

Introduction

The word taxonomy is derived from the Greek words *taxis* (= arrangement) and *nomos* (= law). It was first coined by A.P. de Candolle, a Professor of Montpellier University in France, in his Botany treatise in 1813, as a French word 'Taxonomie,' evidently formed on the analogue of astronomie, economie, agronomie and other similar words. Later in 1819, he spelled it as 'Taxeonomie'. The Greek scholars criticised this spelling as according to them, the correct Greek spelling should have been 'Taxinomie'. Under these circumstances, the correct word presently in use should be spelt as 'Taxinomy' instead of 'Taxonomy'. But the present day taxonomists prefer the already established term 'Taxonomy' as it is in use now for over 190 years. Taxonomy is the science of classifying living things into groups based on their similarities. This science of naming and classifying organisms is the original bioinformatics and a fundamental basis for biology.

The terms taxonomy, classification and systematics are often used interchangeably because they apply to same concept of arranging things in their 'correct relationship'. Systematics stems from the Latinized Greek word 'Systema' applied to the systems of classification developed by Linnaeus in the 4th edition of his historical book, *Systema Naturae* in 1735. It is sometimes incorrectly used in place of taxonomy. Taxonomy is actually the study of the principles and practices of classification and as such it is only a part of systematics.

Various workers have tried to separate these terms into distinct compartments. According to Mason (1950),

"taxonomy is the synthesis of all the facts about (organisms), into a concept and expression of the interrelationships of (organisms)", Heslop-Harrison (1953) explains it as the "study of the principles and practices of classification, in particular the methods, the principles, and even in part the results of biological classification". Simpson (1961) defines it as the theoretical study of classification, including its bases, principles, procedures and rules. Davis and Heywood (1963) consider taxonomy as a way of arranging and interpreting information. Blackweider (1967) explains it as the day-to-day practice of handling different kinds of organisms, it includes collection and identification of specimens, the publication of data, the study of literature, and the analysis of variations shown by the specimens, it is a science of placing biological form in order (Johnson, 1974).

Christoffersen (1995) defined taxonomy as the practice of recognising, naming, and ordering taxa into a system of words consistent with any kind of relationships among taxa that the investigator has discovered in nature. Taxonomy thus becomes the most basic activity in biology, dealing exclusively with the discovery, ordering and communication of patterns of biological taxa.

The classification is the ordering of animals into groups (or sets) on the basis of their relationships, that is, of associations by contiguity, similarity or both (Simpson, 1961). Or it is the arrangement of the individuals into groups (taxa) and the groups into a system in which the data about the kinds determine their position in the system and thereafter are reflected by the position (Blackweider, 1967).

The relationship of taxonomy to systematics is somewhat like that of theoretical physics to the whole field of physics. Taxonomy includes classification and nomenclature, but leans heavily on systematics for its concepts. Systematics includes both taxonomy and evolution. Simpson (1961) explains systematics as that scientific study which deals with kinds and diversity of organisms and any or all relationships among them. Or it is that science which includes both taxonomy and classification, and all the other aspects of dealing with kinds of organisms and the data accumulated about them (Blackweider, 1967). It is thus concerned with organising biological knowledge; taxonomy, with constructing the frame-work for

the organisation; and classification is a hierarchy of names of taxa representing the components of a group of plants or animals, with (included or referred to) characters sufficient to diagnose and differentiate the taxa or it is nothing but a list of taxa names indented to indicate category levels. Christoffersen (1995) defined systematics as the theory, principles and practice of identifying (discovering) systems, i.e., of ordering the diversity of organisms (parts) into more general systems of taxa (wholes) according to the most general casual processes. According to Wagele (2005) the terms taxonomy and systematics could be synonyms but in practice both function differently. Systematics searches for a phylogenetic system but not necessarily to acquire special knowledge on the distinction, validity of proper names and the number of species. In this way systematics works mainly on the phytoeny of supra-specific taxa but can identify new species. Dubois (2005) found even taxonomy and nomenclature different from each other in their function. Taxonomy recognizes classificatory units or taxa where as nomenclature gives unique scientific name to each of these units. Taxonomy is a scientific discipline and nomenclature is a technique.

In simple terms, actually there are two parts of systematics. The first part, *taxonomy*, is concerned with describing and naming the many kinds of organisms that exist today, those that have been extinct for many, even millions of years and also those that are becoming extinct. The second part of systematics, *evolution*, is concerned with understanding just how all of these kinds of animals arose in the first place and what processes are at work today to maintain or change them. There are two distinct taxonomic systems in operation among professional zoologists today. The traditional taxonomy is still largely adopted by field workers, conservationists and animal husbandry people. The **cladistic** taxonomy is mostly supported by evolutionary' biologists. In cladistic taxonomy, an attempt is made to group species in accordance with their evolutionary history. Thus, the original purpose of taxonomy was the recognition, categorization and identification of organisms.

STAGES IN TAXONOMY

It is now well-known that taxonomy of a given group passes through several stages. These stages are referred to as alpha

(analytical phase), beta (synthetic phase) and gamma (biological phase) taxonomy. Alpha taxonomy is the level at which the species are characterised and named; beta taxonomy refers to the arrangement of the species into a natural system of lower and higher categories; and gamma taxonomy is the analysis of intraspecific variations and evolutionary studies, i.e., study of speciation. But in actual practice it is rather difficult to dissociate them because these overlap and intergrade. There are only a few groups of animals (some vertebrates, especially the birds, and a few insect orders like Lepidoptera) where the taxonomy has reached up to gamma level otherwise in almost majority of the groups the works are still at alpha and beta levels.

IMPORTANCE OF TAXONOMY

It is very important to know the living organisms around us. Each species occurs in nature in many different forms like sexes, larvae, nymphs, pupae, seasonal forms, morphs and other phena. Taxonomy is thus the language for communication. Over one and a half million species of animals have been described and it is estimated that about 4 to 40 million or more species still await discovery. Imagine when all these animals did not have a proper name- it would have created total confusion and anarchy. If a research worker does not have a reliable name of the animal, he is working, it will be impossible to communicate and publish the work. It is, therefore, necessary to put such a large number of species into definite groups so that the extent of their harmful and edible properties are established. There is thus subtle relationship between the characterisation of an organism by a systematist and finding solution of a particular problem by a scientist. The assignment of a name to an organism provides the only key to all the information available about that species and its relatives. Careful and accurate identification and classification are of vital importance. Sailor (1969) rightly pointed out that in all the steps necessary to environmental research, from accumulation of data through evaluation of results, storage of information, retrieval of information, and use of the information in action programmes, the taxonomist acts as a necessary catalyst who allows the control of pests through manipulation of habitats as

well as in the management of our environment in the cheapest and most successful way.

The contributions of systematics to biology are both direct and indirect. In some cases total dependence on systematics is not ruled out. To know specifically the areas, both in theoretical and applied biology, benefited by systematics, it is necessary to discuss its role with appropriate examples.

Theoretical Biology

Many of us are unaware of its role in theoretical biology. Systematics has played a very important role in laying the foundations of some important fields of biology. It is responsible in making conceptual contributions like **population thinking**. It is also responsible in solving the problems of **multiplication of species**. One of its greatest contributions lies in the understanding of the **structure of species** and of the evolutionary role of **peripheral populations**. It was only the taxonomist who reaffirmed the role of **natural selection** as evolutionary factor in contrast to **mutation theory** of Mendel. **Mimicry** and other evolutionary areas have also been clearly understood through taxonomy. It has also played a useful role in the development of **behavioural science**. It is a key to the study of **ecology** as no ecological survey or work can be undertaken unless all the species of ecological importance are identified.

Applied Biology

Taxonomy has played quite a wide role in the important fields of applied biology. The applied biologists, too, are heavily relying on it for laying accurate and foolproof experiments and getting quick useful results. It is now well-known that chemical control of pests with insecticides can satisfy only a short term need. The appearance of insecticide resistant strains of pests, and the problem of hazardous residues in food, water, air, etc., have led to the conclusion that the best and perhaps the only way to save our crops from insects and others is to organise an integrated pest management programme. Such a programme is aimed at integrating chemical methods with the use of **resistant plant varieties, predators and parasites, pheromones, hormones and lethal genes**. All these methods (except the use of insecticides) are highly specific and can only succeed if the identity of the

pest or pests is accurately determined. A wrong identification may upset the entire control strategy. To know the useful role of systematics in specific areas of applied biology, it is pertinent to discuss them separately.

Agriculture and Forestry

Presently we are faced with the acute problem of saving our crops and trees from the attack of various kinds of pests, it is essential to know the correct names of such pests before their proper control or eradication. Every species has its own niche in nature and differs from its related species in food preference, breeding season, tolerance to various stimuli, resistance to predators, competitors, pathogens, etc., and all these are essential for an applied worker before applying control measures. All this information can be easily obtained by screening the literature if the identity of the pest is known.

It is also necessary to collect samples of animals occurring on a particular crop when the crop shows early signs of injury or disease. In many cases the crop continues to be damaged even after spraying with suitable recommended pesticides. This may be either due to the entry of some new pest(s) or appearance of some resistant strain of a pest.

It is also sometimes very important to have local observation of the destruction of the crop. When the injury is obvious and the leaves are being eaten, it is often easy to discover the insects like caterpillars or leaf-feeding beetles; some may even defoliate the plants. On the other hand there are many leaf-eating insects that feed at night and hide away in the daytime. Other insects suck juices of plants, e.g., plant bugs and aphids. Besides, there are many other insects that bore into plants or trees, e.g., wood-boring beetles, and their larvae, some moth caterpillars, etc. There are also maggots of certain flies, the fruit flies, that are found in fruits and vegetables. This information is important before controlling any pest with the use of chemicals. On getting the correct identity of the pest species, it becomes easier to collect information about its habits which is vital for its effective control. For example even with leaf-eating insects, specialised ways of control have to be applied taking into consideration whether it feeds on the upper or lower surface of the leaves. Similarly, many of

the plant diseases are caused by certain vectors. The correct identification of a particular vector is vital for bringing the disease under control for killing its vector.

Biological Control

As the use of insecticides is declining and replaced by specific methods of biological control, the use of accurate identification of the pest and its natural enemies is becoming increasingly important. Natural enemies of pests can often be introduced for biological control to the enormous advantage of agriculture, forestry, etc. When successful, the biological control is much more economical than chemical control because it need not be repeated and has no injurious side effects. The controlling agent (parasite, predator, pathogenic organism) is always there in the environment and able to multiply as needed to reduce the members of the pest species. Specific controlling agents are often difficult to distinguish from closely related and nearly identical forms that feed on different hosts. Failure to discriminate between populations of different hosts, and usually other different attributes as well, can result in expensive confusion and even introduction of wrong control agents. For example, in the early 1940s a parasite *Archytas incertus* (Macq.) was introduced from Uruguay and Argentina into the USA for the control of armyworm. Its import was discontinued when the taxonomists reported that the species was already common in southern United States. Similarly, a gall fruit fly, *Procecidochares utilis* Stone was imported from New Zealand into India for the control of crofton weed, *Ageratina trapezoides* (Sprengel) in Darjeeling District. This fly has since been well established there and has also migrated to Nepal where, too, it has become quite well established on this weed. This fly was not imported in Nepal because of its timely discovery there. There are many examples of successful biological control programmes in many parts of the world. In all these cases the correct identification of the parasites (including weed destroyers) and their hosts has been the key factor.

The systematists are presently greatly involved in designing and implementing the biological control programmes of pests and diseases most effectively. Since it is now well-known that knowledge of an organism's relationship with others permits

us to develop means of control more easily, total dependence on correct identification of both the parasite and the host is not ruled out.

Public Health

Taxonomy plays a great role in public health programmes. There are a number of diseases which are spread by many arthropods which are disease-specific. So our control strategy should be planned in such a way that only the target species is attacked. This is possible only on getting the correct identity of that species. For example, some species of *Anopheles* mosquitoes are responsible for transmitting malaria and others not. A good example of such a case is the occurrence of malaria in epidemic form in Europe. The mosquito, *A. maculipennis* Meigen, a supposed vector of malaria, was found prevalent throughout Europe. Large sums of money were wasted in controlling this mosquito, although malaria was not prevalent all over Europe in spite of the presence of this mosquito. The taxonomists Hackett (1937) and Bates (1940) were consulted who took samples of the mosquito from all over Europe. They discovered *A. maculipennis* complex comprising several sibling species of which few were responsible for transmitting malaria. The control measures were then applied only to the target species and malaria was brought under control. In this way a lot of money and manpower were saved. Thus, correct identification ensures a maximum of effective control at minimum cost.

Quarantine

Many new pests and diseases of plants, animals and human beings have already entered many countries and still others are following suit. Their spread from one country to the other is through transportation of various crops, ornamental plants, and mainly through the agency of human-beings. Respective governments have established quarantine laboratories at aerodromes, ports, etc., to check the spread of new pests and diseases. Even when the American astronauts came back from the moon, they were kept in quarantine laboratory for a few days to avoid the risk of introducing new pests or diseases from that heavenly body. Taxonomists play a vital role here

in providing correct and prompt identification of the pest or disease. Unless this is done, no further action is possible in such matters. The most common example of such measures was the rule till quite recently of compulsory inoculation for cholera for every passenger travelling from one country to another. Indian bird pest, Rose-Ringed Parakeet has been found to attack vineyards across Europe. The European Environment Agency has found the parrots introduced from India-intentionally released or accidentally escaped- creating havoc across the continent resulting in expected reduced wine production.

Wildlife Management

Presently *great* attention is being paid to conserve and propagate wildlife. Many programmes have been initiated all over the world to teach the people the importance of fauna and flora for human welfare. The indiscriminate killing of animals and felling of trees have already resulted in great disturbance in the natural environment. Many species of animals have become extinct and still many others are following suit. Taxonomists help the environmental protection protectors to identify all such animals which are endangered by man's activities. This job becomes more challenging in view of widespread support in favour of preservation and protection of our biodiversity. See more detail in chapter 2.

Mineral Prospecting

The sequestering of rocks and geological events in an area is basic to any search for fossil fuels and mineral deposits. Some igneous rocks may be dated by radioactive decay, but sedimentary rocks can be dated only by their enclosed fauna and flora. The palaeontologists play a major role in the identification of the fauna and flora and thus give clear picture of the correct sequence of geological events. Such works have been of great value in the success of oil industry in America. Since the complex faulting and folding of rocks pose great problems in the correct identification of the sequence of rocks, it is only through the fossils that their true sequence is determined.

National Defence

Information concerning disease vectors and parasites is an obvious application of systematic to national defence. During World War II, Japanese paper balloons carrying fire bombs created havoc in the forests of the American northwest. Eventually a balloon was recovered with several bags of ballast sand attached. The sand contained a large number of shells of micro-organisms, which, after careful identification and interpretation, were found to represent both cold and warm water worms which occur in a small area off one of the mainland islands of Japan. Subsequent bombing of this beach area destroyed the balloon launching sites. The use of such biological means in the wars are economical and require less efforts in their operation. In these cases, both in making the bombs and their destruction, the correct identification of the organisms has been the first step. Tills is not the isolated example and the need for taxonomy in national defence still continues. Moreover, the identification of potential disease vectors is vital to the health of both; military and civilian populations all over the world.

Environmental Problems

Systematists have also played a useful role in tackling the various environmental problems. Pollutants such as certain chemical pesticide residues may persist in the environment or even concentrate in certain plants or animals. Tracing the movement of these pollutants to determine their effects requires identification of the species within the food chains. It is also now dear that a biological approach, to be successful, requires a thorough understanding of the taxonomic relationships between pest species and component species of the ecosystem. The taxonomists-dominated survey team of Hoffmann and others (1949) gave extremely useful information on the effects of aeroplane application of DDT on forest invertebrates in the USA.

Presently water pollution is also considered as one of the foremost national problem. Since each species has its own requirements for oxygen, nitrogen, and other organic and inorganic compounds in water, certain algae, aquatic Insects, helminth parasites of fish, and some microscopic organisms

are reliable indicators of the degree and nature of pollution. The identification of species present in a particular location provides a rapid and inexpensive monitoring system for detecting pollution.

Soil Fertility

Many animals play an important role in increasing the fertility of the soil. The soil is tunnelled in such a way that it becomes, more aerated and is also enriched by their secretions and dead bodies. It is necessary to know such animals for their proper management in agriculture.

In Commerce

Products like honey, silk, lac, and dyes are provided by insects. Besides, there are many other animals (including insects) which are directly eaten as food or provide us other useful commercial products. Taxonomists can play an important role in increasing and improving the quality of these products by manipulating the useful species. The introduction of any useful species is possible only through correct identification. Many such species have been established in India and other parts of the world only through intelligent introduction based on sound systematics. It is only through correct identification that pertinent information about the biology of the species (to be introduced) is collected from the literature. The Italian honey bee, *Apis mellifera* and the fish, European carp, *Cyprinus carpio* are two well-known examples of successful introduction in India and which was possible only through correct identification.

PROBLEMS OF TAXONOMISTS

There are many problems which the taxonomists encounter daily but the most important ones are discussed below.

To Characterise Species

The biological species are complex populations or groups of populations which cannot be measured precisely. These can only be sampled and the samples show all the limits or all the variability of the whole population. It is, therefore, agreeable

that the biological species which environmental biologists see and study cannot be treated with mathematical precision.

To Arrange Species in Hierarchy of Higher Categories

The higher categories are always arbitrary although new numerical and mathematical methods are developed to describe them, measure the gap between them, and arrange them in many ways.

AIMS AND TASKS OF A TAXONOMIST

The primary aim of a taxonomist must be the construction of classes of living things about which scientifically useful inductive generalisations can be made. Many workers (Blackweider and Boyden. 1952; Michener, 1963; Ehrlich, 1964; Blackweider. 1967; Mayr. 1969; Darlington, 1969) have enumerated various aims and tasks of a taxonomist. For the sake of convenience to readers, these are summarised below.

1. To catalogue the diversity of life on earth and to preserve large samples, both of extant and extinct organisms, drawn from the diversity in various sorts of collection.
2. To differentiate the various kinds of organisms and to point out their characteristics (both qualitatively and quantitatively) through descriptions, keys, illustrations, etc.
3. To provide names for each kind of organism, so that all concerned can know what they are talking about and so that information can be recorded, stored and retrieved when needed. In other words the goal of the taxonomy is to create a common language so that we know what organisms we are talking about.
4. To develop a set of principles in regard to the choice and relative importance of characters with the ultimate aim of arranging species in hierarchy of higher categories.
5. To estimate genetic and phylogenetic relationships among organisms.
6. To contribute towards the understanding of evolutionary process.

7. To integrate the data from all fields of biology, like behaviour, genetics, physiology, etc., and to detect and then summarise significant patterns possibly with the help of modern electronic computers.
8. To document and preserve specimens to provide a useful reservoir of data.
9. To help in clarifying the place of systematic or taxonomy in general biology by revising their aims and priorities, realistically restructuring the efforts in applied taxonomy and reaffirming faith in taxonomy.

TAXONOMY AS A PROFESSION

Taxonomy requires as much wisdom and intelligence as any other field of biology. But the progress in taxonomy is slow and steady and is without the brilliant discoveries which sometimes come quickly in other fields. Due to this it has never been an attractive profession. We are equally unfavourably placed in terms of scientific capabilities of identifying, working with and adding value to biodiversity resources. Every year more than 100,000 students get a bachelor's degree in one of the Life Sciences. But only a very small fraction of these get an exposure to India's living wealth. Practically none of them are able to name more than 5 to 10 species of plants or animals put together. This is because they are rarely encouraged to look at living creatures abounding around them, their training being confined to identifying a few dead specimens or dissecting a still living cockroach or a dead pigeon. Given such a training programme few teachers of biology know much of the living wealth of India either when this country is recognised as one of the eight mega centres of plant biodiversity having 45,000 species of plants, i.e., 12% of the global floristic wealth. Similarly, India has a large animal genetic diversity with proven potential as is evident from the availability of 26 breeds of cattle, 8 of buffalo, 40 of sheep, 20 of goat, 4 of camel, several breeds of horses, pigs, poultry and 2200 fish and shell fish species and a very large number of other animal species, economically important or unimportant but playing a greater role in keeping firm ecological balance. Furthermore, it receives step-motherly treatment from the financial agencies as well; whenever any economy is to be thought of, the axe first

falls on it. Above all the students, too, find the glamorous fields like molecular biology, biotechnology, etc., more attractive and with better employment prospects. In this way the taxonomists remain the most unfortunate beneficiaries. This is very unfortunate because the biological science would prosper better if the systematic fields were more actively cultivated.

Many taxonomists feel that the lower status allotted to their subject is due to man's own interests which are changing with the time. Originally the cataloguing of the fauna and flora was the exclusive interest of biologists. They were impressed by the variety and grandeur of nature, and undertook to describe and name the organisms. Then followed successively the rise of other fields like comparative anatomy, physiology and genetics, and biotechnology is the latest of these. Thus the tide moved away from taxonomy, and finally even went against it. Nevertheless expensive contributions made by taxonomists cannot be forgotten. It was they who have furnished the bricks on which the whole structure of organic evolution has been constructed.

The arrangement of taxa and establishment of the similarities between them (or Taxonomy) are essential ingredients for all other studies in Biological Diversity. It is not single specialization that stands on its own, but is a lateral study encompassing the full sweep of life whereas the rest of biology is a vertical study of biological organization within a very few species. It is therefore necessary that both taxonomy and rest of biology should be combined to achieve a full study of Biological Diversity. Taxonomy lays the foundations for the Tree of Life and is prerequisite for ecology and conservation. Taxonomy is an exploration of the still largely unknown Biodiversity of Life. There is still a great deal of fauna and flora to be discovered. Molecular Taxonomy cannot be successful without initial identification through traditional taxonomic methods.

Presently the picture is very different and fast changing in favour of taxonomy. A taxonomist is now no more a caretaker of his collection but a well trained naturalist. He goes out in the fields and supplements his studies with more and more information he gathers from field observations as well as from other branches of science like cell biology, physiology and molecular biology. The ferment introduced into systematics

in recent years by biochemists, ethologists, statisticians, and theorists has given a new vitality to it. Sophisticated techniques and equipments, together with the essential role of systematics in increasingly important environmental studies, have made it an exciting and challenging science. Today his taxonomic character does not mean only aspects of morphology but also includes others like physiology, biochemistry, genetics, etc., to establish the relationships among different species. This difficult task of integrating the data from other fields of biology is being aided by modern electronic computers. The use of electronic devices in the analysis of sounds of frogs, cicadas and grasshoppers has helped in the breaking up of complexes of species. The taxonomic research which was at one time considered secondary in importance to other rapidly developing branches of zoology, has now been regarded as basic to these as well as other fields of biology. Even then only those who are willing to make greater than usual sacrifices, and who are sustained by an unquenchable interest in the subject, can expect to make a success in taxonomic research.

Taxonomists are presently employed by universities, research institutes, museums, central and state government agencies, industries and zoos. A well trained taxonomist is well qualified to teach a course in zoology as he has a broad background in morphology, physiology, genetics and ecology, which others, due to lack of time, are not able to acquire. In all types of zoological researches the availability of taxonomic specialists is a guarantee for the identification and homogeneity of the working material; inversely a shortage of such specialists leads to very serious consequences. Still there are not enough openings for the taxonomists. Sometimes a person trained in taxonomy has to look for other interests. When at one stage there are not enough taxonomists available, this diversion makes the situation more acute. It not only results in loss of a few trained persons but also affects the morale of those who are being trained, or still others who are thinking of entering this profession. Furthermore, when continuity in a field is broken, progress not only stops, but the amount of available knowledge also actually declines or temporarily halts until at some later date someone else with waste of time and energy, takes up the group and learns it again.

Even the Convention of Biological Diversity has acknowledged the existence of this 'Taxonomic Impediment' which is affecting the sound management of biodiversity. The shortage of trained taxonomists and curators are showing clear sign of negativity in the protection and conservation of plants and animals, especially the endangered ones. The inability to identify species is a major component of the taxonomic impediment. Still there are millions of undescribed species and there are very few taxonomists to do this job, especially for biodiversity-rich but economically poorer countries. Identification of large and charismatic vertebrates, like birds and mammals, is quite well done but majority of the organisms belonging to arthropods and lower plants, fungi and microorganisms are yet to be discovered. Taxonomy is suffering from lack of funding. Even when a well trained and experienced taxonomist retires, he is not replaced due to shortage of funds as well as non-availability of suitable replacement. Money has to be made available, especially when thousands of species are threatened with imminent extinction (Wheeler, 2004; Wheeler et al., 2004). Presently, there are only 7000-11000 taxonomists worldwide, only few of them are in developing countries which contain most of the world's biodiversity. Moreover, correct identification of organisms is fundamental for the sound assessment and conservation of biodiversity. Species description is seen as an old-fashioned way of doing research. In any case the taxonomists, too, need to improve their image as still various scientists believe that they are artificially increasing the number of species by raising subspecies to species levels, resulting in "**Taxonomic inflation.**" Frequent synonymies, homonymies, new combinations are further adding confusion to diversity studies. To overcome such confusion it would be better for the taxonomists to face species problem only. Taxonomists should take their opportunity of "**BIODIVERSITY BOON**" in their favour and strengthen the taxonomic research to work earnestly for not only discovering biodiversity but also in their conservation.

Until the early 1990's, many taxonomic services were provided free of charge by expert institutes in Europe and elsewhere. To-day, developing countries typically lack the ability to pay for external taxonomic services and have inadequate and poorly resourced local taxonomic capacity,

in many important organism groups, trained taxonomists are totally lacking in most of these regions. At present when many species are yet to be identified and described, lesser number of taxonomists are hampering this important job. Surprisingly, most of the taxonomists are located in countries in North which are relatively poor in their biodiversity. Biodiversity is quite rich in developing countries of the tropics and so a large number of taxonomists are needed in these countries. Recently, Rodman and Cody (2003), in USA, proposed National Science Foundation's Partnerships for enhancing expertise in taxonomy (PEET) as a model to overcome the present taxonomic impediment. This programme has substantial budget to fund projects, enabling intensive training, targeting poorly known groups of organisms for revisionary works or monographic research. Many trainees from under this programme have secured employment in the USA and abroad in academics, museums or government agencies on positions relevant to systematics.

Synthesis of Systematic Resources (SYNTHEsys) is an initiative launched by **Consortium of European Taxonomic Facilities**, it functions in two ways:

i), here the European researchers get access to the collections comprising more than half of the world's natural history specimens, world class libraries, facilities for microscopy, physical, chemical and molecular analysis and experiences hosts and trainers at 20 European institutions: ii), this part is related to networking activities focused on creating a single museum service, an integrated European resource bringing together the collections of the major institutions in Europe.

The PEET and SYNTHEsys, together with others like PBI (**Planetary Biodiversity Initiative**) of the US National Science Foundation, The EDIT programme (**European Distributed Institute of Taxonomy**), UK-NERC funded CATE (**Creating a Taxonomic e-science**) project could serve as role models for future organizations promoting biodiversity studies.

Taxonomy and Biodiversity

TAXONOMY

The importance of taxonomy has already been discussed in the previous chapter. Since, in the present days, biodiversity is the most talked about subject, the role of taxonomy in the conservation of biodiversity is necessary to be discussed separately as well. Taxonomy and biodiversity are interdependent and closely knitted. Biodiversity is simply a very special, unique and wonderful feature of the living world. It needs to be understood and then conserved by humans, both from practical and ethical point of view. Taxonomy is the science of identifying (incl. naming), describing and classifying organisms. Global biodiversity (or The Majesty of Life) is being lost due to human activities at unbelievable fast rate. In view of this taxonomy takes a centre stage to save our biodiversity. How can we develop protected areas when we do not know what is to be protected? How can developing countries reap the benefit of the use of biodiversity when we do not know the biological diversity which is to be used? How can we identify and find harmful invasive species if we cannot distinguish them from native species? Taxonomy plays a major role here to provide basic understanding of various components of biodiversity which finally help in strong decision-making in conservation and sustainable use.

Biodiversity is a concept and has species as its keystone. The scientific names of animal species are crucial to effective global communication about biodiversity. Without broad agreement on the name of a disease-bearing microbe, vital food

species, or threatened animal, we cannot even begin to combat, exploit or conserve them; i.e. in scientific language, humans are *Homo sapiens*, honey bees are *Apis mellifera* and cockroaches are *Blatta orientalis* and this is true ail over the world. The universal acceptance and adoption of a system for naming organisms is an incredible achievement of mankind. In the past 250 years of research the taxonomists have described nearly 1.8 million species of animals, plants and microbes, it is estimated that this number may go up to 40 million or more species alive today. Thus, the species alive today are only a very small percentage (5–9%) of the billions of species which have lived on this Earth since first evolved over 3.5×10^9 years ago. Over 75% of described species belong to Arthropods. Presently, more than billion specimens have been gathered over the last 250 years and most of them are housed in Natural History Museums all over the world. How can such a vast number of specimens/species be arranged, categorized and classified? This is done through "TAXONOMY". Taxonomy provides a framework for understanding organic diversity. Taxonomists first group organisms with common characteristics into species. Although the populations of species are things that can interbreed, taxonomists study morphology and genetics to work out which organisms are the same species. Taxonomy, thus gives us a vivid picture of existing organic diversity of the Earth, provides us much of the information permitting a reconstruction of the phylogeny of life; reveals numerous interesting evolutionary phenomena and supplies classifications which are of great explanatory value in most of biological studies and paleontology.

Taxonomy is a vital component of biodiversity management. Taxonomic skills and products are thus essential for implementing sustainable development (see page 50 also), including conservation of biodiversity and food security. Besides identifying organisms in an area, taxonomy also documents their wide distribution. Moreover, systematic data in the form of collection data are most important as they serve as the only direct evidence of species distributions (Funk and Richardson, 2002). This helps scientists to select which areas are needed to be conserved. The description of new animal phyla, Loricifera in 1993, Cycliophora in 1995 and Mycrognaethozoa in 2000 and a new insect order, Maniophasmatodea (Klass et al.,

2002) together with tropical arthropods alone could number over ten million species is a clear example to show how little is known regarding the magnitude of global species richness (Simonetti, 1997). Thus, it is right if one says that '**Taxonomy**' and '**Biodiversity**' are two sides of the same coin and neither of them is complete without the other.

Thus, taxonomy is indispensable for conserving and sharing the benefits of biodiversity. Presently a little less than two million species of an estimated 5–40 million species have been described. Knowing species and their distribution is the central point to formulate measures for their protection and also for new opportunities for life sciences to realize benefits from biodiversity. Taxonomy is now crucial to the management of biodiversity, public health, agriculture and many other aspects of life and society. It is a science not only for sustainable development but also for sustainable developed science itself.

The world presently lives under greatest mass extinction since the dinosaurs perished 65 million years ago. Most of the loss of the biodiversity is caused by human activities by intensifying habitat loss, introduction of exotic species through trade and travel and climatic change. The survival of our planet is dependant on a fine balancing act where every organism has its role to play. The disturbance in this balance will have far reaching consequences for other organisms and ultimately the planet itself. At least 40% of the world's economy and 80% of needs of the poor are earned from biological resources. Besides, the richer the diversity of life, the greater the opportunity for medical discoveries and economic development and adaptive responses to such new challenges as climatic change. The number of species of plants, animals and microorganisms, the enormous diversity in genes in these species, the different ecosystems of the planet, such as deserts, rainforests and coral reefs are all parts of biological diversity of Earth. By finding out all about biodiversity in order to protect genes, species, habitats and ecosystems, we would be protecting our own future as well as that of our own planet.

Thus, taxonomists play major role in the identification of taxa requiring conservation action; taxonomic understanding of species on red list; reserve site selection criteria based on taxon richness and endemism; identifying agents for use in biological control, invasive species management and disease

control; taxonomy of keystone species for ecosystem services, etc. Taxonomy helps us to formulate methods for conserving biodiversity. These methods are very effective when working in an area where the animals are not well known. By studying the major groups of known animals in an area, taxonomists can find out more about the environment and its protection. Thus, taxonomy provides us with basic understanding about the components of biodiversity which is necessary for effective decision-making about conservation and sustainable use. Without taxonomists the natural world cannot be documented. Taxonomy keeps pace with the present as well as draws the wealth of knowledge accumulated throughout its history. Taxonomy in the twenty-first century will be completely different than its past. Taxonomists do not forget their past, but improve it by adopting more and more creative ways for better understanding of the living world around us.

TAXONOMIC ORGANISATIONS IN SUPPORT OF BIODIVERSITY

Presently, the importance of taxonomy in the conservation of our environment is so largely felt that more and more effective ways are adopted to strengthen it the world over. A number of international organizations are being established for coordinating this effort the world over. A few such important organizations are discussed below:

- i) **BioNET International:** It is an international non-profit organization dedicated for promoting taxonomy, especially in the biodiversity rich but economically poorer countries of the world. It was established at the United Kingdom sponsored international workshop held in Natural History Museum, London in 1993. It provides forum for collaboration that is equally open to all taxonomists and to other users of taxonomy. In partnership, locally and internationally, it contributes to raising awareness of importance of taxonomy to society building and sharing of capacity and meeting taxonomic needs via innovative tools and approaches.
- ii) **Global Taxonomic Initiative (GTI):** It was created under the United Nation's Convention of Biodiversity

(CBD) to provide taxonomic information and expertise needed to support implementation of the objectives of the Convention of Biodiversity. GTI is specifically intended to build a capacity to generate, collect, disseminate taxonomic information on thematic and cross-cutting issues. Taxonomy, in the context of GTI, is also fundamental to work on other CBD issues including invasive alien species, indicators of biodiversity and bio-safety. All the countries signatory to Convention of Biodiversity (CBD) are bound by its programme and nominate a National Focal Point for the GTI in their respective countries. The National Focal Point (NFP) acts as a central point of contact for national centers of taxonomic expertise and as a link for information sharing to other countries through their respective focal points. Its main goal is to reduce the rate of loss of biodiversity.

The working of GTI is coordinated at world level through fourteen loops—**Andinonet** (Andean Countries); **Aseanet** (South-East Asia); **Carinet** (Caribbean); **Eafrinet** (East Africa); **Easianet** (East Asia); **Euroloop** (Europe); **Nafrinet** (Northern Africa); **Pacinet** (South Pacific); **Safrinet** (Southern Africa); **Wafrinet** (West Africa); **Latinet** (South America, S. Cone); **Mesoamerinet** (Mesoamerica); **Nameriloop** (North America) and **Sacnet** (South Asia).

- iii) **Integrated Taxonomic Information System (ITIS):** This is formed in partnership of Federal agencies of USA (like USDA, Smithsonian Institution, Environment Protection Agency, Nature Serve, etc.) to meet their mutual needs for scientifically credible taxonomic information not only for Nation's biota but also of the World, it provides authoritative taxonomic information on plants, animals, fungi and microbes of North America and the World.
- iv) **Fauna and Flora International (FFI):** It was established in 1903 as a non-profit organization with registered offices both in the United Kingdom as well as USA. It is World's longest established international conservation body. It is known for its source based approach for sustainable conservation work, providing solutions

that simultaneously help wildlife, humans and the environment.

- v) **Virtual Museum of Natural History (VMNH):** It is developed with the aim to act as a primary access point for any researcher interested in obtaining accurate information about any animal taxon, down to species level. The primary search and link mechanism is the **VMNH's International Curator Project**. VMNH was incorporated as a non-profit organization in Washington, USA in 1998. The programme of this project is to develop interactive keys to animal groups on a worldwide scale.

BIODIVERSITY

Biodiversity is derived from two Latin words-*bios* means *life* and *diversitas* means *variety*. Biodiversity is thus defined as the 'FULL VARIETY OF LIFE ON EARTH'. in other words it refers to the totality of different kinds of living species, their forms, levels and combinations on Earth. Biodiversity is presently the most talked about term the world over. It was coined as a 'contraction' of 'biological diversity' in 1985. But one can also find, in traces, study of aspects of biodiversity as far as **Aristotle, the father of biological classification**. A symposium held in 1986 on BIODIVERSITY and the subsequent publication of its proceedings (Norton, B.G., ed.,1986) and follow-up book on BIODIVERSITY edited by Wilson in 1988 and again his another book on BIODIVERSITY in 1992 gave it much popularity. Now it will be difficult to count as to how very often 'biodiversity' is used every day by scientists, conservationists, economists, politicians, etc.

Biological diversity or biodiversity is a term which is used to describe the variety of life on Earth-means wide variety of ecosystems and living organisms; it is thus the foundation of life on Earth. Biodiversity is a measure of the health of ecosystem, biome, or an entire planet. It is extremely complex, dynamic and varied as compared to any other feature of the Earth. Its innumerable plants, animals and microbes physically and chemically unite the atmosphere (i.e. mixture of gases around the Earth), geosphere (i.e. solid part of the Earth) and hydrosphere (i.e. the Earth's water, ice and water vapour)

into one environmental system in which millions of species, including human beings, exist.

Biosphere is presently threatened in two ways. One is the continuous degradation of the physical environment due to ozone depletion, global warming by greenhouse gases, etc. and second is the depletion of biodiversity. A clean environment is a question of life and death. Generally three kinds of biodiversities exist—**habitat diversity**, **genetic diversity** and **species diversity**. **Habitat diversity** relates to the variety of habitats, biotic communities and the ecological differences, together with the tremendous diversity present within ecosystems in terms of habitat differences and the variety of ecological processes. **Genetic diversity** refers to the variation of genes within species, i.e. genetic variation between distinct populations of the same species as well as within a population. The large differences in the amount and distribution of genetic variation is attributed in part to the enormous variety and complexity of habitats and the different ways the organisms obtain their living. **Species diversity** refers to the variety of species, i.e. species richness, species abundance and taxonomic or phylogenetic diversity. The species richness count the number of species in a defined area; species abundance means the relative numbers among species (such a sample may contain several very common species, a few less common and numerous rare species); and in taxonomic or phylogenetic diversity, one considers the genetic relationships between different groups of species.

Earth is relatively still unexplored planet in terms of its fauna and flora. The most important driving force behind the current interest in biodiversity is to know how many different life forms exist today on this planet. New species are being continuously added on this planet. Presently, it is believed that the number of species on earth (both below as well as above ground) may be anywhere between 40 to 100 million. Although we spend a fortune in exploring the galaxy and other parts of the Universe yet we have scarcely thought of exploring the biodiversity on our planet on which our very existence is ultimately dependent. Moreover, the warm and humid tropical regions of the earth, between the tropic of Cancer and the tropic of Capricorn are rich in diversity of plant and animal life. This is called 'MEGADIVERSITY'. India is one