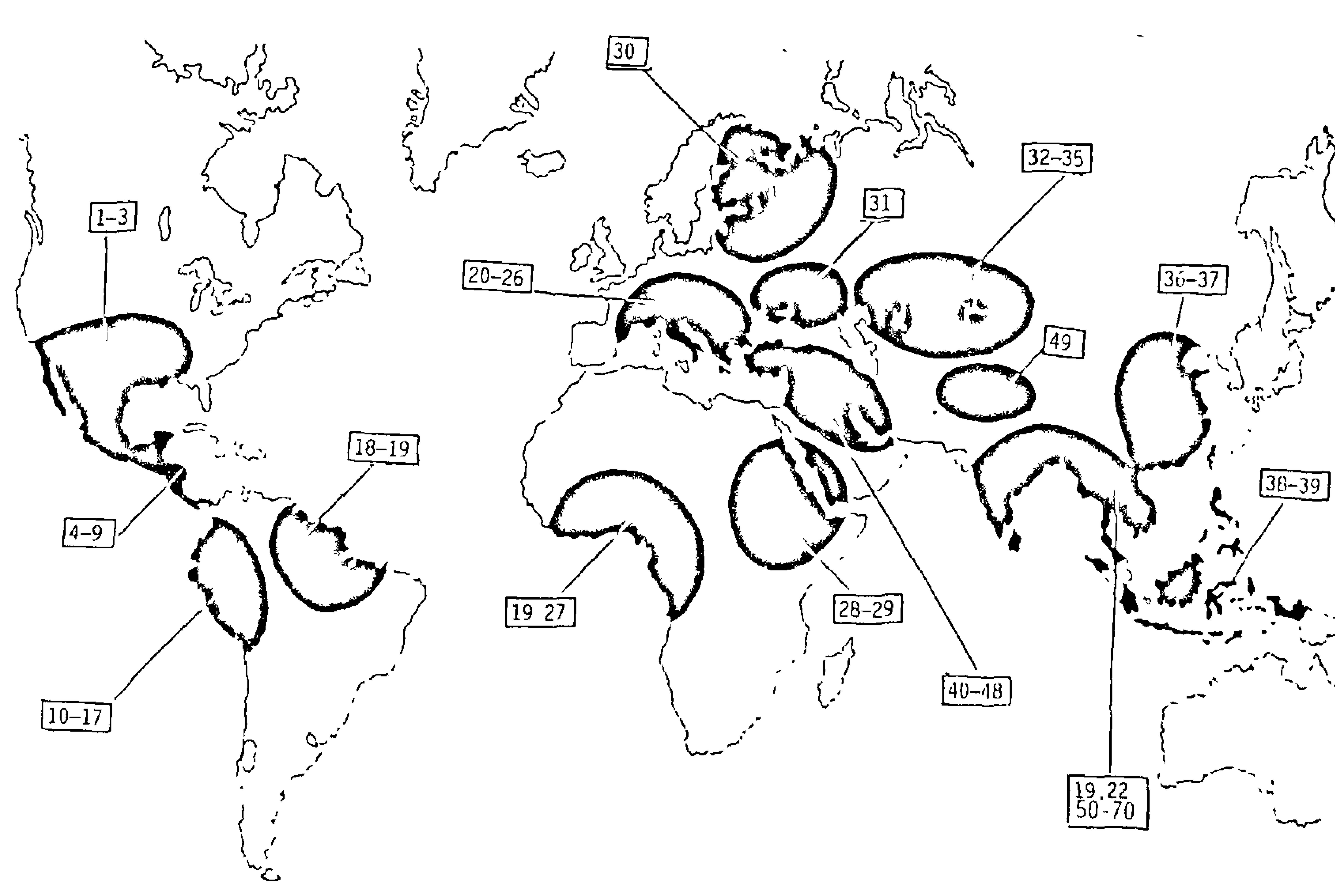
Out of the 126,188 species described from India (Table 1), Monera (bacteria) are 850 species (0 67%), Protista (Protozoa only: minus their multicellular descendants) 2577 species (2 04%), Fungi 23,000 species (18 23%), Animalia 74,875 species (59.27%) and Plantae 24,886 species (19.79%). Nearly 72% of India's biowealth is constituted by fungi (18 23%), insects (40%) and angiosperms (13.50%). This tallies generally with the overall trend seen in tropics and subtropics. Although India has only 2.4% of the land area of the world as a whole, according to the present estimates, India's contribution to the global biodiversity is around 8% species. While India stands seventh as far as the number of species contributed to agriculture (including animal husbandry) is concerned, qualita-

Table 1. Number of biota in India[1–3]

Taxon	Number of species	Percentage
Bacteria	850	0.67
Algae	2500	2.00
Fungi	23,000	18.23
Lichens	1600	1.30
Bryophyta	2700	2.14
Pteridophyta	1022	0.80
Gymnosperms	64	0.05
Angiosperms	17,000	13.50
Protozoa	2577	2.04
Mollusca	5042	4 00
Crustacea	2970	2.35
Insecta	50,717	40 00
Other invertebrates including hemichordata	11,252	9.00
Protochordata	116	0.10
Pisces	2546	2.02
Amphibia	204	0.16
Reptilia	428	0.34
Aves	1228	1.00
Mammalia	372	0.30
Total	126,188	100.00

tively India's contribution to agribiodiversity is indeed very impressive[5]. Among other species, Indian region has contributed zebu, mithun, chicken, water buffalo, camel, rice, sugarcane, banana, tea, mango, cucumber, egg plant, citrus, jute, minor millets, Asiatic vignas, brassicas, rice bean, tree cotton, jackfruit, edible dioscoreas, alocasia, colocasia, amorphophallus, cardamom, black pepper, ginger, turmeric, vegetable amaranths, cucurbits, several umbellifers, bamboos, a number of medicinals, aromatics and ornamentals, etc. (Figure 1; refs. 5 and 6). Besides, India has also been a secondary centre of domestication for horse, goat, sheep, cattle, yak, donkey, tobacco, potato, red pepper, grain amaranths, maize, soyabean, oil palm, etc. Some of these species are very early introductions into India. These have undergone evolution in the Indian region and have been selected in historical time to meet the human needs suiting Indian conditions. India has also contributed very important genes to world agriculture and animal husbandry which have made significant difference to better the human welfare[2].

All the present-day crops and domesticated animals known today were spotted and initially domesticated by the so-called early humans (particularly women). There have not been any additions to the traditional crop and domesticated animal species for the last 10,000 years. This shows the intuitive power of the ancient agriculturists for picking the right kind of animals and plants for domestication. Thereafter, modern science of genetics and breeding has not added any new crop or domesticated animal, but has no doubt increased their productivity beyond measure. However, in time to come, new additions are likely to be from amongst microorganisms for providing new products. They are likely to be the future biofactories as is the case for human insulin. Microorganisms have a big arsenal of enzymes which can perform varied and often weird tasks. Furthermore, these organisms have been performing a unique function from the day plants began to first emerge from sea and colonize totally sterile and barren land devoid of any organic matter. This was rendered possible on account of the mutualistic association between plants on the one hand, and bacteria and fungi on the other, thus helping in the uptake of nutrients by plants. Such mutualistic associations between land plants and microorganisms is seen in most of the fossil species of the then land plants colonizing the earth



1 Turkey
2 Sunflower
3 Tepary bean
4 Avocado
5 Cocoa
6 Sweet potato
7 Maize
8 Runner bean
9 Tomato
10 Llama
11 Guinea Pig
12 Alpaca
13 Cotton
14 Lime bean
15 Peanuts
16 Pepper
17 Potato
18 Pineapple
19 Yam
20 Goose
21 Cattle
22 Pig
23 Grapes
24 Barley
25 Olive
26 Rye
27 Watermelon
28 Finger millet
29 Sorghum
30 Reindeer
31 Horse
32 Bactrian camel
33 Alfalfa
34 Millet
35 Hemp
36 Foxtail millet
37 Soya bean
38 Coconut
39 Breadfruit
40 Barley
41 Dates
42 Onion
43 Peas
44 Wheat
45 Ass
46 Dromedary
47 Sheep
48 Goats
49 Yak
50 Zebu
51 Mithun
52 Chicken
53 Waterbuffalo
54 Banana
55 Rice
56 Tea
57 Sugarcane
58 Mango
59 Cucumber
60 Egg Plant
61 Citrus
62 Jute
63 Jackfruit
64 Cardamom
65 Black pepper
66 Ginger
67 Turmeric
68 Minor millets
69 Veg.amaranths
70 Asiatic Vignas

Figure 1. Centres of origin and domestication of agribiodiversity (after Boyden[6], modified)

nearly 408 to 387 million years ago. For instance, microscopic examination of most fossil plants shows ectomycorrhiza and endomycorrhiza.

Taxonomists: A vanishing tribe

At present good taxonomists are indeed highly endangered specialists among biologists, although India is among the very few countries to have Botanical and Zoological Surveys (BSI and ZSI) which have been rendering yeoman service against all odds. These Surveys in particular and taxonomists in general are today overshadowed by the so-called and more often second-rate biotechnologists and environmentalists. There is, however, no doubt that more investments (accompanied by strict accountability) have to be made in genetics, breeding, biotechnology, and pharmaceutical sciences for gene and drug prospecting and product development. But the country has to realize that *all wisdom begins by calling all living (including humans) and nonliving things by their proper names*. This makes the role of taxonomists most important for all development involving biologicals.

Up to early 1980s, Indians have made world-class contributions in modern taxonomy, biosystematics, experimental taxonomy, circumscription of gene pools and the allied applied aspects. From this work a large number of products (by way of new cultivars) were developed which helped the country in food self-sufficiency and better varieties in horticulture and floriculture and economic animals. Such contributions emerged from some universities in general, but principally from some of the laboratories under the Indian Council of Agricultural Research (ICAR) and the National Botanical Research Institute under the aegies of the Council of Scientific and Industrial Research (CSIR).

Apart from taxonomists, a large number of persons in different trades use taxonomic and floristic information in their work. These are: teachers from primary to adult, to college and to university level for purposes of education in biology, land-use managers, environmental surveyors, geneticists and breeders, biotechnologists, biochemists, microbiologists, pathologists, anatomists, palynologists, embryologists, physiologists, pollination biologists, seed laboratories, nurserymen, forest managers, silviculturists, weed and pest control specialists, fertilizer manufacturers, food quality controllers, agricultural consultants and extension workers, animal feed companies, indigenous medical herbalists using natural medicine, pharmacognostical and pharmaceutical researchers, drug companies, natural dye specialists, dermatologists, toxicologists, allergy specialists, forensic science specialists, ecologists, environmentalists, mining engineers, real-estate appraisers, municipal and regional planners, recreation planners and managers, sports-field managers, landscapists, architects, civil engineers, interior designers, water-way managers, flood control engineers, craftsmen, custom officials, border and enforcement agencies, lawyers, mathematicians, computer scientists and a host of other specialists[7].

The kind of information needed for basic biological, agricultural, biotechnological and pharmaceutical research is: correct identification and accurate naming, reference, systematic relationship, information on intraspecific variation, cultivars, hybrids, size of population, host–parasite relationship, phenology, economic factors, variation, distribution, habitat preference, protection status, etc. This involves many disciplines like anatomy, chemistry, embryology, palynology, cytology/cytogenetics, crossability, genetics, ecology, evolutionary biology, molecular biology, population biology, size of gene pool, etc. Such information need not be generated for all the species, but for those that are related to agribiodiversity and drug industry. Furthermore, conservation biology is becoming a very important field of study and taxonomy is the first and foremost input into this emerging discipline.

Biology at molecular and cellular levels has to be funded, particularly because in India there are some outstanding performers at two or three centres in the country. India has a major stake in this area so as to acquire bargaining power while buying and selling biotechnology and its products. However, the general clan of biotechnologists is not likely to make any worthwhile contribution in the foreseeable future despite heavy investments. This is clear from a critical appraisal of the work done so far with not much on the horizon. However, biology at a grosser level poses equally interesting problems which are likely to be of immediate benefit to science and society. Bawa[8] has rightly concluded that in India world-class work has been done in the past and can be done in future also in such areas involving much less fiscal inputs but with equal if not greater utility.

Partly, the decline in taxonomy is the result of apathy of the biologists themselves, who have willingly taken to the bandwagon of second-rate environmental and biotechnological work. Then followed the increasingly lower priority given to taxonomy and allied subjects not only by the Ministry of Environment and Forests (MoEF) but also by the University Grants Commission, CSIR and ICAR, Department of Science and Technology (DST), etc. According to Father C. Saldanha, taxonomy is unfortunately now regarded as 'tax-on-me'. Such an image of this subject must change at the earliest.

In USA, thanks to the Systematics Agenda 2000 (SA 2000)[9], taxonomy has got a shot-in-the-arm and is poised to become a money-spinner. Proper identification of taxa is of fundamental importance and is going to be a lucrative business on account of tremendous stress on biological products.

SA 2000 is an important study which involved three American Societies of taxonomists and systematists supported by the US National Science Foundation. Initially, they resolved themselves in 27 Standing Committees involving over 300 scientists representing a broad array of institutions and specialities. Their reports were reviewed critically both nationally and internationally. The result was identification of three interrelated missions: namely, (1) to discover, describe and inventorize global species diversity (i.e. discovering biological diversity); (2) to analyse and synthesize the information derived from this global discovery effort into a predictive classification system that reflects the history of life (i.e. understanding biological diversity); and (3) to organize the information derived from this global programme in an efficiently retrievable form that meets the needs of science and society (i.e. managing systematic knowledge).

The value of the study lies in the use of biodiversity for human health, medicine and pharmaceuticals, agriculture, genetic resources, forestry, fisheries, species economics, understanding and conserving earth's life support system, enhancement of quality of everyday life and scientific research base, etc. In short, this effort is an initiative to discover, describe and classify the biota of the world.

In India, special attention has also to be paid to the marine biodiversity, including mangroves. Let us not forget that our country has been endowed with a long coastline and an extended economic zone (EEZ) which is nearly as large in area as the country itself. We know almost next to nothing about this treasure trove.

It is high time that Indian authorities (especially DST and MoEF) consider bringing together a group of informed biologists to do some deep introspection and chalk out a strategy to halt the decline in taxonomy, and revitalize the subject so as to meet the newer and unforeseen challenges of the future.

Biological Survey of India

Another task that merits attention of such a committee is to bring together BSI and ZSI into one connected whole, as Biological or Ecological Survey of India, where botanists, zoologists, ecologists, conservation biologists and others using the most modern tools and skills, including space science, bring out a consolidated picture about Indian biota, their distribution, composition, endemism, rarity, extent and nature of bioenrichment/biodepletion, early warning signals and 'hot spots' of the Indian biota in space and time. Furthermore, based on their study, they establish trends so that meaningful action can be planned for an overall ecological restoration in general, and restoration of endangered species in particular. Gone is the time when the members of the five kingdoms (Monera, Protista, Fungi, Animalia and Plantae) occupying a common habitat and existing as in interacting system are treated as bits and pieces. One cannot delink a flowering plant from its pollinator or mycorrhiza, a carnivore from its prey, a herbivore from herbage that it eats, above all different biota from their common habitat, and numerous other associations. There is a need to understand processes like mutualism, co-adaptation, co-evolution, predation/parasitism and competition, and speciation together with fundamental processes of mutation, recombination and natural selection leading to survival of the fittest. Equally important are the ecological processes and the role of people living harmoniously in an ecosystem, and especially the lessons to be learnt from such associations.

This does not mean that there is a need to disband the staff of the Surveys, but the need is to revitalize and establish a cadre of taxonomists who look at all biota in a given habitat as an interacting, interconnected, interrelated, interdependent and holistic system rather than as isolated bits and pieces. This would need creating a new brand of dedicated taxonomists who do not look at plants, animals and microorganisms with a dry lens and a dry mind, but as ecologic and economic entities. There will have to be specially designed and designated training centres. This has to be done even if it requires the advice and help of foreign experts and agencies. In time to come, enormous gains would accrue out of this exercise. Advanced genetics, breeding, biotechnology and pharmaceutical sciences have to be backed by advanced taxonomy, both classical and experimental.

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SCIENTIFIC CORRESPONDENCE

Record of opal phytoliths and associated palynofossils from Indian crude oils

Opal phytoliths are recorded from the crude oils along with palynofossils. These indicate the Paleogene source for the Bassein crude oils of the Bombay offshore area. The phytoliths, the associated palynofossils and dominant humic organic matter suggest a terrestrial origin for the crude oils.

Five new phytoliths are recorded and described. They are grouped as oval, triangular, ellipsoidal, circular and polygonal phytoliths.

The study of crude oils is an effective tool to determine the age of source rock and source organics of these oils. It is termed as oil palynology. Different types of spores, cellular structures, cuticular structures and wood fragments have been extracted earlier from the crude oils of Digboi field of Assam, India, to find out the source of the oils[1]. Panicoid and elongate type of phytoliths have been recorded from the subsurface sediments of North Bassein Well No. A, Bombay